To my dear wife Odile, who had an enthusiasm for mites and their culture and who made this work possible.
In Memoriam.

B. GUERIN

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FOREWORD

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It is self evident that the benefits of civilization have to be carefully balanced against a series of major problems. Some of these are obvious, e.g. air pollution, trash disposal and the mental damage caused by television. However, in addition it is increasingly obvious that apparent advances in housing such as higher temperatures and tight insulation carry a serious medical risk which has been badly underestimated. In parallel with these improvements in housing there have been apparent increases in allergic disease and particularly in asthma morbidity and mortality. Many different fungi, bacteria and animals can flourish in houses and give rise to immediate hypersensitivity in the occupants. However, in many parts of the world the commonest form of sensitization is to pyroglyphid dust mites. The most wide spread species are delightfully named *Dermatophagoides* (skin eating) *pteronyssinus* (feather loving), and *D.farinae* (flour). Although the first proof that dust mites were a major source of allergen in house dust came in 1964, public awareness of the importance of these arthropods has been delayed. There appear to be several different factors that have contributed to this delay :

1 - Mites are about 1/3 of a mm in length and, thus, not visible to the naked eye ; and many people have difficulty understanding the concept of arthropods that are not visible.

2 - The symptoms, particularly asthma, caused by dust mites are chronic and perennial and because of this are generally not ascribed to an indoor exposure either by the patient (or their physicians).

3 - For some years after the discovery of mites, the skin test reagents necessary to make specific diagnosis of sensitivity to mites were either of poor quality or not widely used.

4 - Until very recently there has not been a technique for establishing the presence of mites in a house or of measuring the quantity of mite allergens.

This monograph by Drs. Fain, Guérin and Hart provides an excellent analysis of the available information about the biology of mites, their ecology and distribution, and their relationship to disease. The book was written both because of the obvious lack of a good text of this kind and also because the need was specifically recognized at an international workshop on dust mites and asthma (J. All. Clin. Immunol. 1989, 83:416-427). This book solves many of the deficiencies recognized by the workshop and goes much further. The section by Professor Fain brings together all the published descriptions of pyroglyphid mites and goes on to propose a new classification for this group. Thus, the book represents a significant taxonomic source as well as a practical guide to the pyroglyphid mites. The next section by Dr. Hart contains a lucid account of the complex biology of mites. It is not always understood how completely different the group of animals, including spiders, ticks and mites is from insects and most other arthropods. Thus, many insecticides have no effect on mites ; mites are more dependent on humidity than most insects and generally have no sight. The book contains a lot of information that is essential both for understanding why mite growth has increased in our houses and the possible approaches to reducing exposure. Finally, the analysis of disease mechanisms and the relevance of control measures by Dr. Guérin presents an excellent background to understanding the present state of research and future developments in clinical practice. The clinical relevance of dust mites covers a large section of allergic disease : from sneezing and rhinitis caused within minutes of exposure to dust ; to the increasingly well understood role of dust mite allergens in the chronic bronchial reactivity of asthma ; and finally the still poorly understood role of dust mite allergens in atopic dermatitis. Thus, understanding the current evidence about the role of mite allergens in allergic disease presents a good basis for much of current interest in research on the role of environmental allergens. Overall, this beautifully printed book represents the best available synthesis of the biology, classification and clinical relevance of dust mites.

The book leaves the reader prepared for the many directions that dust mite research and control of their growth will develop over the next few years. The immunology has reached a point at which the major Group I and Group II allergens of the genus *Dermatophagoides* have been identified, sequenced and cloned. Analysis of the B cell epitopes is rapidly progressing using monoclonal antibodies and structural analysis of proteins. It is now possible to propose the production of fragments of the molecule or genetically engineered molecules that will react with T cells, but lack the ability to react with human IgE antibodies. Indeed research of this kind is proceeding in several parts of the world.

The epidemiology of the relationship between mite allergy and disease was part of the pioneering work of Voorhorst and his colleagues.Subsequently, the relationship was established in many parts of the world. For example, Dr. Morrisson-Smith demonstrated a close relationship between mite allergy and asthma among school children in England. In the last few years the epidemiology of dust mites and disease has moved sharply towards quantitative analysis of the level of

exposure that represent a risk for either the development of allergic disease or the levels that will provoke disease in allergic individuals. Those studies have been dependent on the increasingly widespread ability to measure specific allergens or identify mites. The third area of research that is developing rapidly is the control of environmental exposure to mites. This involves both physical and chemical approaches. Rational use presupposes an understanding of dust mite biology. Indeed, current approaches to controlling allergens in house dust involve a combination of immunochemistry, biology, protein chemistry, building practices and aerobiology.

Professor A. Fain is as described by Professor Michel in the Introduction to the French edition, "Fondateur de l'Acarologie Moderne". Indeed it was Professor Fain who taught Spieksma about the classification of acarids and made possible the studies which established the role of dust mites as the major source of dust allergens.

Dr. Hart, working with Dr. Fain, has made important contributions to our understanding of the biology of dust mites and has analyzed the available literature concisely. Thus, the relevance of using a fungicide Natamycin to control mites or an assay for guanine to detect mites in house dust becomes obvious.

The chapter by Dr. Guérin reflects his extensive knowledge of the history of mite immunology and the campaign to standardize allergens. The depth of his understanding comes over throughout his section. He has also done well in defining the rapidly advancing field of the immunology of mites.

This timely book is recommended for anyone with an interest in house dust mites, especially for physicians or scientists doing research in the area, but also for all who have an interest in allergic disease. Overall, this book represents an important and enjoyable contribution, and the English edition will allow many more of us to understand these delightful creatures which have such a remarkable capacity for causing both misery and severe disease.

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INTRODUCTION

by

A. FAIN, B. GUERIN, B.J. HART

The aetiology of respiratory allergies, primarily asthma, has been recognised for many centuries, and as early as 1698, Floyer reported dust as being one of the major factors involved in this problem. However, it was not until the beginning of this century that Kern (1921), Cooke (1922), Storm van Leuven (1922) and various other workers used skin tests to confirm the presence of allergens in house dust and indroduced the concept of a common allergenic determinant present worldwide. The specific characteristics and the uniformity of the allergens in house dust have since been greatly disputed, particularly since Linblad and Farr (1961) demonstrated that cutaneous reactions to dust extracts depend on the concentration of the extract, and also that dust extracts induce a positive response in more than 50% of clinically diagnosed non-atopic patients, and in an even higher proportion if only skin reactions to extracts applied subcutaneously are considered. The work of these pioneers stimulated considerable interest in dust allergens in the scientific community and as a result various laboratories embarked upon research programmes to investigate the allergenic components of house dust and to determine their origins (Lang *et al.*, 1976).

It is now well established that dust contains a heterogenous mixture, which varies according to region and house, of various allergenic substances, consisting primarily of the somatic and metabolic allergens of mites, and secondarily allergens derived from domestic animals, human skin scales, and domestic insects such as cockroaches. In addition, fungal spores or mycelium and other products of animal or vegetable origin such as feathers, wool and natural fibres may be sources of dust allergens (Berrens, 1971; Pauli *et al.*, 1979).

The primary role of mites in house dust allergy was first suggested in 1928 by Dekker who recorded large numbers of unidentified mites in house dust, particularly in mattresses. He also found in patients suffering from allergies, that their symptoms were greatly relieved when in a mite-free environment. In 1944 Carter, Wedd and d'Abrera described under the name of "pulmonary acariasis" an asthmatic type symptom which they attributed to the presence of mites in the lungs. It was, however, another 20 years beforeVoorhorst *et al.* (1964) established the major role played in house dust allergy by a domestic mite of the genus *Dermatophagoides*, namely *Dermatophagoides pteronyssinus*. These authors discovered that in Europe this mite was present, often in large numbers, in the majority of houses examined and, since extracts of this mite produced similar skin test reactions in atopic patients as does house dust, they concluded that *D. pteronyssinus* was the principal source of house dust allergens.

The hypothesis of Dekker which, although well founded, had been initially underestimated in the United States, was firstly verified in Europe (Voorhorst *et al.*, 1964) and then was confirmed worldwide by studies in Japan (Miyamoto *et al.*, 1968) and also in North America (Bullock *et al.*, 1972; Kawai *et al.*, 1972). This knowledge gave rise to the hope of controlling, by the use of acaricides, the principal source of perennial allergies and it also formed the basis for much research into different aspects of the ecology and biology of house dust mites and into the nature and composition of the allergens produced by them.

During the last twenty years our knowledge of the geographical distribution of the Pyroglyphidae has progressed considerably, but the map of their distribution remains incomplete. Nevertheless, numerous investigations to date have confirmed that *D. pteronyssinus* predominates over all other species in most countries, and that *Dermatophagoides farinae* and *Euroglyphus maynei* may also be present in numbers which vary according to climate (Fain, 1966). Certain species which are abundant in certain countries are completely absent in other geographical regions with apparently similar climate. This is the case notably for *Dermatophagoides siboney* which is very frequent in Cuba, but only exists in this country (Dusbabek *et al.*, 1982). Conversely, similarities exist between the mite fauna of certain countries which are very different climatically and geographically, for example, *Dermatophagoides neotropicalis* is frequently found in Surinam and Brazil but is also represented in India (Fain & van Bronswijk, 1973; ChannaBasavanna *et al.*, 1984). The distribution of *E. maynei* is even more enigmatic; this species has been identified in every continent except Central Africa and Central and North America (Fain, 1979a). More research into the biology and ecology of these mites is required before the reasons for these geographical preferences can be fully understood.

Zoogeographical studies have also revealed that the number of species of pyroglyphid mites is considerably larger than preliminary studies suggested and, therefore, the number of potentially allergenic mite species may be greater than initially supposed. The family Pyroglyphidae contains to date 18 genera and 46 species, of which 13 have been found in house dust (carpets, mattresses, cushions, clothes etc.), 28 exclusively on birds or in their nests and 5 in stored products or on mammals. The existence of many nidicolous or nest-inhabiting species in this family

suggests that the domestic species of Pyroglyphidae may have originated from nidicolous mites.

Despite the large number of species of Pyroglyphidae found in house dust, only 4 species (*D. pteronyssinus*, *D. farinae*, *Dermatophagoides microceras* and *E. maynei*) have been the subject of immunological investigations to determine their potential allergenicity (Charpin *et al.*, 1986; Lind, 1986). Clearly, an important area for future research is to ascertain the precise role played by different species of this family in the pathology of house dust allergy.

Pyroglyphid mites are not the only mites to provoke respiratory and also contact allergies. Certain mites infesting stored products such as foods and belonging to the genera *Acarus*, *Tyrophagus* (Acaridae), *Glycyphagus* and *Lepidoglyphus* (Glycyphagidae) have also been implicated in similar types of allergies (Baker *et al.*, 1956; Araujo-Fontaine *et al.*, 1971; Munoz Lopez *et al.*, 1975; Arlian *et al.*, 1984; Eaton *et al.*, 1985a; van Hage-Hamsten *et al.*, 1987). The people most exposed to these mites are primarily farmers and their families who due to their work are in regular contact with the dust in barns containing hay, straw or grain. The existence of common allergenic determinants in these various mites, seriously complicates the interpretation of skin or blood responses as measured by various provocation tests, and this issue is discussed in detail in Chapter III of this review. In addition, to emphasize the importance of storage mites and to facilitate their identification, we have completed our iconography by drawings and descriptions of the principal characters for identification of the main species of mites responsible for "barn allergy" (see Chapter I).

It is also of interest to note that storage mites (Acaridae and Glycyphagidae) have been recognised for a considerable time as the agents responsible for contact allergies associated with various professions, such as that of grocers produced by *Glycyphagus domesticus*, that of bakers and of cheese produced by *Acarus siro*, dermatitis of copra ("copra itch") for which the usual causative agent is *Tyrophagus*, and dermatitis associated with dried fruits which is produced by *Carpoglyphus lactis* (Baker *et al.*, 1956). This suggests that storage mites may possess certain specific allergenic determinants associated with these various dermal allergies.

One of us (Fain, 1978) proposed the hypothesis that two different mites *D. pteronyssinus* and *Sarcoptes scabiei*, which both share the same nutritional requirement for human skin, may possess common antigens, and that it may therefore be possible to use extracts of *D. pteronyssinus* in diagnosis of mange.Recent studies of scabies mite antigens by Falk *et al.* (1981) and Arlian *et al.* (1988) support this hypothesis.

Since the association of mites with allergies, much research has been undertaken into the ecology and biology of these mites. As previously mentioned, the species and prevalence of mites differ in different geographical areas, but they also vary within regions according to habitat and season. For example, in house dust in Europe, the Pyroglyphidae are most abundant in mattress dust collected in late summer (Spieksma, 1967; Lustgraaf, 1978a), whereas the Acaridae and Glycyphagidae are seldom found in house dust, and if present are usually found in floor dust (Colloff, 1987b; Hart, personal observations).

The influence of predatory mites and fungal flora on the ecology of dust mites has also been investigated. The predatory mite *Cheyletus eruditus* is often abundant in house dust and stored products and has therefore been suggested as a means of controlling allergenic mite populations, however, this predator has not yet proven effective in controlling mite populations in the home or in stored products (Schoonen, 1969; Sinha *et al.*, 1969). Fungi of the genus *Aspergillus* have been suggested to be an important dietary component of the Acaridia (Sinha *et al.*, 1969; de Saint Georges-Gridelet, 1984, 1987). The development of *D. pteronyssinus* reared without fungi in their diet is retarded (Bronswijk & Sinha, 1973; Douglas & Hart, 1989) and consequently the use of fungicides to control mite populations has been investigated (de Saint Georges-Gridelet, 1981).

Laboratory studies have elucidated the life cycle and temperature, humidity and nutritional requirements of several species, the details of which will be discussed in Chapter II of this review. In addition to clarifying the ecology of these mites in vivo, this information has been invaluable in enabling the cultivation of these mites under laboratory conditions for use in immunological (e.g. extraction of allergens) and other studies such as acaricide trials.

The application of mite extracts to modern laboratory techniques using starch, amidon, cellulose acetate and polyacrylamide gel electrophoresis has utilised carboxylesterase isoenzymes to differentiate between various species of Pyroglyphidae, Acaridae and Glycyphagidae (Silberstein *et al.*, 1979; Dujardin *et al.*, 1981; Hart *et al.*, 1989). This approach is particularly useful when species are extremely difficult to separate

using morphological criteria, for example, in *D. farinae* and *D microceras* where the characters presumed to be discriminating have been found to vary from one population to another (see Chapter I), or in various species of the genus *Tyrophagus* which are almost undistinguishable morphologically. It is also now possible to use various immunochemical techniques to identify and quantify the species of mites present in dust samples by means of their specific allergens (Lind *et al.*, 1979; Platts-Mills *et al.*, 1986). Another recent method of quantifying mites and their allergens present in house dust involves a rapid chemical colour detection of the amount of the guanine excretory product of mites. This Acarex test does not, however, provide any information on the species present (Bronswijk, 1986).

Most importantly, the latest technologies have also been applied to investigate the allergens associated with these mites which are responsible for perennial allergies and extrinsic asthma. Considerable progress in this field has been made, particularly in the past 10 years, with the development of new molecular biology techniques. A total of five allergens from three species of dust mites have been identified and monoclonal antibodies against these have been produced (Chapman & Platts-Mills, 1980; Lind, 1986; Stewart *et al.*, 1987). Our knowledge as to how the allergens are produced by the mites is as yet incomplete although recent studies by Thompson and Carswell (1988) and Chua *et al.* (1988) suggest that the major allergen of *D. pteronyssinus* (Der pI) is a soluble glycoprotein synthesized and excreted by the mite. The major mite allergens, this term being used in context of their ability to sensitize, have been found both in the faeces and in the mite bodies themselves (Tovey *et al.*, 1981; Arlian *et al.*, 1987), however, the relative importance of the somatic and metabolic allergens is strongly disputed.

The presence of two opposing schools in this regard has also influenced the definition of two reference mite allergen extracts. One extract, proposed by the sub-committee of standardization of the International Union of Immunology Societies (1986) and recognised by the World Health Organization, is based on primary material obtained from mature whole mite culture, which contains both somatic and metabolic antigens. The other extract, proposed by the Food & Drugs Administration of the United States (1987), contains only mite bodies, separated by sieving or differential flotation, from the rest of the culture including secreted or excreted metabolites.

Despite the mass of knowledge about dust mites and their allergens obtained over the past 10 years, no detailed reviews on this topic have been published for at least 12 years (Bronswijk & Sinha, 1971; Wharton, 1976), except for a recent, principally immunological synthesis by Platts-Mills and Chapman (1987). As a result, an up to date, multidisciplinary, "status of the art" review of the mites associated with allergic disease, is not only desirable but indeed essential.

The three objectives of the present monograph are therefore : firstly, to respond to the wish expressed by many non-acarologists working on allergenic mites (including clinicians and biologists), to have available in a single publication, all the current morphological information, including figures and keys to enable precise identification of the different species of mites which are the subject of their research; secondly, to review our knowledge to date of the ecology, biology and conditions of culture of the most important mite species; and finally, to analyse the information, which is sometimes falsely contradictory due to technical artefacts, relating to the various somatic and metabolic allergens produced by domestic or storage mites, and also to examine the treatment available, especially the various recently proposed methods of controlling mite populations.

To date control measures to eradicate dust mites from houses have involved the use of various acaricides (Jean-Pastor *et al.*, 1986), fungicides (de Saint Georges-Gridelet, 1981a ; 1987b), plastic mattress covers and rigorous cleaning procedures directed primarily at the bedding and carpeting (Vervloet *et al.*, 1982). If certain studies have demonstrated a significant reduction in the number of mites in dust collected after treatment with these products (Heller-Haupt *et al.*, 1974; Mitchell *et al.*, 1985), none of the studies of clinical symptoms of patients in whose homes these treatments have been applied, have provided results which would justify their regular use. In this context the treatment of allergies caused by mites remains dependent on various desensitization programmes, notably the "accelerated" technique (Bousquet *et al.*, 1985) which is achieved using standardised aqueous allergen extracts. The success of this technique has been demonstrated, but its management is extremely difficult in patients with asthma which is unpredictable.

In conclusion, rather than a decrease in the incidence of dust allergy, we are now seeing a progressive increase in the incidence of asthma, which in some countries has practically doubled in the past 10 years (Fleming & Crombie, 1987). This phenomenon is not only seen in developed, urbanised countries, but also in countries in the course of development which are adopting a more

modern life style (Dowse *et al.*, 1985). Clearly, further research on all factors influencing the incidence of asthma and the associated mites is urgently required to halt this alarming trend. Such research should involve, for example, techniques for identification of mite species and studies of their cross allergenicity which may influence specific desensitization treatment, and also a search for better control measures to reduce or eliminate mites in the environment of man and especially of atopic patients.

We hope that this review, by assembling all the relevant information to date, will provide an invaluable tool to those working on this major clinical problem. It should be of interest equally to clinicians and biologists who are confronted daily with patients suffering from allergies or asthma caused by mites.

CHAPTER I

Morphology, systematics and geographical distribution of mites responsible for allergic disease in man

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Introduction

In 1964, Voorhorst and Spieksma demonstrated for the first time that mites living in houses are responsible for house dust bronchial asthma. The mites were assigned to an unidentified species of the genus *Dermatophagoides* (Bogdanov, 1864).

This mite, as well as two other species present in house dust, were identified by the present author. They belonged to the genus *Dermatophagoides* (i.e. *D. pteronyssinus* (Trouessart) and *D. farinae* (Hughes)) and to a new genus *Euroglyphus* Fain (*E. maynei* (Cooreman)). It was the first time that these three species were reported from house dust (Fain, 1965 and 1966a).

This discovery was the starting point for a series of studies in this field. These new investigations showed that *D. pteronyssinus* was not the only species involved in respiratory allergy but that other species may cause the same type of allergy. They also provided many new and important data on the systematics, the geographic distribution, the biology and the pathogenic action of these mites.

The mites living in house dust belong to several families, of which the most important is the family Pyroglyphidae because it includes all the species responsible for the syndrome called house dust bronchial asthma.

The Pyroglyphidae include to date 18 genera and 46 species. Among these species 13 have been found in house dust. Some of these species are cosmopolitan in distribution, while others are confined to one or only a few countries.

It may be difficult for scientists who do not work regularly with pyroglyphid mites, to identify some species with certainty. Moreover, the specialized literature necessary for this identification may be difficult to obtain in some countries. These reasons have incited us to bring together in this book all the information, such as detailed keys, original figures etc..., necessary for a correct identification of these mites. Keys and original figures are also given for the most important species belonging to the families Acaridae and Glycyphagidae and responsible for barn allergy.

Historical review

• INVOLVEMENT OF MITES IN RESPIRATORY ALLERGIES

Dekker (1928) was the first to suspect that mites living in house dust and in mattresses were responsible for respiratory allergies. He obtained positive skin reactions with extracts made from mites found in house dust (Bochofen *et al.*, 1967, cited by Larson *et al.*, 1969).

In 1944, Carter, Webb and d'Abrera, unaware of the paper of Dekker, described in Ceylon (Sri Lanka) a respiratory syndrome characterized by bronchitis, frequently of the asthmatiform type, blood hypereosinophilia and transient condensations in the lungs visible by X-ray. The syndrome was named "Pulmonary acariasis". In the sputum of their patients these authors regularly found free living mites belonging to the fauna commonly found in house dust. The authors surmized that these pulmonary symptoms were caused by the accidental inhalation of mites into the lungs.

New cases of "Pulmonary acariasis" were observed in several other regions of the world, mainly in the tropical countries of Asia, Africa and South America.

It should be noted that this syndrome had never been clearly defined from the medical point of view but was clinically related to several similar, mainly tropical, eosinophilic diseases, such as Loeffler's Syndrome, Eosinophilic lung or Tropical Eosinophilia.

The true etiology of "Pulmonary acariasis" remained obscure. The presence of mites in the lungs of these patients had never been established with certainty and the diagnosis was based only on their presence in the sputum.

The problem of bronchial asthma in relation to house dust was solved in 1964 by Voorhorst and Spieksma in The Netherlands, exactly one century after the discovery of the first pyroglyphid species by Bogdanov. These authors demonstrated that this disease is caused by the inhalation of allergens originating from the mite *Dermatophagoides* sp., which is present in large numbers in house dust.

• SYSTEMATICS OF THE PYROGLYPHIDAE

Bogdanov (1864) described the genus *Dermatophagoides* with *D. scheremetewskyi* as type species. The specimens were collected from the skin of two patients suffering from skin diseases in Moscow.

The presence of mites in houses has been known for a long time and has been repeatedly recorded. In this connection it is interesting to mention the paper of Ludwig (1904, cited by Oboussier, 1939) dealing with "Milbenplage der Wohnungen". Oboussier (1939) devoted her thesis to the study of mites found in houses in Hamburg, Germany. She mentioned the presence of Acaridae (*Tyrophagus* sp), Glycyphagidae (two species of *Glycyphagus*) and Carpoglyphidae (*Carpoglyphus lactis*), all species regularly infesting stored food. It is rather surprising not to find in this material some species of the family Pyroglyphidae, especially *Dermatophagoides* sp. which are generally very abundant in house dust.

In the meantime, Oudemans (1928) had recorded the presence of a *Dermatophagoides* on a plant in a residential flat in Holland. He described this species as new, *Mealia toxopei* but it actually belongs to *Dermatophagoides pteronyssinus* (Fain, 1966a).

A new genus and species, *Hirstia chelidonis*, was described by Hull (1931) from the nest of a House Martin, *Delichon urbica* from Belford, England.

In 1947, Sasa reported the presence of mites in the sputum and urine of patients in Japan. He created a new genus for these specimens, *Visceroptes*, and described two new species, *V. saitoi* and *V. takeuchii*, both represented only by males. In 1950, Sasa recognised that his genus was a synonym of *Dermatophagoides* Bogdanov, 1864, but considered as valid the two species he described in the genus *Visceroptes*. The male that he depicted as *D. saitoi*, actually closely resembles the male of *D. pteronyssinus*. Sasa did not depict the male of *D. takeuchii* but he mentioned that the epimera I are fused in a Y, which is a character shared with *D. farinae*. In 1951, Sasa depicted a female specimen that he assigned to *D. saitoi* but which appeared close to the genus *Hirstia* (legs IV much shorter than legs III). In the same paper he redescribed the female of *D. scheremetewskyi*, but in his drawing it appears that the dorsal striations between setae *d2* and *d3* are mostly transverse as in *D. farinae* and not as in *D. pteronyssinus* where these striations are longitudinal. In 1958, Sasa and Shingai collected, from albumine tannate stored in dispensaries in Japan, numerous mites that they assigned to *D. scheremetewskyi*. However, judging from the drawings given in their paper these mites were very probably *D. farinae*.

Cooreman (1950) described, from decomposing cotton seed cake in Belgium, a new species *Mealia maynei*. This species is the type of the genus *Euroglyphus* Fain, 1965.

Traver (1951) in an auto-observation expressed the opinion that a chronic dermatitis of the scalp, from which she suffered for about ten years, was caused by mites that were identified by E. Baker as *Dermatophagoides scheremetewskyi*. The present author had the opportunity to examine these specimens and found that they actually belonged to two species, *D. pteronyssinus* and *D. farinae*. It seems unlikely that these mites were the cause of the scalp dermatitis of Miss Traver (Fain, 1969a). Dubinin *et al.* (1956) reported similar cases from the U.S.S.R. They found *D. scheremetewskyi* on the skin, mainly of the head, of patients suffering from seborrheal eczema or chronic diffused neurodermatitis.

In 1953, Dubinin placed the genus *Dermatophagoides* in the family Epidermoptidae.

A new species of Dermatophagoides, *D. africanus*, was described by Hughes in 1954, from fishmeal imported from Angola and stored in England.

Baker *et al.* (1956) reported the presence of *D. scheremetewskyi* in various habitats: kapok-filled sofa cushions, feather pillows, sparrows' nests, cereal-like meal for monkeys, from rats and muskrats, from a bat and in houses.

In 1958, Cunliffe created the family Pyroglyphidae for the genus *Pyroglyphus* Cunliffe, 1958 (type species: *Pyroglyphus morlani* Cunliffe, 1958, from the nest of a rodent, U.S.A.).

Gaud, in 1958, cited in a key the new genus name *Onychalges* without any description or designation of a type species. In 1959, Gaud and Mouchet described this genus and designated a type species (*Megninia longitarsus* Bonnet, 1924), thereby validating the genus.

In 1961, Hughes described a new species, *Dermatophagoides farinae* found in poultry and pig meal near Bristol, England.

In 1963, De Leon described a new species, *Dermatophagoides culinae*, collected from biscuit meal in U.S.A.

In 1963, Fain created the subfamily Dermatophagoidinae which he included in the Psoroptidae.

In 1964, Fain described a new species, *Dermatophagoides passericola*, found in the nest of *Passer domesticus* in Belgium.

In 1964, Voorhorst and Spieksma discovered that a mite of the genus *Dermatophagoides* is very common in house dust in The Netherlands and is the cause of bronchial asthma in that country. This mite was sent to the present author for identification. After comparison with the type specimens of *Dermatophagoides pteronyssinus* (Trouessart, 1897) from the Berlese acarotheca of Florence, it was concluded that they belong to the same species. This material also contained two other species, *Dermatophagoides farinae* (Hughes, 1961) and *Euroglyphus maynei* (Cooreman, 1950), not previously reported from house dust (Fain, 1965).

In 1965, Fain revised the family Pyroglyphidae. He included in this family the following taxa: *Pyroglyphus* Cunliffe, 1958 ; *Bontiella* g.n. (type species: *Bontiella bouilloni* sp.n.) ; *Pyroglyphus* (*Hughesiella*) subg.n. (type species: *P.(H.) africanus* Hughes, 1954); *Euroglyphus* (*Euroglyphus*) g.n. (type species: *E.(E.) maynei* (Cooreman, 1950)); *Euroglyphus* (*Gymnoglyphus*) subg.n. (type species: *E.(G.) longior* (Trouessart, 1897)).

Fain (1966a), proposed to select *D. pteronyssinus* (Trouessart, 1897) as type of the genus *Dermatophagoides*. This species was redescribed and redepicted and a list of new localities for some species of Pyroglyphidae was given (Fain, 1966b). In 1967a this author redescribed *D. farin*ae and described several new taxa : *Dermatophagoides (Sturnophagoides)* subg.n. (type species: *D.(S.) bakeri* sp.n.), *Dermatophagoides rwandae* sp.n. from a bird's nest and *Dermatophagoides evansi* Fain, Hughes and Johnston sp.n. collected from feather pillows. In the same year he included the Dermatophagoidinae in the Pyroglyphidae, raised the subgenus *Sturnophagoides* to the genus rank and described two new species: *Sturnophagoides brasiliensis* from house dust in Brazil and *Dermatophagoides aureliani* from the nest of a bird in Rwanda (Fain, 1967b).

In 1968, Gaud described 2 new genera and 6 new species of Dermatophagoidinae, all collected from birds or from their nests, i.e. *Hullia* g.n. (type species *H. anisopoda* sp.n.) ; *Paramealia* g.n. (type species *P. ovata* Gaud and Mouchet, 1959) ; *Onychalges asaphospathus* sp.n. ; *O. pachyspathus* sp.n. ; *O. odonturus* sp.n. ; *O. schizurus* sp.n. and *Paralgopsis ctenodontus* sp.n.

In 1969, Fain, Cunnington and Spieksma described *Malayoglyphus intermedius* g.n. and sp.n. found in house dust in Singapore and Indonesia.

In 1970, Fain and Wharton described *Guatemalichus bananae* g.n., sp.n. from a cluster of bananas originating from Guatemala. In the same year Fain and Feinberg described *Sturnophagoides halterophilus* sp.n. collected from house dust in Singapore.

Griffiths and Cunnington (1971) described *Dermatophagoides microceras* sp.n. from house dust in England.

In 1971, Fain described *Pottocola scutata* g.n., sp.n. and *Sturnophagoides (Kivuicola) kivuana* subg. and sp.n. both from a dried skin of a lemurian from Zaire.

In 1973, Fain and van Bronswijk described *Dermatophagoides neotropicalis* sp.n. from house dust in Surinam and they transferred *Sturnophagoides halterophilus* to the genus *Dermatophagoides*.

In 1973, Fain and Johnston described *Euroglyphus (Gymnoglyphus) osu* sp.n. collected from barn dust in U.S.A.

In 1973, Spieksma described *Malayoglyphus carmelitus* sp.n. from house dust in Israël.

In 1974, Fain, Oshima and van Bronswijk described *Hirstia domicola,* a new species found in house dust in Japan and in Surinam.

In 1974, Fain and Lowry described a new species belonging to a new genus, *Weelawadjia australis* g.n., sp.n. from the guano of a cave and from nests of birds in Australia.

In 1975, Fain described *Dermatophagoides sclerovestibulatus* sp.n. from a South African bird.

In 1976, Baker *et al.* described for the first time the male of *Sturnophagoides bakeri*.

In 1976, Wharton published a comprehensive study of the house dust mite problem, including useful keys to the species of the family Pyroglyphidae.

In 1977, Atyeo and Gaud described *Fainoglyphus magnastermus* g.n. and sp.n. from a bird in Ecuador.

In 1982, 2 new species were described in the genus *Dermatophagoides*: *D. simplex* Fain and Rosa from the nest of a sparrow in Brazil, and *D. siboney* Dusbabek, Cuervo and Cruz, collected from house dust in Cuba.

In 1982, Fain, Gaud and Perez described a new genus *Campephilocoptes* represented by 2 new species, *C. atyeoi* and *C. paraguayensis*, collected from South American piciform birds.

In 1983, Gaud (in Gaud and Atyeo, 1983) considered the name *Onychalges* Gaud and Mouchet, 1959 invalid, and proposed to replace it by the new name *Neonychalges* Gaud, 1983.

In 1984, Fain and Gaud described several new taxa from Central African piciform birds, i.e. *Capitonoecius* g.n. (type species: *C. spinitarsis* sp.n.) and *Pottocola (Capitonocoptes)* subg.n. represented by 3 new species: *P.(C.) ventriscutatus*, *P.(C.) longipilis* sp.n. and *P.(C.) lybius* sp.n.

In 1984, Cruz, Cuervo and Dusbabek described *Guatemalichus tachornis* sp.n. from the nest of a bird in Cuba.

In 1986, Galvao and Neide described *Dermatophagoides deanei* sp.n. from house dust in several towns of Brazil.

In 1987, Cuervo and Dusbabek described *Sturnophagoides petrochelidonis* sp.n. from a "cave swallow" in Cuba.

In 1988, Fain (in "Acariens et Allergies", by Fain *et al.*, 1988b) proposed the following modifications in the taxonomy of the Pyroglyphidae:

New synonymy:

1. The genus *Neonychalges* Gaud, 1983 is synonymized with *Onychalges* Gaud and Mouchet, 1959 (nec *Onychalges* Gaud, 1958)
2. The genus *Capitonoecius* Fain and Gaud, 1984 is synonymized with *Onychalges* Gaud and Mouchet, 1959.
3. The genus *Hullia* Gaud, 1968 is synonymized with *Dermatophagoides* Bogdanov, 1864.
4. *Sturnophagoides halterophilus* Fain and Feinberg, 1970, is synonymized with *Sturnophagoides brasiliensis* Fain, 1967.
5. *Dermatophagoides deanei* Galvao and Neide, 1986, is synonymized with *Dermatophagoides neotropicalis* Fain and Bronswijk, 1973.

Description of new taxa:

1. *Paralgopsinae* Fain, 1988 subf.n., type genus: *Paralgopsis* Gaud and Mouchet, 1959.
2. *Onychalginae* Fain, 1988, subf.n., type genus: *Onychalges* Gaud and Mouchet, 1959.
3. *Guatemalichinae* Fain, 1988, subf.n., type genus: *Guatemalichus* Fain and Wharton, 1970.

New statutes and transfers:

1. The subgenus *Pyroglyphus (Hughesiella)* Fain, 1965 (type species: *Dermatophagoides africanus* Hughes, 1954) is raised to the genus rank: *Hughesiella* Fain, 1965 stat.nov.
2. The subgenus *Euroglyphus (Gymnoglyphus)* Fain, 1965 (type species *Mealia longior* Trouessart, 1897) is raised to the genus rank *Gymnoglyphus* Fain, 1965 stat.nov.
3. The subgenus *Sturnophagoides (Kivuicola)* Fain, 1971 (type species: *S.(K.) kivuicola* Fain, 1971) is raised to the genus rank: *Kivuicola* Fain, 1971 stat.nov.

Definitions of some acarological terms

• IDIOSOMA

The body of the mite is also called the idiosoma. It bears 4 pairs of legs in the adults and the nymphs and 3 pairs of legs in the larva.

The anterior part of the idiosoma bears the mouth, the pedipalps and the chelicerae. There is no true head in the mites. A transverse furrow, generally well distinct, is present between the legs II and III (= sejugal furrow).

The idiosoma is divided into 4 regions:

Propodosoma : region situated between the sejugal furrow and the anterior extremity of the idiosoma. It bears, ventrally, the first and second pair of legs.

Metapodosoma : region bearing the third and the fourth pair of legs.

Opisthosoma : region posterior to the fourth pair of legs.

Hysterosoma : metapodosoma + opisthosoma. It is situated posterior to the second pair of legs.

The dorsal surfaces of the propodosoma and the hysterosoma are also called propodonotum and hysteronotum respectively. The ventral surface of the opisthosoma is given the name of opisthogaster.

In some genera the propodonotum is prolonged anteriorly into a rounded or bifid tegmen which covers the base of the chelicerae (Figs 12 and 15).

• GNATHOSOMA (OR MOUTHPARTS)

It consists of two parts: a ventral hypostome ending anterolaterally into a pair of biarticulate sensorial pedipalps and a pair of dorsal chelate and toothed chelicerae (Fig 4).

• LEGS

There are 4 pairs of legs in the adults and nymphs and 3 pairs in the larvae. The legs are formed of 6 segments, of which the basal segment (epimeron) is fused with the body, whilst the 5 others are free (trochanter, femur, genu, tibia and tarsus). The extremity of the tarsus is prolonged by a soft pretarsus forming generally a fleshy pulvillus and bearing an articulated claw. In the Pyroglyphidae this claw is always vestigial (Fig 28).

• SEXUAL ORGANS

Female : the vulva is ventral and situated at the level of the posterior pairs of legs; it is in the shape of an inverted-Y with two anterolateral lips and one posteromedian lip. The anterolateral lips attach anteriorly to a crescent-shaped sclerite (epigynium) and posteriorly to a pair of posterolateral sclerites (Fig 18). There is a second genital opening at the posterior end of the body, the bursa copulatrix, acting as a copulatory organ. It leads to a thin canaliculus which opens inside into the spermatheca. The shape of the bursa is of great systematic importance in the Pyroglyphidae (Figs 59-61).

The male has a sclerotized penis situated ventrally at the level of the posterior legs. In the Pyroglyphidae and the Acaridae the anus is generally flanked by a pair of adanal copulatory suckers. Two pairs of small suckers are also present on the tarsi IV. These copulatory suckers are lacking in the Glycyphagidae and in some Pyroglyphidae (Figs 5, 36).

• SETAE OR HAIRS

The body, the legs and the gnathosoma bear numerous hairs also called setae. A spine is a thick hair. The true seta has a chitinous core and is closed at its base.

Solenidia : A solenidion is a specialized seta with a hollow core and an open base. The solenidia are situated dorsally on the distal segments of the legs and of the palpi. Tarsus I bears 3 solenidia omega (ω 1, 2 and 3); tarsus II bears only 1. Tibiae I-IV bear only one solenidion phi (φ). Genu I has either one or two solenidia sigma (σ 1and 2); genua II and III have no more than one solenidion (Figs 27-28).

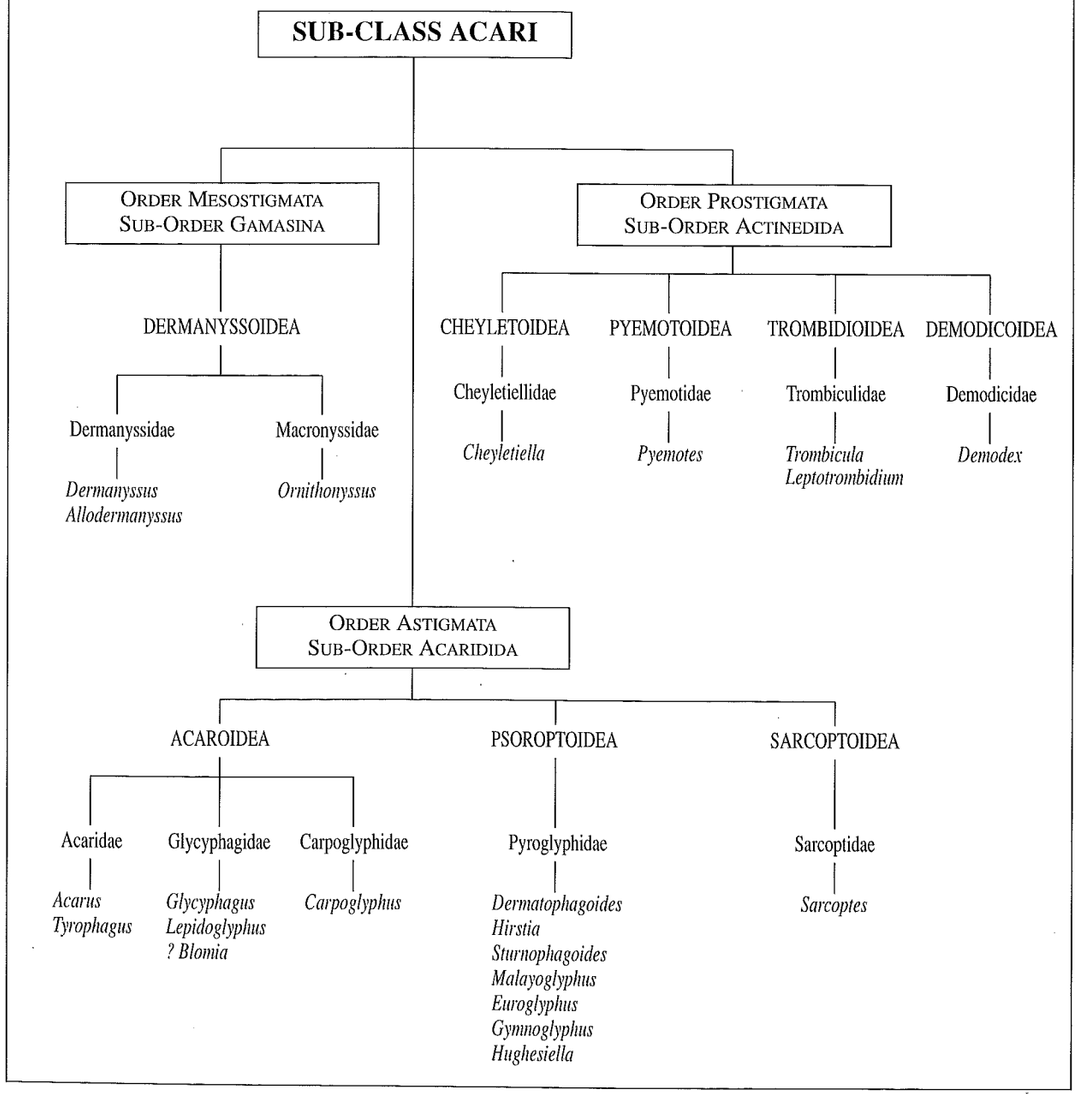
Famulus epsilon (ε) : This specialized seta is present only on tarsus I. It is generally in the shape of a small conical spine with a hollow core and situated very close to the base of ω1. Its function is unknown (Fig 52, 55).

Nomenclature of the idiosomal chaetotaxy (Figs 32, 34, 62, 63 and 67) :

The length, the situation and the number of the setae of the idiosoma and the legs are very important characters in the systematics of mites. Several systems of nomenclature have been proposed for the setae of the idiosoma in the Astigmata. We follow herein a system that we have proposed previously (Fain, 1963) which comprizes the following terms:

Vertical internal : *vi* ; Vertical external : *ve* ; Scapular internal : *sc i* ; Scapular external : *sc e* ; Supracoxal : s *cx* ; Laterals 1 to 5 : *l1 to l5* ; Humeral : *h* ; Subhumeral : *sh* ; Coxal I and III : *cxI* and *cxIII* ; Genital anterior : *g a* ; Genital median : *g m* ; Genital posterior : *g p* ; Anals 1 to 6 : *a1 to a6* ; Anal internal : *a i* (in the Pyroglyphidae) ; Anal external : *a e* (in the Pyroglyphidae).

Classification of the genera of mites responsible for respiratory allergies, scabies or dermatitis (allergic and non-allergic) in man.



Study of the mites causing allergies in man

A. MITES CAUSING BRONCHIAL ASTHMA

• I.FAMILY PYROGLYPHIDAE

1. RELATIONSHIP OF THE PYROGLYPHIDAE TO OTHER MITES

Dubinin (1953) included the genus *Dermatophagoides* in the family Epidermoptidae.

Fain (1963) created for this genus the new subfamily Dermatophagoidinae which he included in the Psoroptidae. In a revision of the family Pyroglyphidae Cunliffe, Fain (1965) recognised the close relationship existing between this family and the genus *Dermatophagoides* and discussed the eventual possibility of retaining only one family Psoroptidae with three subfamilies: Psoroptinae, Pyroglyphinae and Dermatophagoidinae. From a morphological point of view the combination appeared logical, however as far as the ecological aspects of these mites are concerned, such a fusion is not satisfactory. The Pyroglyphidae are all free living, mostly nidicolous (nest-inhabiting) mites, whereas the majority of the Psoroptidae (e.g. all the Psoroptinae) are obligatory parasites of mammals. It was therefore proposed to separate both families and to provisionally retain the Dermatophagoidinae in the Psoroptidae, rather than in the Pyroglyphidae, primarily for morphological reasons. Fain (1967b) completed this revision by transferring the Dermatophagoidinae from the Psoroptidae into the Pyroglyphidae.

Indeed, the Pyroglyphidae form a link between the free living Astigmata and the parasitic Psoroptidia. Gaud (1968), however, has shown that some Pyroglyphidae are able to adopt a parasitic mode of life. The great majority of species live in the nests of birds or on birds, but the latter location is probably accidental, the true habitat most likely being the nest. Among the 46 species described so far, 28 have been found only in birds' nests (or on birds). There are also 3 species found in both birds' nests and house dust and 10 species found mainly in house dust and never in birds' nests. It appears therefore that the nests of birds are the true habitat of these mites and that houses have probably been invaded secondarily by pyroglyphids originating from the nests of small synanthropic passeriform birds (sparrows and swallows). Morphologically the Pyroglyphidae present the same characters as the parasitic Psoroptidia. It seems that in this group the regression of the organs has preceeded the invasion of the host as if there were a preadaptation (Fain, 1979b). This may have been induced by the repeated contact between host and mite which has elicited the same reaction as true parasitism. I have postulated (1963) that all the parasitic Psoroptidia of mammals and all the parasitic Analgoidea of birds, may be derived from the nidicolous Pyroglyphidae.

2. CHARACTERS OF THE PYROGLYPHIDAE

The Pyroglyphidae present, as in the Psoroptidae, a regression of most of the organs. This regression involves the legs (reduction of legs IV, especially in the males), the shields (mainly the hysteronotal), the sexual suckers (vestigial and reduced in the shape of small sclerotized rings), the tarsal claws (only represented by a small median axis) and the chaetotaxy. The latter has the same aspect as in the parasitic Astigmata: the *ve* are lacking and the *vi* are present only in the genus *Paralgopsis* ; there are only two pairs of anals in the female (five or six pairs in the Acaridae). On legs I and II the tarsi bear eight setae and the tibiae one seta.

Besides these regressive characters, there is also a very unusual specialized character, namely the apical migration of the solenidion ω1 of tarsus I. The solenidia ω1 and ω3 are situated close to each other at the apex of this tarsus. This character seems to be particular for the Pyroglyphidae and is not observed in the other free

living Astigmata nor in the parasitic Psoroptidia (Fain, 1963, p. 47). The famulus is in the shape of a short spine and is situated proximal to ω1. The exact significance of the apical migration of ω1 in the Pyroglyphidae is unknown.

The degree of sclerotization of the cuticle is very variable in the Pyroglyphidae. In some genera the cuticle is almost completely sclerotized without striations whilst in others the cuticle is soft and striated and the shields poorly developed. Some genera produce both normal and heteromorphic males, the latter showing a thickening of the first pair of legs and sometimes a fusion of the epimera I with the formation of a sternum.

3. DIVISION OF THE PYROGLYPHIDAE

The family Pyroglyphidae includes at present 18 genera and 46 species. This family has been divided into 5 subfamilies (Fain, 1988b):

Subfamily **Pyroglyphinae** Cunliffe, 1958, Fain, 1988b

Fain (1965) revised the family Pyroglyphidae and added to the only known genus (*Pyroglyphus* Cunliffe), 2 other new genera (*Bontiella* and *Euroglyphus*) and 2 new subgenera (*Pyroglyphus (Hughesiella)* and *Euroglyphus (Gymnoglyphus)*). Fain (1967b) divided the Pyroglyphidae into 2 subfamilies, Pyroglyphinae and Dermatophagoidinae. In 1988 he added three new subfamilies to this family and elevated the subgenera *Hughesiella* and *Gymnoglyphus* to the genus rank.

Definition : Tegmen well developed. Cuticle from slightly to strongly sclerotized. Striations either relatively thick, irregular and well spaced, or completely lacking. The median area separating the epimera I is punctate. Body setae variable, either all very thin and very short, or with some setae very long and strong (*sc e, d5* and *l5*). Female with posterior vulvar lip always punctate, generally fairly long and in some species incised in its anterior angle. Male : adanal suckers either present or lacking; suckers of tarsi IV generally replaced by very short setae; tarsi III without forked apical spine.

This subfamily includes 7 genera (Fain, 1988b): *Pyroglyphus* Cunliffe, *Hughesiella* Fain, *Bontiella* Fain, *Euroglyphus* Fain, *Gymnoglyphus* Fain, *Weelawadjia* Fain and Lowry and *Campephilocoptes* Fain, Gaud and Perez. Only 3 of these genera include species found in houses. The others are nidicolous.

Subfamily **Dermatophagoidinae** Fain, 1963, 1988b

Definition : Tegmen absent. Cuticle soft with well-developed striations, the latter generally very thin and set close together, rarely of the striated-punctate type (*Sturnophagoides*). The area separating epimera I exceptionally punctate. Setae *sc e* strong and long except in genus *Malayoglyphus* where they are short or very short. Setae *d5* and *l5* long. Female with posterior vulvar lip soft and striated, not punctate and not incised anteriorly except in *Sturnophagoides* where this lip is punctate (either partly or completely) and incised anteriorly. Hysteronotal shield in female present only in *Sturnophagoides*. Male with adanal suckers; the suckers of tarsi IV are present except in *Malayoglyphus*; tarsi III with a strong furcate apico-ventral spine except in *Malayoglyphus* and *Sturnophagoides* where this spine is lacking.

This subfamily includes 4 genera: *Dermatophagoides* Bogdanov, *Hirstia* Hull, *Malayoglyphus* Fain, Cunnington and Spieksma and *Sturnophagoides* Fain. All of these genera contain one or several domicolous species (Fain, 1988b).

Subfamily **Guatemalichinae** Fain, 1988b
Guatemalichinae Fain, 1988b: 20

Definition: Tegmen poorly developed or absent. Cuticle finely striated. Female with a median hysteronotal shield. Epigynium displaced forwards and either contiguous to or fused with epimera I. Posterior vulvar lip striated, long and narrow. Setae *sc e, d5* and *l5* long and strong. Tarsi III and IV ending in 2 apical, conical, not forked spines. The male in the typical genus is unknown.

Typical genus : *Guatemalichus* Fain and Wharton, 1970.

This subfamily includes 3 genera:

1. *Guatemalichus* Fain and Wharton, 1970: The typical species *G. bananae* Fain and Wharton, 1970 was found in a stem of bananas originating from Guatemala. A second species *G. tachornis* Cruz, Cuervo and Dusbabek, 1984, was described from the nest of a bird, *Tachornis phoenicobia iradii* (Apodidae), in Cuba.

2. *Pottocola* Fain, 1971: The typical species, *Pottocola scutata* Fain, 1971, was found on a dried skin of a lemurian in Zaïre. The same species was found again on birds in Zaïre (Fain and Gaud, 1984). This genus includes another subgenus *Pottocola (Capitonocoptes)* Fain and Gaud, 1984 including 3

species: *P. (C.) ventriscutata* Fain and Gaud, 1984 (type species), *P.(C.) longipilis* (Fain and Gaud, 1984) and *P.(C.) lybius* Fain and Gaud, 1984. These 3 species were collected from birds (or from their nests) in Zaïre or in Togo.

3. *Fainoglyphus* Atyeo and Gaud, 1977: The typical species, *Fainoglyphus magnasternus* Atyeo and Gaud, 1977, was found on a bird *Cranioleuca erythrops* (Furnariidae) from Ecuador.

No species of this subfamily has been found in houses to date.

Subfamily **Onychalginae** Fain, 1988b
Onychalginae Fain, 1988b: 21

Definition: Tegmen wide, slightly convex. Cuticle striated. Setae *sc e*, *d5* and *l5* long and strong. Tarsi III and IV with a strong bifid or trifid subapicoventral spine. Ventral surface of tarsi I and II with small irregular pointed or rounded projections generally forming an axial denticulate crest; these projections are more developed in females than in males where they may be inconspicuous or lacking. Female with a small hysteronotal shield (genus *Kivuicola*) or without this shield (other genera). Male (only known in genera *Onychalges* and *Paramealia*) with posterior extremity bilobed (*Onychalges*) or entire (*Paramealia*). Adanal suckers and tarsal (tarsi IV) suckers present. Legs III thicker than legs IV.

Typical genus: *Onychalges* Gaud and Mouchet, 1959.

The Onychalginae differ from the other subfamilies of Pyroglyphinae, in both sexes, mainly by the presence on tarsi III and IV of a strong bifid or trifid subapicoventral spine.

This subfamily includes 3 genera:

1. *Onychalges* Gaud and Mouchet, 1959 (syn. *Neonychalges* Gaud, 1983 and *Capitonoecius* Fain and Gaud, 1984) (Fain, 1988b, in Fain *et al.*, 1988).

Gaud (1958) cited the name *Onychalges* but did not describe it and omitted to designate a type species. In 1959, Gaud and Mouchet described the genus and designated a type species (*Megninia longitarsus* Bonnet, 1924) thus validating the genus with the date 1959. The subsequent proposal of Gaud (in Gaud and Atyeo, 1983) to replace the name *Onychalges* by *Neonychalges* is therefore not founded (Fain, 1988b).

The genus *Onychalges* includes, in addition to the type species, the following 6 species: *O. asaphospathus* Gaud, 1968, *O. schizurus* Gaud, 1968, *O. odonturus* Gaud, 1968, *O. pachyspathus* Gaud, 1968, *O. spinitarsis* (Fain and Gaud, 1984) and *O. nidicola* Fain and Rosa, 1982.

2. *Paramealia* Gaud, 1968. Monotypic genus. Type species: *P. ovata* (Gaud and Mouchet, 1959).

3. *Kivuicola* Fain, 1971 (= *Sturnophagoides (Kivuicola)* Fain, 1971) (Fain, 1988b). Type species: *Sturnophagoides (Kivuicola) kivuana* Fain, 1971).

All species of the Onychalginae have been found from birds or nests of birds except *Kivuicola kivuana* which was described from a dried skin of a mammal, but we surmise that its true habitat was a bird's nest. Until now no species of this subfamily has been recorded from houses.

Subfamily **Paralgopsinae** Fain, 1988b
Paralgopsinae Fain, 1988b: 21

Definition: In both sexes : presence of setae *vi*. Tegmen absent. Anus terminal. Tarsi I and II with a curved apical process (= ongle), without ventral projections. Tarsi III and IV without spines. Setae *sc i, sc e, d5, l1, l2, l3, l5* strong and long or very long. In the female the cuticle is soft, not striated but bears numerous very thin projections as in *Glycyphagus* spp.; hysteronotum lacking a shield, epimera I fused into a V or Y. In the male the cuticle is striated - sclerotized, there is a large hysteronotal shield, the posterior extremity bears two large triangular lobes, epimera I are fused into a Y, there is a pair of small adanal suckers, the legs III are strongly expanded and their femora bear a strong ventral spur.

Type genus (and only known genus): *Paralgopsis* Gaud and Mouchet, 1959. This genus includes 2 species: *P. paradoxus* (Trouessart, 1899) (type species) from South American parrots and *P. ctenodontus* Gaud, 1968, found on *Ara macao* in Brazil. We have found a number of specimens of *Paralgopsis* species in the shafts of the wing feathers of several South American parrots. It appears therefore that the members of this genus can behave as true parasites. To date, no member of this subfamily has been found in house dust.

4. KEY TO THE PYROGLYPHIDAE (SUBFAMILIES)

Females

1. Setae *vi* present. Cuticle soft, bearing thin projections as in the genus *Glycyphagus*. Setae *sc i* very strong and long, subequal to the *sc e* .....
.....*PARALGOPSINAE* Fain, 1988b

Setae *vi* absent. Cuticle lacking these projections. Setae *sc i* never very strong and long 2

2. Tarsi III and IV with a strong, bifid or trifid apicoventral spine. Ventral surface of tarsi I and II with projections. Cuticle striated.....
.....*ONYCHALGINAE* Fain, 1988b

Tarsi III and IV lacking this spine. Tarsi I and II without projections. Cuticle variable 3

3. Epigynium contiguous to or fused with epimera I. Vulva long and narrow. Tarsi III and IV with 2 apical, conical and unforked spines .....
.....*GUATEMALICHINAE* Fain, 1988b

Epigynium distinctly separated from epimera I. Tarsi III and IV lacking apical spines except in *Weelawadjia* which presents these spines.....4

4. Tegmen well developed. Cuticle from slightly to strongly sclerotized, the striations when present are irregular, thick and well spaced. Cuticle between epimera I punctate. Posterior lip of the vulva completely punctate .....
.....*PYROGLYPHINAE* Cunliffe, 1958

Tegmen absent. Cuticle soft, finely striated. Hysteronotal shield present only in *Sturnophagoides*. Posterior lip of vulva not punctate except in *Sturnophagoides* where it is punctate.....
.....*DERMATOPHAGOIDINAE* Fain, 1963

Males

(Note: the male is not known in the genus *Guatemalichus*)

1. Setae *vi* present ; *sc i* strong and very long. Tarsi IV very short. Legs III much larger than legs IV and bearing a spur on the femora. Cuticle striated.....
.....*PARALGOPSINAE* Fain, 1988b

Setae *vi* absent ; *sc i* never very strong or very long. Tarsi IV normal. Legs III variable. Femora III lacking a spur. Cuticle variable.....2

2. Tarsi III and IV with a strong bifid or trifid subapicoventral spine. Cuticle striated .....
.....*ONYCHALGINAE* Fain, 1988b

Tarsi IV always lacking a bifid or trifid subapicoventral spine. Tarsi III with or without this spine. Cuticle variable.....3

3. Tegmen well developed. Cuticle slightly or strongly sclerotized. Striations either present but irregular, thick and well spaced or absent. Adanal suckers present or lacking. Tarsal suckers (tarsi IV) either present or replaced by thin, short setae. Setae *sc e* either long and strong (*Weelawadjia* and *Campephilocoptes*) or short and thin (other genera). Tarsi III lacking an apical forked spine.....
PYROGLYPHINAE Cunliffe, 1958

Tegmen lacking. Cuticle soft and striated. Adanal suckers present. Tarsal suckers (tarsi IV) present except in *Malayoglyphus*. Setae *sc e* strong and long except in *Malayoglyphus* where they are thin and short. Tarsi III with an apical forked spine except in *Malayoglyphus* and *Sturnophagoides* where this spine is lacking.....
.....*DERMATOPHAGOIDINAE* Fain, 1963

5. STUDY OF THE PYROGLYPHINAE

A. KEY TO GENERA AND SPECIES

Females

1. Setae *sc e* strong and very long (180 to 250 µm) .2

Setae *sc e* thin and short (maximum 50 µm).....4

2. Epimera I fused in the midline, forming a short sternum. Anterior angle of posterior vulvar lip not incised. Tarsi III and IV with 2 conical apical spines. Setae *d5* and *l5* very strong and very long .....
.....Genus *Weelawadjia* Fain and Lowry
(One species: *W. australis* Fain and Lowry)

Epimera I free. Anterior angle of posterior vulvar lip incised. All setae of tarsi III and IV thin. Setae *l5* very long and strong, *d5* variable .....
.....Genus *Campephilocoptes* Fain *et al.*
3

3. Setae *d5* very long and strong. Dorsal surface with long longitudinal and transverse folds .....
.....*C. atyeoi* Fain *et al.*

Setae *d5* very short and thin. Dorsal surface without such folds .....*C. paraguayensis* Fain *et al.*

4. Setae *d5* and *l5* strong and very long (300 to 350 µm). Bases of legs II with sclerotized and punctate pouches .....Genus *Bontiella* Fain
(One species: *B. bouilloni* Fain)

Setae *d5* and *l5* short or very short (less than 50 µm) and thin. No chitinous pouches at the bases of legs II .....
.....5

5. Tegmen triangular, prominent with apex forked. Posterior vulvar lip very long anteriorly and completely covering the vulvar slit, its anterior angle not incised.....
.....6

Tegmen either triangular and prominent but with apex rounded and not forked or poorly developed, rounded with a small median notch. Posterior vulvar lip short, not covering the vulvar slit.....8

6. Bursa lacking a vestibule (pouch). Dorsal surface of the body strongly and completely sclerotized with irregular folds. Epimera I fused to form a V .....
.....Genus *Pyroglyphus* Cunliffe
(One species: *P. morlani* Cunliffe)

Opening of bursa situated near the posterior extremity of anus and followed by a small ovoid strongly sclerotized pouch (vestibule). Dorsum with thick striations and a small median opisthonotal shield. Epimera I free.....
.....Genus *Gymnoglyphus* Fain
7

7. Posterior region of opisthonotum not punctate. Setae *ai* situated at the junction of the anterior third and the posterior two thirds of the anus. Setae *l5* 20-25 µm long. Idiosoma 280-290 µm long .....
.....*G. longior* (Trouessart)

Posterior region of dorsum punctate. Setae *ai* situated close to anterior angle of the anus. Setae *l5* 40-50 µm long. Idiosoma 328-345 µm long.....
.....*G. osu* Fain and Johnston

8. Anterior angle of posterior vulvar lip not incised. Tegmen triangular with rounded, not incised apex. Hysteronotum striated with a median shield. Presence of a small, ovoid, strongly sclerotized pouch (vestibule). Absence of trochanteral I-III, tibial IV and *ae* and *ga* setae .....Genus *Euroglyphus* Fain
(One species: *E. maynei* (Cooreman))

Posterior vulvar lip with anterior angle incised. Tegmen small (narrow and short), rounded with a small median notch. Hysteronotum completely striated and lacking a shield. Vestibule lacking. Trochanters I-III and tibia IV with a seta; *ae* and *ga* present .....
.....Genus *Hughesiella* Fain
(One species: *H. africana* (Hughes))

Males

(Note: The male of *Gymnoglyphus osu* is unknown)

1. Adanal suckers vestigial or lacking. All dorsal setae (including *sc e*, *d5* and *l5*) very thin and very short 2

Adanal suckers well developed. Dorsal setae variable.....3

2. Tegmen long, narrowly triangular and forked at apex. Legs I-II compressed laterally and with chitinous membranes on the 3 distal joints. Genu I with a short solenidion.....Genus *Pyroglyphus* Cunliffe
(One species: *P. morlani* Cunliffe)

Tegmen small (short and narrow) with a small median notch. Legs cylindrical, lacking chitinous membranes. Genu I with 2 unequal solenidia .....
.....Genus *Hughesiella* Fain
(One species: *H. africana* (Hughes))

3. Setae *d5* and *l5* strong and long (150-500 µm) .....
.....4

Setae *d5* and *l5* very thin and short (maximum length 50 µm) 7

4. Setae *sc e* very thin and very short (5 µm). With chitinous pouches at the bases of legs II. Legs I and II with chitinous membranes.....
.....Genus *Bontiella* Fain
(One species: *B. bouilloni* Fain)

Setae *sc e* strong and long (150-280 µm). Without chitinous pouches at the bases of legs II. Legs I and II lacking chitinous membranes 5

5. Body striated ventrally and laterally. Legs III approximately 1.3 times longer and 1.5 times wider than legs IV. Tarsus III ending in a very small curved process (ongle) and one strong conical spine.....
.....Genus *Weelawadjia* Fain and Lowry
(One species: *W. australis* Fain and Lowry)

Body completely sclerotized, lacking distinct striations. Legs III approximately twice as long (length of the apical segments) and 2.5 times as wide (at level of femur) as legs IV. Tarsi III ending in 2 strong curved processes (ongles) and no spines .....
.....Genus *Campephilocoptes* Fain *et al.*
6

6. Chitinous perianal frame denticulate. Opisthosoma longer than wide. Dorsum with numerous small rounded or elongate depressions.....
.....*C. atyeoi* Fain *et al.*

Chitinous perianal frame not denticulate. Opisthosoma much wider than long. Dorsum without depressions .....
.....*C. paraguayensis* Fain *et al.*

7. Tegmen with rounded, unforked apex. Opisthosoma slightly but regularly narrowed backwards. Anus more posterior (anal suckers situated at 25 µm from the posterior margin of the body). Posterior margin of body straight and wide with 2 very small paramedian lobes. Chaetotaxy reduced (all trochanterals, tibials IV, *ae* and *ga* lacking).....Genus *Euroglyphus* Fain
(One species: *E. maynei* (Cooreman))

Tegmen deeply incised at apex. Opisthosoma strongly narrowed backwards. Anus more anterior (adanal suckers at 40 µm from posterior margin of body). Posterior margin of body narrower, concave in the middle and with 2 small but well distinct paramedian lobes. Chaetotaxy normal (trochanteral setae I-III, tibial IV setae, *ae* and *ga* present . . Genus *Gymnoglyphus* Fain
(One species: *G. longior* (Trouessart))

B. STUDY OF SPECIES

Genus **Pyroglyphus** Cunliffe, 1958

Definition : Tegmen well developed, triangular with forked apex. Body completely sclerotized without true striations but with a few irregular folds. All body setae very thin and short. Epimera I fused to form a V. Tibiae I and II and probably also genua and femora I and II with apicoventral chitinous membranes. Legs I and II compressed laterally, especially in the male. Female: posterior lip of vulva completely punctate and very long, completely covering the vulvar slit. Male lacking adanal and tarsal (tarsi IV) suckers.

Type species and only known species: *Pyroglyphus morlani* Cunliffe, 1958.

Pyroglyphus morlani Cunliffe, 1958
(Fig. 1-3, 18)

This species was described from the nest of a rodent, *Neotoma albigula* (Cricetidae), in Santa Fe, New Mexico, and from *Neotoma* sp. in the same locality.

Holotype female in the U.S. National Museum, Washington.

Genus **Hughesiella** Fain, 1965

Pyroglyphus (Hughesiella) Fain, 1965
Hughesiella, Fain, 1988b
Recently we have elevated this subgenus to the genus rank. We give herein a table of the main characters separating this genus from *Pyroglyphus* (Table I).

Hughesiella africana (Hughes, 1954)
Dermatophagoides africanus Hughes, 1954
Pyroglyphus (Hughesiella) africana (Hughes) Fain, 1965
Hughesiella africana (Hughes) Fain, 1988b
(Fig. 4-5, 18-19)

The typical series was found in fishmeal originating from Angola and stored in warehouses in England.

This species is also known from house dust in Columbia in two villages situated at 1400 and 1700 m altitude (Charlet *et al.*, 1977a). In Brazil, Rosa and Flechtmann (1979) found this species in 3 houses of a total of 72 houses examined in the city of Rio Claro (Sao Paulo). It has also been recorded from the nest of *Passer domesticus* in Piracicaba, Brazil (Fain and Rosa, 1982).

We have also seen specimens collected from house dust in Madagascar and from the litter of a poultry house in Beit Shamrok in Israël and sent for identification by Dr Y. Mumcuoglu (Fain, 1988b).

This species produces two different types of males, homeomorphic and heteromorphic, the former type being the most frequent. In the heteromorphic forms the legs I are strongly expanded and the epimera I are fused in a Y. We redescribed this species in 1965 and these figures are reproduced herein.

Table I : Morphological characters separating the genera *Pyroglyphus* and *Hughesiella*

	Pyroglyphus morlani	*Hughesiella africana*
In both sexes		
Epimera III - IV	indistinct	well developed
Genu I	1 solenidion	2 solenidia
Chitinous membranes on Legs I - II	present	absent
Tegmen	narrow, long and forked	short, rounded and with a small median notch
In the female		
Posterior vulvar lip	long, covering the vulva and not incised anteriorly	short, not covering the vulva, its anterior angle incised
Dorsal surface of the body	sclerified with few folds	completely striated

Holotype in the British Museum (Natural History), London.

Genus **Bontiella** Fain, 1965

Definition : Tegmen strongly developed and bifurcate or trifurcate apically. Body heavily sclerotized and lacking true striations. Legs with chitinous membranes on tibiae and genua I and II. Presence on the bases of legs II of voluminous sclerotized pouches. Female: posterior vulvar lip completely punctate and covering the vulvar slit as in *Pyroglyphus*, its anterior angle not incised. Male with adanal suckers but lacking suckers on tarsi IV, the latter being replaced by small setae. This genus is monotypic (type species: *Bontiella bouilloni* Fain, 1965).

Bontiella bouilloni Fain, 1965
(Fig. 7-9, 18-19)
The typical series of this species was found in nests of *Spermestes cucullatus* (Ploceidae, Estrildinae) in a savanna area in the vicinity of Kinshasa, Zaïre. We later found this species in nests of birds or rats around Butare, Rwanda on the following hosts: *Textor cucullatus*, *Cinnyris venustus, Nectarinia kilimensis, Colius striatus* and *Grammomys surdaster*.

Holotype female in the Museum of Tervuren.

Genus **Euroglyphus** Fain, 1965

Definition : Tegmen well developed, triangular with rounded apex (not bifid in the male as figured in the typical description). Cuticle slightly sclerotized with rather well formed striations or folds. Hysteronotum with in both sexes a median shield with poorly distinct margins. Anterior legs lacking chitinous membranes. Chaetotaxy reduced: trochanterals I-III, tibials IV, *ga* and *ae* setae are lacking. Tarsi III with 5 setae, tarsi IV with 3 setae (in both sexes). Dorsal setae very thin and short, 15 not exceeding 30 µm. Genu I with one solenidion. Female: posterior lip of vulva punctate, short and not covering the vulvar slit ; its anterior angle not incised. Copulatory vestibule ovoid, strongly sclerotized and opaque. Tarsi I-IV without apical processes nor spines. Male : adanal suckers well developed ; tarsi IV lacking suckers. This genus is monotypical.

Type species : *Mealia maynei* Cooreman, 1950.

Euroglyphus maynei (Cooreman, 1950)
Mealia maynei Cooreman, 1950
Dermatophagoides maynei Hughes, 1954
Euroglyphus (Euroglyphus) maynei, Fain, 1965
Euroglyphus maynei, Fain, 1988b
(Fig. 10-12, 18-19)

The typical series of this species was found on decomposing cotton seed cake at Gembloux, Belgium. It has since been found in house dust in Belgium and Holland (Fain, 1965, Spieksma and Spieksma-Boezeman, 1967) and in many other countries.

Holotype in the Institut Royal des Sciences naturelles de Belgique, Brussels.

In Europe *E. maynei* is the second or the third most frequent species (according to the country) found in house dust or in mattresses. Its biology is less well known than that of *D. pteronyssinus* or *D. farinae* with which it is generally associated.

E. maynei is also widespread outside Europe in house dust or mattresses. It has been recorded from Asia (Israël, Iran, India, Malaysia, Singapore, Japan, China, Taiwan, Papua), Australia, North and South Africa, South America (Brazil, Columbia, Chile, Peru). Surprizingly this species has not been recorded from North America, Cuba and Central Africa. It is relatively more frequent in mountainous areas than *D. pteronyssinus* and *D. farinae* (Portus and Gomez, 1976).

This species is generally more frequent and abundant in old, damp houses (Fain, 1966b). In a survey on house dust mites in Liverpool, a good correlation was found between increasing numbers of *E. maynei* and decreasing social class, but only a weak correlation with relative humidity. High ionic sodium levels in bed dust were suggested as being associated with decreasing social class and increasing *E. maynei* levels (Walshaw and Evans, 1987).

(Fig. 13-15, 18-19)

The typical slide is labeled "Sur des matières animales en décomposition, France". Trouessart precised (1901) that "Les poussières contenant les acariens furent recueillies sur des peaux de mammifères préparées et plus ou moins attaquées par des insectes ou acariens rongeurs". Further (p. 8) he completed "Sur des peaux préparées et attaquées par des moisissures".

This species was also found in the dust and debris of a granary at Slough, Berkshire, England (Hughes, 1976) and in Canada (Sinha *et al.*, 1970).

This species described as *Dermatophagoides dalarnaensis* Sellnick was also found in granary dust, in Sweden.

Wilson and Haas (1980) recorded this species from birds in Alaska.

G. longior has also been found in house dust in Peru (Caceres and Fain, 1979), in Italy (Ottoboni *et al.*, 1984), in Bulgaria (Todorov, 1979) and in the U.S.S.R. (Tareev and Dubinina, 1985). We have identified this species from the litter of a poultry house in Switzerland (Fain, 1988b).

Holotype in the Acarotheca of Berlese in Florence.

Genus **Gymnoglyphus** Fain, 1965

Euroglyphus (Gymnoglyphus) Fain, 1965
Gymnoglyphus Fain, 1988b

Definition : This genus is distinguished from *Euroglyphus* by the following characters (in both sexes) : the tegmen is triangular with bifid apex and the chaetotaxy is not reduced. The setae trochanterals I-III, tibials IV, *ae* and *ga* are present and the tarsi III and IV bear 6 and 5 setae respectively. In the female the posterior vulvar lip is punctate and long, completely covering the vulvar slit. In the male the posterior margin of the body is distinctly concave and there are two lateral, rather well developed lobes.

Type species : *Mealia longior* Trouessart, 1897

1. *Gymnoglyphus longior* (Trouessart, 1897)
Mealia longior Trouessart, in Berlese, 1897 and 1898 ; Trouessart, 1901
Dermatophagoides longior, Dubinin, 1953
Dermatophagoides dalarnaensis Sellnick, 1958
Euroglyphus (Gymnoglyphus) longior, Fain, 1965
Gymnoglyphus longior Fain, 1988b

2. *Gymnoglyphus osu* (Fain and Johnston, 1973)
Euroglyphus (Gymnoglyphus) osu Fain and Johnston, 1973
Gymnoglyphus osu, Fain, 1988b
(Fig. 16-17)

Only the female of this species is known. It differs from *G. longior* by the presence of a distinct punctation in the posterior part of the body, the more anterior situation of setae *ai*, the larger size of the body and the smaller length of the solenidia of tibiae I and II.

The type series was collected in granary dust of barns in Columbus, Ohio, U.S.A.

Holotype in University of Ohio, Columbus, U.S.A.

Genus **Weelawadjia** Fain and Lowry, 1974

Definition : Tegmen slightly triangular and rather poorly developed. Dorsum with large punctate shields, only the lateral parts of the body and the opisthogaster are striated. Coxae strongly punctate. Setae *sc e* strong and long (150-180 µm), *d5* and *l5* very long (250-300 µm). Female with posterior vulvar lip punctate, well developed and completely covering the vulvar slit, its anterior angle not incised; epimera I fused, forming a very short sternum; legs III and IV with 2 conical, unforked apicolateral spines. Male with epimera I fused to form a Y; adanal and tarsal (tarsi IV) suckers well developed; legs IV shorter and narrower than legs III; tarsi III with only one conical not forked apical spine.

The genus *Weelawadjia* is monotypical.

Weelawadjia australis Fain and Lowry, 1974
(Fig. 20-22)

This species has been described from guano in the Weelawadjia cave, near Eneabba, Western Australia. This cave was inhabited by bats and swallows (*Hirundino neoxena*). Most of the specimens were collected near the entrance of the cave, in both bat guano and swallow's nests.

We have seen in the British Museum, London, females and males belonging to this species, but not paratypes; they had been collected in the same place as the types.

We have also seen a nymph of this species collected by Dr F. Lukoschus in 1976, from a bird *Lonchura castaneothorax*, at Mount Hart, Western Australia.

Holotype in the Australian National Insect Collection, CSIRO, Canberra, Australia.

This species has never been encountered in houses.

Genus **Campephilocoptes** Fain, Gaud and Pérez, 1982

Definition : Tegmen straight or slightly convex. Body strongly sclerotized, lacking striated areas, but with various patterns (folds, depressions). Setae *sc e* and *l5* very long (250-300 µm) and strong, setae *d5* either very long and strong or very short and thin. Tarsi I and II ending in 1 or 2 curved processes (ongles). Genua I with 2 very short unequal solenidia. Female with epimera I free; posterior vulvar lip very large, sclerotized, reaching close to the epigynium, its lateral margins strongly sclerotized and its anterior angle incised ; legs III and IV subequal ; tarsi III and IV with all the setae thin. Male with epimera I fused to form a Y; legs III strongly expanded, legs IV reduced. Adanal and tarsal (IV) suckers present.

This genus includes 2 species found from South American Piciformes.

Type species : *Campephilocoptes atyeoi* Fain, Gaud and Pérez, 1982, from *Campephilus rubricollis*, Bolivar, Venezuela. Other species : *C. paraguayensis* Fain, Gaud and Pérez 1982, from *Campephilus leucopogon*, from Gran Chaco, Paraguay.

Holotypes in the U.S. National Museum, Washington, U.S.A.

6. STUDY OF THE DERMATOPHAGOIDINAE

A. KEY TO GENERA AND SPECIES

Females

(Note : *Hirstia chelidonis* whose types are lost is not mentioned herein)

1. Dorsum with a median hysteronotal shield. Cuticle striated-punctate over a large part or all of the body. Cuticle between epimera I punctate. Posterior lip of vulva long, with anterior angle incised .....
.....Genus *Sturnophagoides* Fain
2

Hysteronotum striated, lacking a median shield. Cuticle with non-punctate striations. Cuticle between epimera I not punctate. Posterior lip of vulva smaller and shorter and not incised anteriorly 4

2. Small species (idiosoma 246 to 262 µm long). Posterior lip of vulva punctate only in its lateral parts. Hysteronotal shield situated inside setae *d3*. Striations behind this shield distinctly thickened, more punctate and more spaced than on other parts of the body. Solenidia of genua I very short (10 and 4 µm).....
.....*S. brasiliensis* Fain

Larger species (idiosoma 310 to 420 µm). Posterior lip of vulva completely punctate. Hysteronotal shield variable. Striations behind this shield not modified.....3

3. Idiosoma 390-420 µm long. Setae *d2* and *d3* situated outside the hysteronotal shield. Solenidia of genu I 30-35 and 6 µm long respectively...*S. bakeri* Fain

Idiosoma 310-376 µm. Setae *d2* and *d3* situated on the margins of the shield (from the original description).
.....*S. petrochelidonis* Cuervo and Dusbabek

4. Legs III distinctly longer (length of the 4 apical segments) and thicker than legs IV, the ratio of the lengths of legs IV: legs III = 1:1.4 to 1.56. Cuticle with very thin striations separated by less than 1 µm (at the level of setae *d2*).....Genus *Hirstia* Hull

5

Legs III and IV equal or subequal in length and in width. Cuticle with dorsal striations more spaced (separated by 1.2 to 2.3 µm at level of setae *d2*).....6

5. Posterior region of dorsum not punctate and not sclerotized. Length of legs III 174 µm, legs IV 118 µm (= length of 4 apical segments). Length of tarsi I-IV: 40-43-66-48 µm. Idiosoma 395-426 µm long.....
.....*H. passericola* (Fain)

Posterior region of dorsum sclerotized and punctate mainly around the bases of setae *d5* and *l5*. Legs III and IV 123-129 and 85-90 µm long. Tarsi I and IV 27-32-43-32 µm long respectively. Idiosoma 298-310 µm long
.....*H. domicola* Fain *et al.*

6. Setae *sc* i and *sc e* thin and short, either equal or subequal, or slightly unequal (*sc e* less than 35 µm long). Epigynium poorly developed and slightly sclerotized. Genu I with only one very short solenidion (5-6 µm).....Genus *Malayoglyphus* Fain *et al.*

7

Setae *sc i* and *sc e* very unequal, the *sc e* long and strong. Epigynium well developed and sclerotized. Genu I with 2 very unequal solenidia .....
.....Genus *Dermatophagoides* Bogdanov

8

7. Setae *sc i* and *sc e* equal or subequal (about 12-15 µm). Posterior half of opisthonotum distinctly punctate and with thicker and more spaced striations than on other parts of the dorsum. Idiosoma 218-243 µm long ...
.....*M. intermedius* Fain *et al.*

Setae *sc e* distinctly longer (30-35 µm) than *sc i* (15 µm). Punctation of posterior half of opisthonotum indistinct. Idiosoma 320-348 µm long .....
.....*M. carmelitus* Spieksma

8. Median area comprized between setae *d2* and *d3* (= M area) completely striated longitudinally. Opening of the bursa situated on posterior margin of the body .....
.....9

Anterior part of area M with straight transverse striations, posterior part with striations either slightly convex or strongly oblique or longitudinal. Opening of bursa terminal or ventral 10

9. Bursa very narrow, of uniform calibre and ending inside (proximally) in a daisy-like sclerite.....
.....*D. pteronyssinus* (Trouessart)

Bursa strongly enlarged in its distal third and very narrow in its proximal two thirds (internal). Spermatheca sclerotized and tulip-like .....
.....*D. evansi* Fain *et al.*

10. Striations of the posterior half or two thirds of the area M either strongly convex or oblique and abruptly bent on the median line to form an inverted V .
.....11

Striations of the posterior half of the area M only slightly convex. Opening of the bursa situated ventrally, on the side of the posterior third of the anus. First part of the bursa forming (sometimes not) a sclerotized pocket (vestibule).....Group *farinae*

15

11. Tarsi I and II lacking an apical curved process (ongle). Epigynium thick, strongly curved and not bearing setae *ga*. Opening of the bursa on the posterior border of the body in the middle of a small sclerotized plate; this opening is followed by a voluminous, refringent, unsclerotized pouch (40-45 x 20 µm) (vestibule) oriented transversely and projecting under the skin of the posterior border of the body. Setae of the coxae, *gp* and *ae* relatively very long (60-80 µm) .....
.....*D. aureliani* Fain

Tarsi I and II with an apical curved process. Epigynium thick, strongly bent, longer and bearing laterally the setae *ga*. Bursa otherwise shaped.....12

12. Opening of the bursa situated in the middle of a large sclerotized oval plate (22 x 12 µm) situated near the posterior angle of the anus. Vestibule absent .....
.....*D. sclerovestibulatus* Fain

Bursa of another shape 13

13. Bursa opening in the depth of a small sclerotized and conical shaped funnel, as long as wide (6 µm) situated on the posterior margin of the body. Tarsi I and II with a well developed curved process (ongle). Tarsi I-IV 45-57-60-66 µm long. Setae *h* short (30 µm). Setae *gm* and *gp* almost on the same transverse line and subequal in length. Setae *d5* 150 µm long. Solenidia of genu I 38 and 7 µm long respectively ...*D. rwandae* Fain

Bursa otherwise shaped. Setae *h* strong and long (100-110 µm) ; *gp* distinctly longer than *gm*.....14

14. Opening of bursa situated on a raised rounded papilla on posterior margin of body. Bursa 45-50 µm long, narrow but slightly widened and very finely ringed in its distal (external) part. Setae *gm* and *gp* almost on the same transverse line. Striations of posterior half of the area M strongly convex but not angled in the midline
.....*D. neotropicalis* Fain and van Bronswijk

The bursa opens in the middle of a chitinous oval plate (8.5 x 6 µm) situated ventrally at 15 µm from the posterior margin of the body and 20 µm from the anus. Vestibule lacking. Canal of the bursa very thin and long (80 µm). Seta *s* of tarsi III and IV with expanded bases. Setae *gm* distinctly anterior to *gp*. Striations of the posterior half of area M strongly oblique, in the shape of an inverted V .....*D. simplex* Fain and Rosa

15. Idiosoma 395 to 435 µm long. Propodonotal shield approximately 1.4 times as long as wide.....16

Idiosoma 258 to 311 µm long. Propodonotal shield approximately twice as long as wide.....
.....*D. siboney* Dusbabek *et al.*

16. Vestibule well sclerotized and shaped like a calabash pipe; beyond this vestibule the bursa is not expanded. Tarsus I generally with a well developed curved process (ongle).....*D. farinae* Hughes

Vestibule lacking, the bursa opens at the bottom of a non-sclerotized depression of the tegument. The first part of the bursa proper is slightly dilated and distinctly sclerotized. Apical process of tarsus I generally very small or lacking .....
.....*D. microceras* Griffiths and Cunnington

Males

(Note: The male of *D. rwandae* is unknown)

1. Perianal chitinous frame finely denticulate inside. Legs III much thicker than legs IV and from 1.8 to 1.9 times longer than the latter (= length of the 4 apical segments). Tarsi III bearing in their middle 2 strong conical spines (= setae *w* and *r*) .....
.....Genus *Hirstia* Hull

2

Perianal chitinous frame not denticulate. Legs III and IV less unequal, the legs III a maximum of 1.6 times as long as legs IV. Tarsi III with either setae *w* and *r* thin, or *w* thin and *r* in the shape of a small forked spine 3

2. Idiosoma 321 to 345 µm long. Tarsi I-IV 33-39-51-24 µm long.....*H. passericola* (Fain)

Idiosoma 240 to 248 µm long. Tarsi I-IV 22-27-32-18 µm long .....*H. domicola* Fain *et al.*

3. Setae *sc e* thin and short (maximum 30 µm long). Tarsi III with only thin setae. Tarsi IV without suckers. Adanal suckers poorly developed. Tarsi I and II without apical processes. Legs III and IV subequal .....
.....Genus *Malayoglyphus* Fain *et al.*

4

Setae *sc e* strong and long (minimum 110 µm). Tarsi III either with only thin setae or with one small conical spine or with one stronger bifid subapical spine. Tarsi IV with 2 small copulatory suckers. Adanal suckers well developed. Legs III distinctly stronger and longer than legs IV. At least tarsus I with an apical process 5

4. Setae *sc e* and *sc i* equal or subequal (12-15 µm). Striations of the posterior half of hysteronotum thick, punctate and sclerotized. Idiosoma 168 to 175 µm long..
.....*M. intermedius* Fain *et al.*

Setae *sc e* longer (30 µm) than setae *sc i* (15 µm). Posterior half of the hysteronotum with a large punctate and not striated shield. Idiosoma 240 to 283 µm long .....
.....*M. carmelitus* Spieksma

5. Tarsi III either with a subapical conical unforked spine, or with all setae simple .....
.....Genus *Sturnophagoides* Fain

6

Tarsi III with a strong subapical forked spine (seta *f*)
.....Genus *Dermatophagoides* Bogdanov

8

6. Idiosoma 175 to 185 µm long. Perianal chitinous frame narrow, oval in shape. Tarsi III with an apical curved process but lacking a subapical spine.....
.....*S. brasiliensis* Fain

Idiosoma 245 to 272 µm long. Perianal chitinous frame wide, piriform (pear-shaped). Tarsi III ending in a conical spine and a curved apical process.....7

7. Idiosoma 270 to 290 µm long. Hysteronotal shield piriform passing hardly beyond setae *d2* (in the heteromorphic male).....*S. bakeri* Fain

Idiosoma 245 to 272µm long. Hysteronotal shield rectangular, reaching setae *d1* (in the heteromorphic male).....*S. petrochelidonis* Cuervo and Dusbabek

8. Hysteronotal shield short, extending forwards to a point situated at equal distance from *d2* and *d3* 9

Hysteronotal shield reaching forwards to setae *d2* or further in front 11

9. Hysteronotal shield longer than wide (in its middle). Seta *r* of tarsus III is a short forked spine (situated in the middle of tarsus). Epimera I fused to form a Y in the homeomorphic male. No heteromorphic males.....
.....*D. aureliani* Fain

Hysteronotal shield wider than long (in its middle). Seta *r* of tarsus III is thin and situated basally. Epimera I free in the homeomorphic males 10

10. Small species (idiosoma 199 to 245 µm long). All the males are homeomorphic .....
.....*D. siboney* Dusbabek *et al.*

Larger species (idiosoma 285 to 345 µm long). Males either homeomorphic with epimera I free or heteromorphic with epimera I fused to form a V or Y.....
.....*D. farinae* Hughes and *D. microceras* Griffiths and Cunnington.

11. Hysteronotal shield reaching forward to the bases of setae *d2*. Coxae II open. Legs III from 1.3 to 1.4 times as long as legs IV.....12

Hysteronotal shield distinctly extending forward to beyond the bases of setae *d2*. Other characters variable..
.....13

12. Hysteronotal shield strongly narrowed anteriorly, its anterior margin reaching setae *d2* but without including them. Seta *h* 66 µm long, the *sc e* 93 µm and the *ae* 42 µm .....*D. sclerovestibulatus* Fain

Hysteronotal shield trapezoidal, only slightly narrowed anteriorly and including setae *d2*. Setae *h* 100-120 µm long, the *sc e* 120-150 µm and the *ae* 50-65 µm
.....*D. neotropicalis* Fain *et al.*

13. Coxae II closed. Adanal suckers 12 µm in diameter. Epimera I free. Tarsi I with 2 unequal apical processes (ongles), tarsus II with a small apical process. Males homeomorphic.....14

Coxae II open. Adanal suckers larger. Epimera I fused in a Y shape. Males heteromorphic 15

14. Legs III 1.3 times thicker (at level of femur) and 1.46 times longer (length of 4 distal segments) than legs IV. Setae *d5* and *l5* with bases poorly sclerotized. Setae *h* 80-90 µm long; the *l2* situated at 40 µm from the opening of the fat gland.....*D. pteronyssinus* (Trouessart)

Legs III 1.8 times thicker and 1.6 times longer than legs IV. Setae *d5* and l5 with bases strongly sclerotized. Setae *h* 110 µm long ; setae *l2* situated at 55-65 µm from the opening of the fat gland.....
.....*D. evansi* Fain *et al.*

15. Tarsi II lacking an apical process (ongle). Idiosoma 270 µm long. Tarsi I-IV 39-45-47-32 µm long. Setae *l3* situated on the margins of the shield. Perianal chitinous frame as wide as long. Leg III 1.52 times as long as leg IV .....*S. simplex* Fain and Rosa

Tarsi II with a strong apical curved process. Idiosoma 315 µm long. Tarsi I-IV 45-54-54-36 µm long. Setae *l3* situated lateral to the hysteronotal shield. Perianal chitinous frame distinctly wider than long. Leg III 1.42 times as long as leg IV .....*D. anisopoda* (Gaud)

B. STUDY OF SPECIES

Genus **Dermatophagoides** Bogdanov, 1864

Dermatophagoides Bogdanov, 1864
Pachylichus Canestrini, 1894
Mealia Trouessart, 1897
Visceroptes Sasa, 1948
Hullia Gaud, 1968 ; Fain, 1988b

The type species is *Dermatophagoides scheremetewskyi* Bogdanov, 1864.

The genus *Hullia* Gaud is based on a heteromorphic male presenting all the characters of the genus *Dermatophagoides*. Male heteromorphism in this genus was only described in 1973 (Fain and Bronswijk) which probably explains the error of Gaud.

For a more complete analysis of the synonymy of the genus *Dermatophagoides* see Fain (1966a and 1967a).

1. *Dermatophagoides pteronyssinus* (Trouessart, 1897)
Dermatophagoides scheremetewskyi Bogdanov, 1864
Pachylichus crassus Canestrini, 1894
Mealia pteronyssina Trouessart, in Berlese 1897
Dermatophagoides pteronyssinus, Dubinin, 1953; Fain, 1965
Mealia toxopei Oudemans, 1928
Visceroptes saitoi Sasa, 1948
Dermatophagoides saitoi Sasa, 1950
Dermatophagoides sp. Voorhorst *et al.*, 1964
Dermoglyphus (Paralges) pteronyssoides Trouessart, 1886 ; Gaud, 1968 ; Fain, Oshima and Bronswijk, 1974 (*nom. oblitum*)

(Fig. 18-19, 23-28, 59)

We have given (Fain, 1966a) the reasons which have led us to choose *Dermatophagoides pteronyssinus* (Trouessart) instead of *D. scheremetewskyi* Bogdanov to represent the species of *Pyroglyphidae* most commonly found in houses in Europe. However it is not possible to affirm with certainty that *D. pteronyssinus* is identical with the species of Bogdanov. Unfortunately the types of this species are lost and the original drawings of Bogdanov do not allow recognition of the species with certainty. We have therefore proposed to maintain both species until new material from the typical locality (Moscow) becomes available and allows us to determine the status of *D. scheremetewskyi*.

In the meantime numerous authors have accepted our proposal and recently Samsinak, Vobrazkowa and Dubinina (1982) have proposed to the International Commission of Nomenclature the inclusion of the name *Dermatophagoides pteronyssinus* (Trouessart, 1897) in the list of valid names (nomina conservanda) (Art. 23, b, III of the Code) with as synonym *D. scheremetewskyi*.

Habitat of D. pteronyssinus :

D. pteronyssinus is a true domestic mite and has a cosmopolitan distribution. It has been recorded from a number of countries in all parts of the world. In most countries it is the most frequent and abundant species of Pyroglyphidae found in house dust and bedding. Beds usually show much higher infestations than carpets or floor dust (see Table VII).

Mite stratification in the bed

Maunsell, Wraith and Cunnington (1968) have shown that dust from the surface of the mattress generally contains many more pyroglyphids, mostly *D. pteronyssinus*, than the dust of the living room. They suggested that the microclimate (relative humidity and temperature) of the mattress is very important in the development of the mites and probably as important as the conditions of the house itself.

Haarløv and Alani (1970), in Denmark observed that the main population of mites was centred outside the mattress below the cross-bars, on wooden slats and on floor panels beside the bed.

Mulla *et al.* (1975) studied the spatial distribution of *Dermatophagoides* populations in mattresses in California. The highest densities of mites (mostly *D. pteronyssinus*) were found at the surface, near the edges and along the welt cording of mattresses. They were much less numerous in the centre. The mites were confined to the superficial layer of the mattress, almost all being found in the top few mm. No evidence of living mites was found at 1 cm below the surface. Mattresses which had been in use for less than 5 years contained significantly fewer mites than older ones.

In contrast, Dusbabek (1979) in Czechoslovakia, did not find significant differences in the stratification of *D. pteronyssinus* and *D. farinae* in mattresses. Both species were most often found at the sides of the mattresses, less often on the bottom and least of all on the top side.

Sesay and Dobson (1972) in Scotland, studied mite populations not only from mattresses but also from other layers of the bedding. Each bed was regarded as consisting of 4 layers : 1) the superficial (eiderdown, quilt, or other top layer) ; 2) the intermediate (all other layers above the occupant) ; 3) the lower (all layers below the occupant and 4) the pillows. The highest density (number of mites per gram of dust) of *D. pteronyssinus* and *E. maynei* occurred in the intermediate layer (blankets and sheets). The superficial layer contained about half the density of the intermediate layer, the lower layer a little less than the superficial layer and the pillows only one fourth or one fifth of the number found in the intermediate layer.

Pyroglyphid mites in bedroom air

Cunnington and Gregory (1968) have shown that pyroglyphid mites can become temporarily airborne during bed making by catching the mites in a cyclone extractor. Most of the specimens belonged to *D. pteronyssinus* and small numbers to *E. maynei*.

Non domestic habitats of *D. pteronyssinus*, *D. farinae* and *E. maynei* :

Baker *et al.* (1956) recorded the presence of *D. scheremetewskyi* in various non domestic habitats in the U.S.A. We have also given a list of such habitats for *D. pteronyssinus*, *D. farinae* and *E. maynei* (Fain, 1967a).

We think, however, that *D. pteronyssinus* is essentially a domestic species and that the other habitats mentioned in the literature or found by us are accidental.

The domestic pyroglyphids are frequently found in clothes (Hewitt *et al.*, 1973) which suggests that man is probably the most efficient carrier of these species. We

can therefore expect to find this mite in all places visited by man. In this connection the specimens of *D. farinae* and *E. maynei* found on a street pavement in Prague by Samsinak *et al.* (1983 and 1985) were certainly introduced by man. Colloff (1987a) collected *D. pteronyssinus* and *E. maynei* specimens from cloth covered seats of passenger trains in Glasgow. It seems that here also the mites had been transported from homes via clothing or pets.

Geographical distribution of *D. pteronyssinus* :

The geographical distribution of *D. pteronyssinus* and other domicolous pyroglyphids is given in Table VI. The situation in Europe is treated separately in more detail later. We recall herein some features of this distribution in other countries of the world.

D.pteronyssinus (under the name *D.scheremetewskyi*) and *D.farinae* were recorded from floor dust of schools in Japan by Oshima, in 1964.

In the U.S.A. the number of *D. pteronyssinus* compared with that of *D. farinae* varies widely according to region. In all states situated far from the sea coast and subject to a dry continental climate, *D. farinae* is the dominant species. This is especially evident in Ohio (Wharton, 1970 ; Larson *et al.*, 1969) and the Eastern part of California. In Tennessee (Shamiyeh *et al.*, 1971) and Texas (Hall *et al.*, 1971) *D. farinae* is the only species found in houses. On the contrary, in coastal parts of California *D. pteronyssinus* is the dominant species (Furumizo, 1975). To date there is no information on the situation prevailing along the Atlantic coast but we surmize that in these areas *D. pteronyssinus* is more frequent than *D. farinae*.

In Hawaii *D. pteronyssinus* is the dominant species (Sharp and Haramoto, 1970).

In Egypt (Frankland and El-Hefney, 1971) and in some villages of Eastern Israël (Feldman-Muhsam *et al.*, 1985), *D. farinae* is as frequent or more frequent than *D. pteronyssinus*.

In New Guinea (Anderson and Cunnington, 1974), Japan (Oshima, 1970), Australia (Domrow, 1970), Cuba (Cuervo *et al.*, 1983), Brazil (Rosa and Flechtmann, 1979), Columbia (Charlet *et al.*, 1977b) and in many other countries, *D. pteronyssinus* is more frequent and abundant than *D. farinae*.

In Central Africa, as in Zaïre (Fain, 1967a, 1988b), Rwanda and Burundi (Fain, 1988b) *D. pteronyssinus* is the only species of Pyroglyphidae in house dust.

In Zaïre *D. pteronyssinus* was found in Bukavu (Kivu province), in Bokela (Equateur province) and in Lubumbashi (Shaba province). In Rwanda this mite was collected from houses in Kigali, and in Burundi from house dust in Bujumbura (Fain, 1988a and 1988b).

We also recorded this species from Tahiti (Pacific area), Tristan Da Cunha, Morocco and Turkey (Fain, 1988a and 1988b).

2. *Dermatophagoides evansi* Fain, Hughes and Johnston, 1967
Dermatophagoides evansi Fain, Hughes and Johnston, in Fain (1967a).
(Fig. 29-31, 59)

This species closely resembles *D. pteronyssinus*. The female has the same type of dorsal striation (area M with only longitudinal striations) and in the male the coxae II are closed as in *D. pteronyssinus*.

D. evansi clearly differs from *D. pteronyssinus* in the female by the characteristic aspect of the bursa (distal half much wider than proximal half) and the spermatheca (sclerotized and tulip-like). In the male the dorsal shield is longer and narrower (ratio width (at level of *d2*) : length = 1 : 2.5), whilst in *D. pteronyssinus* this ratio is 1.8 to 1.9, and the legs III and IV are much more unequal.

Holotype in the British Museum (Natural History).

Geographical distribution :

The typical series was found in feather pillows made in Boston (England) and consigned to Ghana.

This species is frequently found in nests of birds. In the U.S.A. it has been reported from nests of *Quiscalus quiscala* (Icteridae), near Wooster, and in the nest of a "cave swallow" near Carlsbad, New Mexico (Fain, 1967a).

Baker *et al.* (1976) mentioned this species in nests of unidentified birds near New York and they believed that it is the most common pyroglyphid species infesting birds' nests in these regions. It is also known from the nest of a "tree swallow" in Winnipeg, Manitoba, Canada (Sinha *et al.*, 1970).

We have seen specimens collected in the nest of a sparrow of East Lansing, U.S.A., by Dr W. Chmielewski and in chicken litter in Israël (Coll. Dr Rosen).

D. evansi has been reported, but always in small numbers, in house dust from the following countries: U.S.A., locality not precised (Wharton, 1970) and in California (Furumizo, 1975); France, in the region of Strasbourg (Araujo-Fontaine *et al.*, 1973) and in the region of Grenoble (Lascaud, 1978); Portugal (Pinhao and Gracio, 1978); Iran, in the region of the Caspian Sea (Amoli and Cunnington, 1977); oriental region of U.S.S.R. (Tareev and Dubinina, 1985).

Treat (1975) found a female of this species on a Noctuidae in New York.

3. *Dermatophagoides farinae* Hughes, 1961
? *Visceroptes takeuchii* Sasa, 1948
? *Dermatophagoides takeuchii* Sasa, 1950; Sasa and Shingai, 1958
? *Dermatophagoides scheremetewskyi* Dubinin, 1953 (nec Bogdanov, 1864); Dubinin *et al.* 1956 (nec Bogdanov, 1864); Sasa and Shingai, 1958 (nec Bogdanov, 1864).
Dermatophagoides scheremetewskyi, Traver, 1951 (in part) (nec Bogdanov, 1864)
Dermatophagoides farinae Hughes, 1961
Dermatophagoides culinae De Leon, 1963
(Fig. 32-34, 59)

Visceroptes takeuchii Sasa (1948) described from a male is probably identical with *D. farinae*, but it is no longer possible to ascertain this since the types are now lost.

Sasa and Shingai (1958) assigned to *D. scheremetewskyi* several specimens (males and females) found in stored albumin tannate in Japan. Judging from the figures given by these authors their specimens closely resemble *D. farinae* (or *D. microceras*) but they are clearly distinct from *D. neotropicalis* Fain and Bronswijk, another species of the group *farinae*, by several important characters (female with epigynium less convex and shorter, not bearing the setae *ga* ; *gm* more anterior ; male with hysteronotal shield wider than long). It should also be noted that to date *D. neotropicalis* has never been recorded from Japan.

D. farinae is easily distinguished from *D. pteronyssinus* in the female by the broader shape of the body and the different aspect of the dorsal striations in the M area. In *D. pteronyssinus* these striations are longitudinal, whilst in *D. farinae* they are transverse or slightly convex. The male differs from that of *D. pteronyssinus* by the shape of the hysteronotal shield which is wider than long.

Holotype of *D. farinae* in the British Museum (Natural History).

Geographical distribution :

The typical series of *D. farinae* was found in poultry and pig rearing meal near Bristol, England. *D. culinae* (= *D. farinae*) was described from self-raising biscuit flour in Tennessee, U.S.A. However, the main habitat of *D. farinae* seems to be house dust, especially bedding.

D. farinae is cosmopolitan, but curiously enough, this species is completely lacking in Central Africa, Cuba and some South American countries. Moreover, this species is much more frequent and abundant in regions subject to a dry continental climate than in humid areas situated near the sea coast.

Waki and Matsumoto (1973) have shown that *D. farinae* has its optimum development at a temperature of 25-30°C and a relative humidity of 50-60%. A relative humidity of 76% or more was unfavourable.

In Europe this species is rare or very rare in all areas situated close to the coast (Holland, England, Scotland, Belgium, coast of Spain), but is on the contrary abundant in countries situated far from the sea coast (Czechoslovakia, East of France, East of Finland, some dry areas far from the coast in Spain).

In Israël its distribution varies according to the degree of humidity of the region : relatively more rare in the western humid area than in the drier areas of the eastern region (Feldman-Muhsam *et al.*, 1985).

The distribution of this species in the U.S.A. has been discussed above.

We have previously reported the presence of *D. farinae* in Tahiti and in Syria.

Variability of *D. farinae* (Table II)

The variability of *D. farinae* has not, until now, been studied in detail. This question, however, may be important in the evaluation of some characters used in the separation of this species from *D. microceras*. The same problem is also worth consideration for the latter

species, as well as for *D. siboney*, another species very close to *D. farinae*.

The separation of *D. microceras* from *D. farinae* is mainly based on the following characters (for the females) :

1. Shape of the copulatory vestibule or the cuticular depression situated at the opening of the bursa copulatrix.

2. Absence or presence of apical curved process (ongle) on tarsi I and II and their degree of development.

3. Distance between setae *gp* (= *gp-gp*) and distance between seta *gp* and the genital apodeme (= *gp-ag*). The ratio between these two distances is thought to be significantly different in both species.

We have examined these characters in specimens of our collection from the following origins :

1. 15 specimens originating from a culture that we received from Dr J. van Bronswijk in 1971 and is still in maintenance.

2. 8 females of the typical series of *D. farinae*

3. Females originating from several localities, most of them from house dust. They were collected in Belgium, England, South Africa (Johannesburg), Israël, Singapore, Japan, Tahiti (Papeete), U.S.A. (New York, Columbus), Columbia. Most of these specimens had been sent to us for identification.

The specimens that we assign to *D. farinae* present a well developed copulatory pouch (vestibule) which opens onto the surface of the body by a cuticular slit which is relatively long and oriented obliquely. This slit is situated ventrally at some distance from the posterior margin of the body and from the anus. The bursa proper is a very narrow canal originating at the bottom of the vestibule. The walls of the vestibule are in most of the specimens well sclerotized. Only in a few specimens from a laboratory culture was the vestibule less sclerotized.

Table II shows the great variability of certain characters in the same population of *D. farinae*. In 15 specimens from the culture "Brussels" the distance *gp-gp* varies from 36 to 64 µm and the ratio (*gp-ag*) : (*gp-gp*) from 1 : 1.5 to 1 : 5.7. The length of the apical process of tarsus I fluctuates from 6 to 10 µm.

In some populations originating from non-European countries (except perhaps Japan) the apical processes of tarsi I and II are distinctly smaller than in the European specimens. They are particularly small in the specimens that we have received from Israël. All these specimens, however, have a well developed and sclerotized vestibule as in the typical series of *D. farinae*. These new findings show that *D. farinae* presents a double variability, one appearing within the same population and concerning mainly the distance between the setae *gp*, the other related to the geographical isolation and affecting especially the size of the apical processes of tarsi I and II.

Heteromorphism of the males

Heteromorphism in males has been reported in the genera *Dermatophagoides* (*D. farinae*, *D. neotropicalis*, *D. simplex*, *D. anisopoda*, *D. sclerovestibulatus*), *Sturnophagoides* (*S. brasiliensis*, *S. bakeri*, *S. petrochelidonis*) and *Hughesiella* (*H. africana*) (Fain, 1967a and 1988b).

Heteromorphic males differ from homeomorphic ones by the thickening of the legs I and the fusion of the epimera I to form a V or Y. The degree of thickening or fusion of epimera I may vary according to individuals in the same population. In some species the epimera I are fused in a Y but the legs are not thickened (*D. aureliani*).

We believe that this heteromorphism is of the same type as that reported in the genus *Cheyletus*, namely that it has no genetic basis (Regev, 1974). It appears during ontogenesis under the influence of some external factor, still insufficiently understood.

4. *Dermatophagoides microceras* Griffiths and Cunnington, 1971
(Fig. 60)

Geographical distribution :

This species has been described from the dust of a house in London (holotype). The authors also recorded the finding of 3 other populations: one originating from a feather mattress in a house at Greenwich, London, in 1968, the second was taken from feather cushions in a house in Barcelona, Spain, in 1969, and the third was collected from mattress dust, New Orleans, U.S.A. Our collection includes specimens from house dust in Louvain (Belgium) and in Johannesburg (South Africa), laboratory cultures (Dr A. Cunnington and B.J.H.,

England) and a feather mattress (Mrs Bridge, 1968) in England. We also received, from Dr Araujo-Fontaine, specimens originating from a culture. We do not know the exact origin of this culture but in one of her publications she refers to a strain of *D. farinae* that had been sent to her by Dr Spieksma. It is possible that our specimens belonged to this culture, originally misidentified.

D. microceras has also been recorded from Italy (Ottoboni *et al.*, 1984) and Switzerland (Mumcuoglu, 1976).

The holotype of *D. microceras* is in the British Museum, Natural History, London.

According to Griffiths and Cunnington this species is distinguished from *D. farinae* by the following characters (in the female) :

1. Setae *gp* further apart and closer to the genital apodemes laterally.

2. Apical process of tarsus I smaller and with a rounded apex. Absence of a process on tarsus II.

3. Inseminating organ without a sclerotized vestibule, the sclerotization is confined to the narrow neck of the funnel (bursa) which is slightly dilated compared to the rest of the bursa.

From our own observations it appears that there is not a true vestibule in this species but rather a simple funnel-shaped cuticular depression; the opening of this depression is generally widely open without a true flap.

We have shown above that the first two characters (distance *gp-gp* and size of apical process of tarsus I) are variable in *D. farinae* even in the same population (Table III) and thus these characters cannot be used to separate this species from *D. microceras*. The only valid character seems to be the shape of the insemination organ in the female.

Variability of *D. microceras* : (females, Table III)

Table III reveals an important variability in the female of *D. microceras*. The 4 specimens from a feather mattress in England are completely lacking an apical process on tarsus I whereas the 6 specimens from Strasbourg possess a rather well developed process on this tarsus. An intermediate form is found in the cultures of B.J.H. Another variable character is the distance *gp-gp* (varying from 37 µm to 54 µm) with a ratio (*gp-ag* : *gp-gp*) from 1 : 1.5 to 1 : 5.2. In all these specimens the inseminating organ has the same aspect as in the typical *D. microceras*.

These new observations demonstrate the difficulties in unequivocally separating *D. microceras* from *D. farinae*.

5. *Dermatophagoides siboney* Dusbabek, Cuervo and Cruz, 1982
(Fig. 60)

This species is close to *D. farinae*. It differs from it by the smaller size of the body and the various organs and setae, the more elongate shape of the propodonotal shield and, in the female, by the relatively smaller size of the vestibule.

We have examined 2 paratypes (one male and one female) of this species. In the female the apical process of tarsus I is distinctly smaller than on the original figure but this character is probably variable. All the known males are homeomorphic.

This species has been found in the dust of mattresses in Cuba. It is known only from Cuba and in this country it is almost as frequent as *D. pteronyssinus*.

Holotype in the Institute of Zoology, Academy of Sciences of Havana, Cuba.

6. *Dermatophagoides neotropicalis* Fain and van Bronswijk, 1973
Dermatophagoides neotropicalis Fain and van Bronswijk, 1973
Dermatophagoides deanei Galvao and Neide, 1986; Fain, 1988b
(Fig. 35-37, 61)

This species is close to the "*farinae*" group. In the female the striations of the M area (median area comprized between setae *d2* and *d3*) are mostly transverse but they are much more convex in the posterior part than in the species of the *farinae* group. Moreover the bursa is differently shaped in this group; it opens onto the posterior margin of the body at the top of a small raised papilla and there is no vestibule. In addition the epigynium is thicker, longer and bears the setae *ga* ; the *gm* are more posterior. The male differs from those of the *farinae* group by the elongate shape (longer than wide) of the hysteronotal shield. The males are either homeomorphic or heteromorphic.

Table II : Variability of some characters in female *D. farinae* (dimensions in µm)

Origin of specimens	N° of females	Distance *gp-gp*	Distance *gp-ag*	Ratio *gp-gp/gp-ag*	Length of apical process		Vestibule (pouch)	
					Tarsus I	Tarsus II	Well sclerified	Poorly sclerified
Chicken food Bristol	1	54	18	3	6	3.6-0	X	
(typical series)	2	50	14	3.6	6	0	X	
	3	43	22	1.9	7	3	X	
	4	42	20	2.1	6	2.5	X	
	5	42	18	2.3	6	3	X	
	6	40	15	2.6	6	4.8	X	
	7	36	17	2.1	6	3.5	X	
	8	35	17	2	5	2.5	X	
Culture n°4	1	51	16	3.1	8	5	X	
(Dr Cunnington,8.1967)	2	51	16	3.1	7	3	X	
	3	48	13	3.7	9	6	X	
	4	48	24	2	7	6	X	
Culture Brussels	1	64	18	3.5	6	4		X
	2	63	12	5.2	9	4		X
	3	63	11	5.7	9	4		X
	4	62	15	4.2	7.2	2-0	X	
	5	61	18	3.4	8	5		X
	6	60	16	3.7	7	0	X	
	7	60	14	4.3	7.2	4	X	
	8	52	17	3	8.5	4.5	X	
	9	48	14	3.4	8	4	X	
	10	47	20	2.3	7.2	5.5	X	
	11	45	18	2.5	7	0	X	
	12	42	20	2.1	8.2	7	X	
	13	40	15	2.7	10	4	X	
	14	37	24	1.5	7.5	5		X
	15	36	15.6	2.3	9.6	0-3.6	X	
House dust								
Louvain (Belgium)	1	30	18	1.7	5	-	X	
	2	34	20	1.7	4	-	X	
	3	37	15	2.5	3	-	X	

Table II : Variability of some characters in female *D. farinae* (dimensions in µm) (continued)

Origin of specimens	N° of females	Distance *gp-gp*	Distance *gp-ag*	Ratio *gp-gp/gp-ag*	Length of apical process		Vestibule (pouch)	
					Tarsus I	Tarsus II	Well sclerified	Poorly sclerified
Israël								
(house dust)	1	36	15	2.4	0	0	X	
	2	35	15	2.3	2	0	X	
	3	34	12	2.8	2	0	X	
	4	33	12	2.8	0	0	X	
	5	33	21	1.6	2	0	X	
	6	32	15	2.1	2.5	0	X	
	7	30	15	2	0	0	X	
	8	30	10	3	2.5	0	X	
	9	30	18	1.7	2.5	1.5	X	
	10	30	14	2.1	3	1.5	X	
Syria (Damas)								
(house dust)	1	33	18	1.8	5.5	0	X	
	2	30	15	2	-	-	X	
Singapore								
(house dust)	1	42	13	3.2	5	3	X	
	2	30	8	3.7	4	2	X	
Japan (Yokohama)								
(house dust)	1	36	13	2.7	6	5	X	
Tahiti (Papeete)								
(house dust)	1	25	10	2.5	3.5	0	X	
Columbia								
(house dust)	1	38	11	3.4	3.6	0	X	
	2	36	12	3	-	-	X	
U.S.A. (house dust)								
Columbus	1	39	19	2	4	2	X	
New York	1	48	18	2.7	4	2	X	
	2	45	15	3	4	0	X	
	3	36	20	1.8	5	0	X	
South Africa								
(Johannesburg)								
House dust	1	48	15	3.2	3.6	0	X	
Culture	1	36	17	2.1	6	3.5	X	
	2	42	18	2.3	7	5	X	
	3	36	16	2.2	6	4.5	X	

Table III : Variability of some characters in female *D. microceras* (dimensions in µm)

Origin of specimens	N° of females	Distance *gp-gp*	Distance *gp-ag*	Ratio *gp-gp/gp-ag*	Length of apical process	
					Tarsus I	Tarsus II
England						
Culture n°3	1	45	15	3	3.5	0
(Dr Cunnington)	2	37	24	1.5	0	0
Culture B.J.H.	1	48	15	3.2	3	0
	2	48	15	3.2	3	0
	3	37	24	1.5	2.5	0
Ex feather mattress						
(Mrs Bridge, 1968)	1	42	11	3.8	0	0
	2	41	12	3.4	0	0
	3	40	10	4	0	0
	4	40	10	4	0	0
France						
Culture						
(Dr Araujo-Fontaine,	1	54	12	4.5	5	0
1978)	2	49	13	3.7	5	0
	3	48	13	3.7	3.5	0
	4	48	13	3.7	6	0
	5	43	13	3.3	4.5	0
	6	50	10	5	4.2	0
	7	54	18	3	3.5	0
Belgium (Louvain)						
(house dust)	1	48	10	4.8	2	0
	2	47	9	5.2	0	0
	3	45	9	5	-	-
South Africa						
(Johannesburg)						
(house dust)	1	42	18	2.3	-	-

Status of *Dermatophagoides deanei* Galvao and Neide, 1986

Galvao and Neide (1986) described a new species *D. deanei* found in house dust in several towns in Brazil. Through the courtesy of Dr Galvao we were able to examine the holotype female and a paratype male of this species. The study of these specimens has convinced us that this species is a synonym of *D. neotropicalis*. All the characters are identical in both species. The authors have based their diagnosis mainly or exclusively on the shape of the internal sclerite of the bursa copulatrix ("cum aspecto de candelabro de lâmpada única"). Actually this sclerite does not belong to the bursa but is simply the anal sclerite, which exists in all the Pyroglyphidae but becomes more apparent in strongly flattened specimens as is the case for the holotype of *D. deanei*. Moreover, in this specimen this sclerite is, by chance, superimposed upon the bursa producing the illusion that both organs are connected to each other, whereas they are actually situated at different dorsoventral levels.

We give herein a figure of the anal area of the holotype of *D. deanei* (Fig. 61a) and 2 figures of paratypes of *D. neotropicalis* (Fig. 61b and 61c) drawn in the same scale. This clearly shows that there is no difference between the two species.

Geographical distribution :

D. neotropicalis was described from mattress dust in Paramaribo, Surinam. Holotype male in the Rijksmuseum van Natuurlijke Historie, Leiden, The Netherlands.

It has also been found by Galvao and Neide in house dust in several towns in Brazil (Sao Luis, Natal, Fortaleza, Maceio, Belo Horizonte and Rio de Janeiro), but reported under the name *D. deanei*. The holotype of *D. deanei* is deposited in the Instituto Oswaldo Cruz, Rio de Janeiro, Brazil.

7. *Dermatophagoides rwandae* Fain, 1967
(Fig. 38-39, 59)

This species differs from *D. farinae* by the very oblique and almost longitudinal orientation of the cuticular striations in the M area (between setae *d2* and *d3*) and by the characteristic shape of the bursa copulatrix which opens onto the posterior border of the body at the bottom of a small triangular and sclerotized vestibule. Moreover, the epigynium is thick, strongly curved and bears the setae *ga*; the setae *gm* and *gp* are situated on the same transverse line and the setae *h* are very short. This species is known only from the holotype female, collected from the nest of a *Buphagus africanus* at Astrida (now Butare) in Rwanda. Holotype in the Museum of Tervuren, Belgium.

8. *Dermatophagoides aureliani* Fain, 1967
Dermatophagoides passericola Fain, 1964 (in part)
(Fig. 40-42, 60)

In the female of this species the dorsal striations in the posterior half of the M area are very oblique and almost longitudinal as in *D. rwandae*. It differs from this species and from *D. farinae* by the characteristic aspect of the bursa copulatrix. The opening of the bursa is situated on the posterior margin of the body and it is followed by a voluminous cylindrical, refringent, unsclerotized pouch (= vestibule). This pouch is orientated transversely and slightly obliquely, it is 40-45 µm long and 20-22 µm wide. The male differs from that of *D. farinae* by the narrow shape of the hysteronotal shield, the fusion of the epimera I and a normal aspect of legs I. This species has been recorded in the nest of *Passer griseus ugandae* in Butare, Rwanda. It had previously been reported under the name *D. passericola* (in Fain, 1964).

Holotype in the Museum of Tervuren, Belgium.

9. *Dermatophagoides sclerovestibulatus* Fain, 1975
(Fig. 43-45, 60)

In the female of this species the striations of the M area (between setae *d2* and *d3*) are transverse in the anterior third or quarter of this area and strongly oblique or longitudinal in the rest of this area. The bursa is characteristic, its opening is situated on the posterior margin of the body in the middle of a strongly sclerotized oval plate 22 µm long and 12 µm wide. This plate is situated close to the midline and near the posterior angle of the anus. In this species there is no vestibule, only a large, sclerotized and superficial plate bearing the opening of the bursa. The epigynium is thick, strongly bent and bears the setae *ga*. The setae *gm* are far in front of the *gp* and the *h* are very short as in *D. rwandae*. The male is heteromorphic, the legs I being slightly thicker than legs II and the epimera I fused to form a Y. The hysteronotal shield is distinctly narrowed in its anterior half and arrives anteriorly at the level of setae *d2*.

All known specimens were collected in the nest of *Buphagus erythrorhynchus* (Sturnidae), near Satara, National Kruger Park, South Africa. Holotype in the Museum of Tervuren, Belgium.

10. *Dermatophagoides simplex* Fain and Rosa, 1982
(Fig. 60)

In the female of this species the striations of the anterior half of the M area are transverse as in *D. farinae*, however in the posterior half of this area these striations are much more convex than in the latter species.

This species is well characterized by the aspect of the bursa copulatrix which opens in the middle of a small oval sclerotized plate 8 to 9 µm long and 6 µm wide. This plate is situated ventrally, slightly closer to the posterior margin of the body (15 µm) than to the anus (20 µm). Epigynium well sclerotized and bearing the setae *ga* ; the *gm* are more anterior than *gp*, the *h* relatively long. Male heteromorphic with a large hysteronotal shield arriving anteriorly to a point closer to the setae *d1* than to the *d2*; laterally the shield extends to the setae *l3*.

This species has been collected in several nests of *Passer domesticus* at Piracicaba, State of Sao Paulo, Brazil. Holotype in the Museum of Zoology, ASALQ University of Sao Paulo, Brazil.

11. *Dermatophagoides anisopoda* (Gaud, 1968)
Hullia anisopoda Gaud, 1968

Dermatophagoides anisopoda, Fain 1988

This species is known from a single male (holotype) and 9 nymphs. This male is heteromorphic and shows all the characters of the genus *Dermatophagoides*. The legs I are thicker than the legs II and the epimera I are fused to form a Y.

Through the courtesy of Dr J. Gaud we were able to examine the holotype of this species. It differs from *D. sclerovestibulatus* by the greater length of the hysteronotal shield (arriving anteriorly midway between setae *d1* and *d2*), the larger size of the idiosoma (330 µm instead of 216 to 278 in *D. sclerovestibulatus*), the legs (tarsi I-IV 45-54-54-36 µm long, compared to 33-37-38-26 µm long in *D. sclerovestibulatus*), the adanal suckers (diameter 21 µm compared to 15 µm in *D. sclerovestibulatus*), and the greater length of the seta *h* (130 mm compared to only 65 µm in *D. sclerovestibulatus*).

The typical series was taken from an African parakeet *Agapornis pullaria*, in Yaounde, Cameroon.

Genus **Hirstia** Hull, 1931

The genus *Hirstia* is distinguished from *Dermatophagoides*, in both sexes, by the aspect of the cuticular striations, which are finer and set closer together , and by the more important reduction of the legs IV compared to legs III. The ratio of the lengths (leg IV : leg III) is 1 : 1.4 to 1.56 in the female and 1 : 1.8 to 1.9 in the male. In addition, the male differs from those of the other genera of Dermatophagoidinae by the spinous aspect of the setae *r* and *w* of tarsus III (situated in the middle of the tarsus) and by the presence of denticles along the inner border of the perianal chitinous frame.

Table IV : Lengths of legs and tarsi in *Hirstia passericola* (types) and *Hirstia domicola* (types and paratypes) (dimensions in µm)

	Length of legs				Length and width of tarsi			
	I	II	III	IV	I	II	III	IV
H. passericola								
Female	135	150	175	118	40x12	43x14	66x9	48x6
Male	123	132	163	88	33x13	39x14	51x15	24x9
H. domicola								
Female	108	116	127	85	27x14	32x15	43x10	32x9
Male	92	105	102	64	22x12	27x12	32x13	18x9

The type species is *Hirstia chelidonis* Hull, 1931.

1. *Hirstia chelidonis* Hull, 1931
? *Dermatophagoides passericola* Fain, 1964
(Fig. 46-48, 59)

Hirstia chelidonis was described from the nest of the House Martin (*Delichon urbica* or *Chelidon urbica*) in Belford, England.

In 1967, we examined specimens of *H. chelidonis* from the collection of the British Museum, London, believing that they belonged to the typical series. Comparing them with our *D. passericola* we did not find important differences between both specimens and we have concluded that they are synonymous. However, the specimens that we examined from the British Museum were not from the type series and did not originate from the typical locality. According to Dr K.H. Hyatt, of the British Museum, these types are very probably lost. The synonymy that we proposed previously (Fain *et al.*, 1974) should therefore be reconsidered when new material from the typical host and locality becomes available.

D. passericola was described from the nest of *Passer domesticus* in Belgium. We have also found this species in the nests of several other species of birds in Belgium and in the nest of *Apus apus* in France (Fain, 1967a). In Poland, Chmielewski (1982) found it in the nest of the typical host.

We have reported this species from the nest of *Passer griseus ugandae* in Rwanda (Fain, 1964). In fact, these specimens belonged to a new species, *D. aureliani* that was described a few years later (Fain, 1967b).

2. *Hirstia domicola* Fain, Oshima and van Bronswijk, 1974
Hirstia chelidonis Fain, Cunnington and Spieksma, 1969 (nec *Hirstia chelidonis* Hull, 1931)
(Fig. 49-51)

This species is distinguished from *D. passericola* (typical specimens) by the following characters:

In both sexes the idiosoma is smaller, the legs shorter, all the tarsi shorter and relatively thicker. In the female the cuticle of the posterior region of the body is distinctly more sclerotized, especially on the dorsum. Table IV gives the measurements of the legs and tarsi in both species.

H. domicola has been described from house dust or mattresses in different localities of Japan and Surinam. We have also seen specimens of this species from house dust from Kampong, Negri Sambilan, Malaysia (Coll. Nadchatram) and Johannesburg (Coll. Dr Zumpt, 1967).

The following records were found in the literature (sometimes under the name *H. chelidonis*) : from Taiwan, Thailand (Bangkok) and U.S.A. (Columbus) (Oshima, in Fain *et al.*, 1974), Columbia (Charlet *et al.*, 1977a), India (ChannaBasavanna *et al*, 1984), France (Penaud *et al.*, 1972), Cuba (Cuervo *et al.*, 1983), U.S.S.R. (Dubinina and Pletiev, 1978), Brunei (Woodcock and Cunnington, 1980), Java (Fain *et al.*, 1969). In Spain it has been cited under the name *D. passericola* (Blasco *et al.*, 1975). In all of these localities the mites were found in the dust of houses or mattresses.

H. domicola is more frequent in Japan than in the other countries listed. According to Oshima (1967), in some houses this species represents more than one third of the total mite population.

The holotype is deposited in the National Science Museum, Tokyo, Japan.

Genus **Malayoglyphus** Fain, Cunnington and Spieksma, 1969

This genus differs from *Dermatophagoides*, in both sexes, by the short, thin shape of the setae *sc e*, the normal development of legs IV which are as long as legs III, and the presence of only one solenidion on genu I. In the female the epigynium is poorly developed. In the male the adanal suckers are reduced and tarsus IV bears 3 thin setae and one rounded papilla which is a remnant of a sucker. There is no forked spine on the apex of tarsus III as in *Dermatophagoides*.

1. *Malayoglyphus intermedius* Fain, Cunnington and Spieksma, 1969
(Fig. 52-54)

This is the typical species, collected from house dust in Java and Singapore.

Since then it has been found in Taipei (Taiwan) (Oshima, 1970), Thailand (Wongsathuaythong *et al.*, 1972; Boonkong *et al.*, 1987), India (ChannaBasavanna *et al.*, 1984), South Africa (Fain and Lowry, 1974),

Surinam (Bronswijk *et al.*, 1975), Cuba (Cuervo *et al.*, 1983), Columbia (Charlet *et al.*, 1977a). In addition we have seen some specimens collected in Kuala -Lumpur by Furumizo (1976), in Nigeria (Dr Y. Mumcuoglu) and in Tahiti (Fain, 1988b).

In the original drawing of *M. intermedius* we omitted to depict the epigynium. We give herein a new, complete figure of the female of this species.

The holotype is in the Institut Royal des Sciences naturelles de Belgique, Brussels.

2. *Malayoglyphus carmelitus* Spieksma, 1973

This species is larger than *M. intermedius* and in both sexes the setae *sc e* are distinctly longer than the *sc i*.

M .carmelitus was found in the dust of a house situated on the slope of Mount Carmel, in Haifa, Israël. It has also been found in Barcelona, Spain (Blasco and Portus, 1973), in Columbia (Charlet *et al.*, 1977a) and in India (ChannaBasavanna *et al.*, 1984).

The holotype is in the Rijksmuseum voor natuurlijke Historie, Leiden, The Netherlands.

Genus **Sturnophagoides** Fain, 1967

Dermatophagoides (*Sturnophagoides*) Fain, 1967a
Sturnophagoides, Fain, 1967b, 1988b

This genus is distinguished from the other genera of the Dermatophagoidinae by the following characters : In both sexes the striations of the cuticle are punctate and more or less sclerotized over a part or all of the body; the region between epimera I is completely punctate; the setae *sc e*, *d5* and *l5* are long or very long, the setae *h* are very short. The female bears a hysteronotal shield (which is absent in the other genera) and the posterior vulvar lip is punctate (either partially or completely) and incised in its anterior angle (as in some Pyroglyphinae). In the male tarsus III bears either only simple setae or 5 thin setae and a conical, unforked apical spine.

The type species is *Dermatophagoides (Sturnophagoides) bakeri*, Fain, 1967.

1. *Sturnophagoides bakeri* Fain, 1967
Dermatophagoides (Sturnophagoides) bakeri Fain, 1967a
Sturnophagoides bakeri Fain, 1967b, 1988b
(Fig. 55)

The typical series, only females, has been found on starlings (*Sturnidae*) in Virginia, U.S.A.

Baker, Delfinado and Abbatiello (1976) also found this species in nests of unidentified birds at Heidelberg (New York) and at Stoughton (Mass.), U.S.A. and they described for the first time the male.

Holotype in the U.S. National Museum, Washington.

2. *Sturnophagoides brasiliensis* Fain, 1967
Sturnophagoides brasiliensis Fain, 1967b
Sturnophagoides halterophilus Fain and Feinberg, 1970, Fain, 1988b
(Fig. 56-58)

The typical series of this species was found in house dust in Tejipio, near Recife, Brazil. This species was also found in house dust in Singapore (Fain *et al.*, 1969), in Kuala-Lumpur, Malaysia (Coll. Nadchatram), Djakarta, Java, and in Strasbourg, France (Fain and Lowry, 1974). The house in Strasbourg infested by this species had been inhabited by a Brazilian who made frequent trips between France and Brazil.

The species *Sturnophagoides halterophilus* Fain and Feinberg, based on a single, strongly heteromorphic male found in house dust in Singapore, is now considered as a synonym of *S. brasiliensis* (Fain, 1988b). In 1973, Fain and Van Bronswijk transferred this species to the genus *Dermatophagoides*, but some characters , such as the punctate aspect of the striations and the short setae h are more in keeping with the genus *Sturnophagoides*.

Holotype in the Institut Royal des Sciences naturelles de Belgique.

3. *Sturnophagoides petrochelidonis* Cuervo and Dusbabek, 1987

We have not seen specimens of this species, however, according to the description of the authors, this species differs from *S. bakeri* by the larger size of the hysteronotal shield in the female (125 x 68 µm, compared to 105 x 42 µm in *S. bakeri*). In the male this shield is rectangular whilst in *S. bakeri* it is piriform.

This species was described from the nest of the "cave swallow" *Petrochelidon fulva*, in Cuba.

Holotype in the Academy of Sciences, Havana, Cuba.

7. RELATIVE FREQUENCY AND ABUNDANCE OF THE DOMICOLOUS SPECIES OF PYROGLYPHIDAE IN EUROPE

We give herein a summary of observations on the distribution and frequency of the *Pyroglyphidae* found in houses in some countries of Europe.

THE NETHERLANDS

In 1967, Spieksma and Spieksma-Boezeman published their observations on the mite fauna found in the dust of 150 houses in the Netherlands. They collected a total of 9209 Pyroglyphidae. *D. pteronyssinus* was present in every house and represented 87.6% of the total number of pyroglyphid mites. *E. maynei* was found in 53% of the houses and formed 11.2% of the pyroglyphids. *D. farinae* was observed in only 2% of the houses and represented 1.2% of the pyroglyphids.

Van Bronswijk (1973) has shown that during the summer (June to September) mattresses contain far more specimens of *D. pteronyssinus* than dust of carpets or floors.

BELGIUM

We were asked by Dr F. Spieksma to identify the mites that he found in house dust in The Netherlands, especially those belonging to the genus *Dermatophagoides*. In this material we recognised 2 species of the genus *Dermatophagoides*, one very common (*D. pteronyssinus*), the other very rare (*D. farinae*). A third species described under the name *Mealia maynei* Cooreman, 1950 was also present and relatively frequent. This material provided the ideal opportunity for a revision of this group of mites and to create a new genus (*Euroglyphus*) for the species of Cooreman (Fain, 1965).

In 1965, we started to search for these mites in house dust in Belgium. The dust of 20 houses in 6 towns (Brussels, Antwerp, Malines, Louvain, Ostend and La Louvière) were examined, 18 were positive for *D. pteronyssinus* and in 1 of these houses *D. pteronyssinus* was associated with *E. maynei*. In every house *D. pteronyssinus* was the most abundant species. These mites were found to be more numerous in old, damp houses (Fain, 1966a and b).

Further studies enabled us to discover low numbers of *D. farinae* and *D. microceras* from a house in Louvain (Fain, 1988b).

In 1973, Gridelet and Lebrun studied the evolution of the pyroglyphid fauna in house dust during a whole year by taking 6 samples throughout the year. They observed that *D. pteronyssinus* represented 70.5% of the total mite fauna (non-Pyroglyphidae and immatures of *D. pteronyssinus* included), *E. maynei* 11%, *Dermatophagoides* sp. 3% and *D. farinae* 0.4%.

ENGLAND

Maunsell, Wraith and Cunnington (1968) collected 186 samples of dust from houses in London, the Home Counties and South Wales between September 1966 and October 1967. *D. pteronyssinus* was the most common species. It was found in 82.3% of the samples. Less frequent and less numerous was *E. maynei*, present in 40.3% of the samples..The dust collected from the surfaces of mattresses contained many more mites (with a mean of 2568 mites per gram of dust) than from the living room (with a mean of 22 mites per gram of dust).

Walshaw and Evans (1987) made a survey of the house dust mite population in the homes of 50 asthmatic patients in Liverpool. *D. pteronyssinus* was the most common species found. *E. maynei* made up 37% of the total adult mite count and was the predominant species in 48% of the beds examined, whilst *D. pteronyssinus* was predominant in the remainder. *E. maynei* was present in 80% of the beds, in 76% of bedroom floors and in 61% of lounge floors. *D. farinae* was rare. According to the authors "There was a good correlation between increasing numbers of *E. maynei* and decreasing social class, but only a weak one with percentage relative humidity". High ionic sodium levels in beds were suggested as being related to decreasing social class and increasing levels of *E. maynei*. To explain these higher sodium levels they postulated that "lower social classes perspire more (due to increased manual labour) or might wash less (due to lower standards of personal hygiene)".

SCOTLAND

Sesay and Dobson (1972) made a survey of 60 beds, mainly from the Glasgow area. They found *D. pteronyssinus* in 59 beds, with a maximum of 1927 mites per gram of dust. *E. maynei* occurred in 27 beds, it was dominant in 4 beds and was the only pyroglyphid found in one bed. The beds contained more mites than

the floor dust and in the bed the blankets were infested by relatively more pyroglyphid mites (per gram of dust) than the mattress.

Colloff (1987b) collected 124 samples of house dust from beds and carpets in 74 homes in Glasgow. Among the 5272 mites collected 76% were Pyroglyphidae. *D. pteronyssinus* formed 64.3% of the total mite population and occurred in every house. *E. maynei* represented 11.6% of the total mite population and was present in 32.4% of the houses. *D. farinae* formed 0.06% of the total number of mites and occurred in 2.7% of the houses. The largest number of mites found in one sample was 12,100 mites per gram of dust. The number of mites occurring in 15 centrally heated homes was well below the overall mean of 970 mites per gram of dust.

FRANCE

The acarofauna of house dust has been studied in 4 regions of the Eastern and Southern parts of France.

1. Languedoc-Roussillon : Rousset (1971) collected 36 samples of house dust (floor and mattress dust). He found *D. pteronyssinus* in 26 samples, *D. farinae* in 7 and *E. maynei* in 5 of them. The total number of mites collected was 537 including 453 Pyroglyphidae.

2. South-East region : Penaud *et al.* (1972) collected house dust mites during a period of about one year. They examined 233 samples from the lower plain (altitude not precised) and 20 samples from the higher mountain area (altitude between 1326 and 1470 m). In the plain 158 samples contained in total 154 pyroglyphids, of which 71 were *D. pteronyssinus*, 49 *D. farinae*, 36 *E. maynei*, 1 *D. evansi* and 1 *H. chelidonis* (? *D. domicola*). In the mountain area 7 samples contained 1 *D. pteronyssinus*, 2 *D. farinae* and 4 *E. maynei*.

3. Region of Grenoble : Lascaud (1976 and 1978) collected mites from mattresses of 13 houses from several localities in the area of Grenoble, at different altitudes. The samples were taken during a whole year every one or three months, according to area. *D. pteronyssinus* and *D. farinae* were found in 12 mattresses, and *E. maynei* in only 9 mattresses. A fourth pyroglyphid species, *D. evansi* was found sporadically.

In the lower (214 to 300 m) or medium-high (568 to 832 m) areas *D. farinae* was the most abundant species in 5 mattresses (for a total of 9 mattresses). In contrast, in one mattress *D. pteronyssinus* was predominant over *D. farinae* and in 3 mattresses the difference between these two species was not significant owing to the small number of mites collected. In the higher areas (1218 to 1470 m) both species were low in number and *D. farinae* was lacking in one mattress. The total number of mites collected was 33,493 and 94% of these were Pyroglyphidae.

4. Region of Strasbourg : Araujo-Fontaine (1974) collected 150 samples of house dust (floor or mattresses). Among the 135 samples positive for mites, 133 contained *D. pteronyssinus* (= 99.5%), 73 contained *E. maynei* (54%) and 46 contained *D. farinae* (34%). The dust from the old typical Alsation houses in the ward "Petite France" contained far more mites than that from new and more modern houses. Among the older houses 34.6% contained 100 to 500 mites per gram of dust, 11.5% between 500 and 1000 and 7.6% more than 1000 mites per gram of dust.

DENMARK

Haarløv and Alani (1970) collected 69 samples of dust from mattresses in Copenhagen. *D. pteronyssinus* was slightly more frequent than *D. farinae*. Only one specimen of *E. maynei* was collected.

FINLAND

Stenius and Cunnington (1972) observed that *D. farinae* is more frequent (62%) in the Eastern region of Finland than in Helsinki (28.9%). The opposite is true for *D. pteronyssinus* (65.6% at Helsinki, for 22.9% in the Eastern areas) and *E. maynei* (25.9% at Helsinki, for 4.7% in the Eastern areas).

FEDERAL REPUBLIC OF GERMANY

Keil (1983) collected 67 samples of dust from 28 houses in Hamburg (mattresses and bedroom carpets) during a year. He found 6914 mites, of which 6469 were Astigmata. Among them 5927 belonged to the Pyroglyphidae (= 84% of the Astigmata). The frequency of the different species was as follows : *D. pteronyssinus* formed 80.3% of the Pyroglyphidae and 72.8% of the total number of mites. *D. farinae* represented 18% of the Pyroglyphidae and 10% of the total number of mites. *E. maynei* formed only 1.7% of the Pyroglyphidae and 1.2% of the total number of mites.

DEMOCRATIC REPUBLIC OF GERMANY

Karg (1973) during May and June 1972, collected 9 samples of dust from 3 houses in Berlin. They were taken from beds (5 samples), arm-chairs and cupboards (4 samples). Among the 70 mites collected 42 were Pyroglyphidae belonging to 3 species : *E. maynei* (27 specimens), *D. pteronyssinus* (14 specimens) and *D. farinae* (1 specimen).

Enge, Hiepe and Rubbeck (1984) studied the nests or litter of various domestic animals. Among the 68 samples that they collected, 5 contained pyroglyphid mites, all of the species *D. farinae* ; they were from the litter of chickens or pigeons (4 samples) and cages of rodents (1 sample).

SWITZERLAND

Mumcuoglu (1976) examined 190 samples of house dust from Basel and its surroundings. He found 11,000 mites. *D. pteronyssinus* represented 70.75% of the total mite population and occurred in 89.3% of the samples. *E. maynei* formed 17.8% of the total number of mites and was present in 36.66% of the samples. *D. farinae* and *D. microceras* formed 5.7% of the mites and occurred in 33.84% of the samples. The largest number of mites found in 100 mg of dust from a bed was 1054. Eighty-five percent of the samples collected from houses in autumn contained mites; in winter the percentage dropped to about 50%.

D. pteronyssinus and *D. farinae* (less frequent) were found in the bedding of dogs and cats living in these houses.

CZECHOSLOVAKIA

In 1972, Samsinak, Dusbabek and Vobrazkova collected 83 samples of house dust from floors and mattresses in Czechoslovakia. They found that *D. farinae* was more frequent than *D. pteronyssinus* and that *E. maynei* was completely lacking. They concluded that the distribution of the 3 main domicolous species of Pyroglyphidae in their country corresponded rather more with the results obtained in North America than with the data from Holland, England and other countries of Western Europe.

Further investigations conducted by some of these authors, however, did not agree with these first conclusions and have shown that the acarofauna of house dust in Czechoslovakia is actually closer to that of Holland, Belgium and England. The main difference between both fauna lies in the relative abundance of *D. pteronyssinus* and *D. farinae* which can be explained by the differences in the climate between countries (maritime and humid in Western Europe, continental and dry in Central Europe).

In 1978, Samsinak, Vobrazkova and Spicak collected the mites of 338 beds from two geriatric homes, from flats inhabited by asthmatic children and from beds used in sanatoria. A total of 5695 mites were found in these beds and among them 5025 were Pyroglyphidae. *D. pteronyssinus* was represented by 1783 specimens, *D. farinae* by 514 specimens, *E. maynei* by 831 specimens and *H. chelidonis* by 32 specimens. There were also 1865 specimens of immature pyroglyphids. In the 55 samples from the two geriatric homes, *D. pteronyssinus* represented 54% of the total mite count, *D. farinae* 45% and *E. maynei* 1% of the total number of mites. The mites were more numerous in the home which had a higher degree of relative humidity. In the flats occupied by the children the numbers of mites was roughly the same as in the geriatric homes. In contrast, in the sanatoria beds this number was very low. There is a discrepancy between the large number of *E. maynei* (831) given in the general list of p. 158 and the very low percentage of that species in the samples (only 1%).

The authors also studied the influence of the mattress padding on the number of mites. The highest number of mites was found in old mattresses stuffed with feathers (454 mites per gram of dust). In mattresses padded with card wool the number of mites was only 60 per gram of dust. Very low numbers of pyroglyphid mites were found in straw padding (1 mite per gram of dust), but in this padding storage mites (Glycyphagidae etc...) were abundant.

In 1979, Vobrazkova, Samsinak and Spicak observed that the bed mite fauna of periodically inhabited houses (such as country cottages serving as holiday homes) markedly differs, in quality and number of mites, from the bed mite fauna in regularly inhabited town apartments. In country cottages *E. maynei* may represent up to 70.4% of the total mites but only 28% in the town apartments used regularly by the owners of these cottages. In other apartments in the city this mite was, on the contrary, very rare. The authors explained the increase of this mite by the higher relative humidity in these country houses (75%) compared with that in the town apartments (30%). The relatively high number of *E. maynei* in the town apartments permanently inhabited by the owners of the holiday homes suggests that man transports these mites from the country to the city.

Table V : Percentage of pyroglyphid species in five localities of Catalonia

Localities	*D. pteronyssinus*	*D. farinae*	*E. maynei*
Barcelona	85.30 %	9.90 %	4.40 %
Reus	98.50 %	1.30 %	0.20 %
Torello	1.30 %	98.10 %	0.00 %
Castelltersol	18.30 %	81.10 %	0.70 %
Puigcerdà	29.60 %	12.30 %	58.00 %

The authors also reported the presence of *E. maynei* (the most abundant), *D. pteronyssinus* (frequent) and *D. farinae* (very rare) in the bedding of dogs and cats in the houses that they examined.

BULGARIA

Todorov (1979) collected 519 samples of house dust from 173 houses in the North-East of Bulgaria (Silistra) where the climate is of the continental-moderate type. A total of 15,414 mites were collected, of which 82% were Pyroglyphidae. *D. pteronyssinus* was found in 97.7% of the houses and represented 52.9% of the total mite fauna. *D. farinae* was present in 36.4% of the houses and formed 3.1% of the mites and *E. maynei* was found in 64.2% of the houses and formed 26% of the total mite number. Another species, *G. longior* was also represented but only by 7 specimens.

U.S.S.R.

Dubinina and Pletiev (1978) reported the presence in houses of the Western parts of the U.S.S.R. of several species of Pyroglyphidae. The most common is *D. pteronyssinus*. The other species, *H. chelidonis* (? *H. domicola*), *D. farinae*, *E. maynei*, *D. evansi* and *G. longior* were less frequent or rare.

Tareev and Dubinina (1985) studied this mite fauna in the Eastern parts of the U.S.S.R. They found that *D. pteronyssinus* represented 92% of the total number of Pyroglyphidae and *D. farinae* represented only 0.56%. The other species *D. evansi*, *H. chelidonis* (? *H. domicola*) and *G. longior* were very rare.

SPAIN

Research conducted in the province of Catalonia provided the following information:

1. Barcelona and its surroundings : Blasco *et al.* (1975) collected 182 samples of house dust during a period of 3 years. A total number of 124,900 mites were found and among them 58,111 were Pyroglyphidae. They belonged to the following species : *D. pteronyssinus* (49,591 specimens), *D. farinae* (5,349 specimens), *D. microceras* (389 specimens), *E. maynei* (2,449 specimens), *M. carmelitus* (230 specimens) and *H. passericola* (3 specimens). *D. pteronyssinus* occurred in 175 samples, *D. farinae* in 95 samples, *E. maynei* in 75 samples and *D. microceras* in 19 samples. The other species were each found in a single sample.

2. Other areas of Catalonia: Portus and Gomez (1976) collected house dust in five localities selected for their different ecological characteristics. Two of these localities (Barcelona and Reus) are situated on the sea coast and their climate is of the humid maritime type. Two other localities (Torelló and Castelltersol) are far from the sea coast and have a dry, continental type of climate. The fifth locality is Puigcerdá situated in the mountains (Pyrenees).

The total number of Pyroglyphidae was far lower in Puigcerdá (81 mites per 5 grams of dust) than in the other localities (340 to 1836 mites per 5 grams of dust). The relative number of *D. pteronyssinus*, compared with the other species varied considerably according to the locality. In the humid coastal area *D. pteronyssinus* represented more than 85% of the mite population while

in the two localities of the dry area the situation was completely reversed, the percentage of *D. pteronyssinus* dropped to a maximum of 18.3% while *D. farinae* increased considerably reaching 81% and 98.7% of the total pyroglyphid fauna. In Puigcerdá the percentage of both species dropped (29.6% of the total pyroglyphid population for *D. pteronyssinus* and only 12.3% for *D. farinae*) compared with *E. maynei* (58% of the total) (see table). Unfortunately the authors do not give the total number of mites they collected in these five localities and it is thus impossible to elucidate whether the increased percentage of *D. farinae* in the dry areas is simply a consequence of a drop in the number of *D. pteronyssinus* or if there is, in addition, an increase in the number of *D. farinae* (Table V).

8. INFLUENCE OF SEASON, ALTITUDE AND CLIMATE ON POPULATION FLUCTUATIONS OF HOUSE DUST MITES

Influence of season

The fluctuations in the number of *D. pteronyssinus* in house dust according to season (increasing in summer and decreasing in winter) depend mainly on the variations in the relative humidity of the indoor air (higher in summer than in winter), and this factor depends itself on the temperature of the outdoor air.

The amount of water vapour contained in the air (= absolute humidity) depends on the temperature. In winter the outdoor air is colder and contains less water vapour than in summer. When this cold air enters the living room and is heated to 20°C, the relative humidity of that air will drop abruptly, from about 90% to 40% without a modification in the amount of water vapour. In summer the relative humidities in the outdoor and indoor air are almost the same, i.e. between 70 and 80%, which corresponds precisely with the optimal requirements of *D. pteronyssinus* (Spieksma, 1967; Voorhorst *et al.* 1969).

Influence of altitude

Zuidema *et al.* (1970) have shown that there is a negative correlation between the number of mites in house dust and altitude. The drop in the number of mites is related to the low outdoor temperature causing a decrease of relative humidity indoors. The influence of altitude on house dust mites is therefore the same as that of winter in lower countries. Among the three most frequent pyroglyphid species *D. pteronyssinus* is the most susceptible to a lowering of relative humidity. Its numbers will therefore decrease more rapidly than those of *D. farinae* and *E. maynei*. Indeed, *E. maynei* seems to be better adapted to high altitude as shown by the observations of Portus and Gomez (1976) (see above).

Gomez *et al.* (1981) studied the pyroglyphid fauna of house dust from several villages of Catalonia, Spain, situated at different altitudes. At Reus (altitude 76 m) they collected 53,041 *D. pteronyssinus*, 1007 *D. farinae* and 191 *E. maynei*. In the houses of Puigcerdá (altitude 1202 m), these numbers were 795 *D. pteronyssinus*, 1074 *D. farinae* and 1696 *E. maynei*.

The drop in *D. pteronyssinus* in the mountain village of Puigcerdá is explained by the lowering of the indoor relative humidity in relation to the colder outdoor temperature. The maintenance of the populations of *D. farinae* at approximately the same levels in both localities, probably results from a combination of two factors : a lower relative humidity in the houses of Puigcerdá (favourable for this species, at least in comparison to the conditions in Reus), and a drop of the temperature outdoors and probably indoors in Puigcerdá (unfavourable for *D. farinae*). The increase in the populations of *E. maynei* in Puigcerdá is more difficult to explain. We do not think that the lowering of the relative humidity is the reason for this increase. It is well known that in all the humid sea coast areas of Europe (Scotland, England, Holland, Belgium), *E. maynei* is far more frequent than *D. farinae*. Moreover in dry and arid climates *E. maynei* is scarce or lacking. In Israël, Feldman-Muhsam *et al.* (1985) have shown that *E. maynei* is more abundant in the humid coastal plain than in the arid Eastern areas. The true reason for this increase of *E. maynei* in mountain areas is still unknown.

The lowering of temperature related to high altitude is less important in the tropics and this explains the presence of *D. pteronyssinus* at more than 3,000 m in Peru (Caceres and Fain, 1979).

Influence of climate

Waki and Matsumoto (1973) (cited by Dusbabek, 1975) have shown that a relative humidity of 50-60% and a temperature of 25-30°C are the optimal conditions for the development of *D. farinae*. A relative humidity of 76% was unfavourable and 42% was unsatisfactory. These conditions are different for *D. pteronyssinus*. For this species the optimal relative humidity is higher (70-80%) and the optimal temperature is slightly lower (25°C) (Spieksma, 1967).

TABLE VI: GEOGRAPHICAL DISTRIBUTION OF DOMESTIC PYROGLYPHIDAE

(Mattresses, dust, carpets, etc...) (Compiled by A. Fain and B. Hart)

Explanation of abbreviations

Symbols :

X = Present but prevalence not precised
+++ = Very frequent
++ = Frequent
\+ = Rare or very rare

Species :

D.pt. = *Dermatophagoides pteronyssinus*
D.f. = *Dermatophagoides farinae*
D.m. = *Dermatophagoides microceras*
D.e. = *Dermatophagoides evansi*
D.si. = *Dermatophagoides siboney*
D.n. = *Dermatophagoides neotropicalis*
E.m. = *Euroglyphus maynei*
G.l. = *Gymnoglyphus longior*
Hu.a. = *Hughesiella africana*
H.d. = *Hirstia domicola* (or *? H. chelidonis*)
M.i. = *Malayoglyphus intermedius*
M.c. = *Malayoglyphus carmelitus*
St.b. = *Sturnophagoides brasiliensis*

	D.pt.	D.f.	D.m.	D.e.	E.m.	G.l.	H.d.	M.c.	St.b.	References
EUROPE										
Belgium	+++	+	+	-	++	-	-	-	-	Fain (1965,1966b,1967a, 1988b) Gridelet & al. (1973)
Holland	+++	+	+	-	++	-	-	-	-	Fain (1965,1966b,1967a) Spieksma & al. (1967) Bronswijk (1973) Cunnington & al. (1987)
England	+++	+	+	-	++	-	-	-	-	Maunsell & al. (1968) Griffiths & al. (1971) Walshaw & al. (1987)
Scotland	+++	+	-	-	++	-	-	-	-	Sesay & al. (1972) Colloff (1987b)
Ireland	X	-	-	-	-	-	-	-	-	Spieksma (1967) Fain (1988b)
France										
South-East	+++	++	-	+	+ to ++	-	+	-	-	Penaud & al. (1972)
Grenoble	++	++	-	+	+ to ++	-	-	-	-	Lascaud (1976, 1978)
Languedoc-Roussillon	+++	+	-	-	+	-	-	-	-	Rousset (1971); Guy & al. (1972)
Strasbourg	+++	+ to ++	-	+	++	-	-	-	+	Araujo-Fontaine (1974) Araujo-Fontaine & al. (1973)
Spain (Catalonia)										
Barcelona	+++	++	+	-	++	-	+	+	-	Blasco & al. (1973 et 1975) Portus & al. (1976)
Torello et Castelltersol	+	+++	-	-	+	-	-	-	-	Portus & al. (1976)
Puigcerdà	+	+	-	-	++	-	-	-	-	Portus & al. (1976)
Portugal	+++	+	-	+	++	-	-	-	-	Pinhao & Gracio (1978) Fain (1988b)
Italy	+++	+	X	-	++	+	+	-	-	Fain (1965) Nannelli & al. (1983) Ottoboni & al. (1984)
Western Germany										
Hamburg	+++	+ to ++	-	-	+	-	-	-	-	Keil (1983) Keil & Rack (1985)
Heligoland	X	X	-	-	X	-	-	-	-	Bronswijk & al. (1975)
Eastern Germany	++	+	-	-	+++	-	-	-	-	Karg (1973)
Switzerland	+++	+	+	-	++	-	-	-	-	Zuidema & al. (1970) Mumcuoglu (1975; 1976)

	D.pt.	D.f.	D.m.	D.e.	E.m.	G.l.	H.d.	M.c.	St.b.	References
EUROPE (continued)										
Denmark	+++	+ to ++	-	-	+	-	-	-	-	Haarlov & al. (1970)
Norway	X	-	-	-	-	-	-	-	-	Spieksma (1967)
Finland										
Eastern Region	++	+++	-	-	+	-	-	-	-	Stenius & al. (1974)
Helsinki	+++	++	-	-	++	-	-	-	-	Spieksma (1967) Stenius & al. (1972)
Bulgaria										
North-East	+++	++	-	-	++ to +++	+	-	-	-	Todorov (1979)
Rumania	+++	-	-	-	-	-	-	-	-	Popescu & al. (1975)
Hungary	++ to +++	+ to +++	-	-	+ to ++	-	++	-	-	Halmai (1980, 1984)
Czechoslovakia										
Urban Area	+++	++	-	-	+	-	-	-	-	Samsinak & al. (1972, 1978) Vobrazkova & al. (1979) Dusbabek (1979)
Rural Area	++	+	-	-	+++	-	+	-	-	Vobrazkova & al. (1979)
U.S.S.R.										
Western Region	+++	+	-	+	-	+	++	-	-	Bogdanov (1864) Dubinina & Pletiev (1978)
Eastern Region	+++	+	-	+	+	+	+	-	-	Tareev & Dubinina (1985)

	D.pt.	D.f.	D.m.	D.e.	E.m.	G.l.	H.d.	References
NORTH AMERICA								
U.S.A.								
California	+ to +++	+ to ++	+	+	-	-	-	Furumizo & Mulla (1971); Furumizo (1975)
Other regions	+	++ to +++	+	-	-	-	+	Baker & al. (1956) ; Larson & al. (1969) Wharton (1970, 1976) ; Griffiths & al. (1971) Fain (1988b)
Canada	+	++	-	-	-	-	-	Sinha & al. (1970)

	D.pt.	D.f.	D.si.	D.n.	E.m.	G.l.	M.i.	M.c.	H.d.	Hu.a.	St.b.	References
SOUTH AMERICA												
Brazil												
Minas Gerais	+	+++	-	++	+	-	-	-	-	-	-	Greco & al. (1974) Moreira (1975; 1980) Rosa & al. (1979) Galvao & Neide (1986)
Other regions	+++	+	-	++	+	-	-	-	-	+	++	Fain (1966b) Amaral (1968) Rosa & al. (1979) Galvao & al. (1986)
Surinam	+++	-	-	++	-	-	+	-	+	-	-	Bronswijk, van (1972a) Fain & al. (1974)
Argentina	X	X	-	-	-	-	-	-	-	-	-	Mauri & al. (1980)
Columbia	+++	+ to ++	-	-	+	-	+	+	+	+	-	Charlet & al. (1977a & 1977b)

	D.pt.	D.f.	D.si.	D.n.	E.m.	G.l.	M.i.	M.c.	H.d.	Hu.a.	St.b.	References
SOUTH AMERICA (continued)												
Chile	++	-	-	-	+	-	-	-	-	-	-	Casanueva & al. (1985)
Peru	+++	-	-	-	+	+	-	-	-	-	-	Cacères & Fain (1979)
Cuba	+++	-	++	-	-	-	+	-	++	-	-	Dusbabek & al. (1982) Cuervo & al. (1983)
Barbados	+++	+	-	-	-	-	-	-	-	-	-	Pearson & al. (1973)
Ecuador	X	X	-	-	-	-	-	-	-	-	-	Lopez-Lara (1977)

	D.pt.	D.f.	D.e.	D.n.	E.m.	M.i.	M.c.	H.d.	St.b.	References
ASIA										
Israël										
East	++	++	-	-	+	-	-	-	-	Feldham-Muhsam & al. (1985)
West	+++	+	-	-	++	-	+	-	-	Spieksma (1973) Feldham-Muhsam & al. (1985)
Turkey	X	X	-	-	-	-	-	-	-	Griffiths & al. (1971) Fain (1988b)
Iraq	X	-	-	-	-	-	-	-	-	Bronswijk & al. (1971)
Syria	-	X	-	-	-	-	-	-	-	Fain (1988b)
Iran	+++	++	+	-	+	-	-	-	-	Spieksma (1967) Amoli & al. (1977) Sepasgosarian & al. (1979)
Pakistan	X	-	-	-	-	-	-	-	-	Spieksma (1967)
India	+++	+ to ++	-	+	+ to ++	+	+	+	-	Fain (1966a) Griffiths & al. (1971) Rao & al. (1973, 1977) ChannaBasavanna & al (1984)
Birmania	-	X	-	-	-	-	-	-	-	Griffiths & al. (1971)
Thaïland	+++	+++	-	-	-	++	-	+	-	Wongsathuaythong & al. (1972) Boonkong & al. (1987)
Malaysia	++	+	-	-	+	+	-	+	++	Griffiths & al. (1971) Fain (1988b)
Singapore	+	+	-	-	-	+	-	+	++	Fain, Cunnington, Spieksma (1969) Griffiths & al. (1971)
Indonesia	++	+	-	-	-	++	-	+	+	Fain, Cunnington, Spieksma (1969) Fain & Lowry (1974)
Brunei	+++	+	-	-	-	-	-	++	-	Woodcock & al. (1980)
China	+++	+	-	-	+	-	-	++	-	Wen & al. (1988)
Taïwan	+++	++	-	-	+	+	-	+	-	Oshima (1970);Fain & al. (1974)
Korea	+	++	-	-	-	-	-	-	-	Cho & al. (1977)
Japan	+++	+ to ++	-	-	+	+	-	+ to ++	-	Oshima (1967, 1968 , 1970) Miyamoto & al. (1968) Fain, Oshima & al. (1974) Ishii & al. (1979)
Papua	+++	+	-	-	++	-	-	-	-	Anderson & al. (1974)

	D.pt.	D.f.	D.e.	D.n.	E.m.	M.i.	M.c.	H.d.	St.b.	References
AUSTRALIA AND POLYNESIA										
Australia	++	X	-	-	X	-	-	-	-	Spieksma (1967) Domrow (1970)
New-Zealand	+++	-	-	-	-	-	-	-	-	Cornere (1972)
Tahiti	+++	X	-	-	-	X	-	-	-	Fain (1988b)
Hawaii	+++	+	-	-	-	-	-	-	-	Spieksma (1967) Sharp & al. (1970)

	D.pt.	D.f.	D.m.	E.m.	Hu.a.	M.i.	H.d.	References
AFRICA								
Algeria								
Algiers	+++	+	-	++	-	-	-	Abed & al. (1983)
Morocco	X	-	-	-	-	-	-	Fain (1988b)
Egypt	++	+++	-	-	-	-	-	Griffiths & al. (1971) ; Frankland & al. (1971) Gamal-Eddin & al. (1982) Feldham-Muhsam & al. (1985)
Madagascar	-	-	-	-	++	-	-	Fain (1988b)
South Africa	+++	+	+	+ to ++	-	+	+	Ordman (1971) ; Fain & Lowry (1974) Fain (1988b)
Zaïre	+++	-	-	-	-	-	-	Fain (1967, 1988b)
Rwanda	+++	-	-	-	-	-	-	Fain (1988b)
Burundi	+++	-	-	-	-	-	-	Fain (1988b)
Angola	+++	-	-	-	-	-	-	Fain & Caceres (1973) ; Fain (1988b)
Kenya	X	-	-	-	-	-	-	Rees & al. (1974)
Nigeria	-	-	-	-	-	+	-	Fain (1988b)
Tristan da Cunha	X	-	-	X	-	-	-	Fain (1988b)

TABLE VII: HABITATS OF THE PYROGLYPHIDAE

Species	Houses (Bedding, carpets, clothing, floors))	Stored products Barn dust	Birds (on birds or in nests)	Other habitats	Countries
DERMATOPHAGOIDINAE					
Dermatophagoides					
D. pteronyssinus	+	? +	? +	+	Cosmopolitan
D. evansi	+	-	+	+	U.S.A., France, Portugal, Iran, U.R.S.S., Hawaii
D. farinae	+	+	-	+	Cosmopolitan
D. microceras	+	-	-	+	Europe, U.S.A., South Africa
D. siboney	+	-	-	-	Cuba
D. neotropicalis	+	-	-	-	Surinam, Brazil, India
D. rwandae	-	-	+	-	Rwanda
D. aureliani	-	-	+	-	Rwanda
D. sclerovestibulatus	-	-	+	-	South Africa
D. anisopoda	-	-	+	-	Cameroon
D. simplex	-	-	+	-	Brazil
Hirstia					
H. domicola	+	-	-	-	Cosmopolitan
H. chelidonis	-	-	+	-	England
(? H. passericola)	-	-	+	-	Europe, Japan
Malayoglyphus					
M. intermedius	+	-	-	-	Far East, Tahiti, South Africa, South America, Nigeria, Cuba, India
M. carmelitus	+	-	-	-	Israël, Italy, Spain, India, Columbia
Sturnophagoides					
S. bakeri	-	-	+	-	U.S.A.
S. brasiliensis	+	-	-	-	Brazil, Far East, France
S. petrochelidonis	-	-	+	-	Cuba
PYROGLYPHINAE					
Pyroglyphus					
P. morlani	-	-	-	+	U.S.A.
Hughesiella					
H. africana	+	+	+	+	Angola, Brazil, Columbia, Israël, Madagascar
Bontiella					
B. bouilloni	-	-	+	+	Zaïre, Rwanda
Euroglyphus					
E. maynei	+	+	-	+	Cosmopolitan (except North America, Cuba and Central Africa)
Gymnoglyphus					
G. longior	+	+	+	-	Europe, U.S.A., Canada, Peru
G. osu	-	+	-	-	U.S.A.
Weelawadjia					
W. australis	-	-	+	+	Western Australia

TABLE VII: HABITATS OF THE PYROGLYPHIDAE (continued)

Species	Houses (Bedding, carpets, clothing, floors)	Stored products Barn dust	Birds (on birds or in nests)	Other habitats	Countries
PYROGLYPHINAE (contd)					
Campephilocoptes					
C. atyeoi	-	-	+	-	Venezuela
C. paraguayensis	-	-	+	-	Paraguay
GUATEMALICHINAE					
Guatemalichus					
G. bananae	-	-	-	+	Guatemala
G. tachornis	-	-	+	-	Cuba
Fainoglyphus					
F. magnasternus	-	-	+	-	Ecuador
Pottocola					
P. scutata	-	-	+	+	Zaïre
P. ventriscutata	-	-	+	-	Zaïre
P. longipilis	-	-	+	-	Togo
P. lybius	-	-	+	-	Togo
ONYCHALGINAE					
Kivuicola					
K. kivuana	-	-	-	+	Zaïre
Onychalges					
O. longitarsus	-	-	+	-	Congo
O. asaphospatus	-	-	+	-	Cameroon
O. odonturus	-	-	+	-	Cameroon
O. pachyspathus	-	-	+	-	Cameroon
O. schizurus	-	-	+	-	Cameroon
O. spinitarsis	-	-	+	-	Zaïre
O. nidicola	-	-	+	-	Brazil
Paramealia					
P. ovata	-	-	+	-	Cameroon
PARALGOPSINAE					
Paralgopsis					
P. paradoxus	-	-	+	-	Columbia
P. ctenodontus	-	-	+	-	Brazil

These differences in requirements for microclimate can explain the different geographical distribution of both species. In dry continental climates (e.g. central region of the U.S.A., Central Europe, Egypt etc.) *D. farinae* is abundant and generally as frequent or more frequent than *D. pteronyssinus*, exceptionally the latter may disappear completely (certain areas of U.S.A.).

On the contrary in humid, maritime climates as in coastal areas (e.g. The Netherlands, Great Britain, Belgium, coastal areas of Spain etc.) the situation is reversed and *D. pteronyssinus* is the predominant species whilst *D. farinae* is very rare.

• II.FAMILY ACARIDAE AND GLYCYPHAGIDAE

Barn allergy is a well known syndrome observed in farmers and related to the inhalation of barn dust. It is characterized by conjunctivitis, rhinitis and bronchial asthma.

It has now been proven that this type of allergy is caused not by the dust itself but by allergens originating from various storage mites infesting barns used to store hay or grain. These mites belong to the families Acaridae and Glycyphagidae.

The most frequent species found in barn dust are *Acarus siro* L, 1758, *Tyrophagus putrescentiae* (Schrank, 1781) and *T. longior* (Gervais, 1844) in the Acaridae, and *Glycyphagus domesticus* (De Geer, 1778) and *Lepidoglyphus destructor* (Schrank, 1781) in the Glycyphagidae. These mites are frequently found infesting stored food (grain, flour, cheese, dried fruit, ham etc.) and they are of great economic importance.

Cuthbert *et al.* (1979) and Wraith *et al.* (1979) have shown that farm workers handling hay and grain and suffering from barn allergy present skin and serological (RAST) reactions against extracts of these mites.

A key to the most important species of storage mites is given below.

KEY TO THE SPECIES OF ACARIDAE AND GLYCYPHAGIDAE CAUSING BRONCHIAL ASTHMA IN MAN

1. Tarsi I with both solenidia ω1 and ω3 in apical situation. Chaetotaxy reduced : tibiae I-II with one seta ; only one or two pairs of anal setae in both sexes. Sexual suckers vestigial, in the shape of small chitinous rings.... .....PYROGLYPHIDAE

Tarsi I with ω3 apical and ω1 basal. Chaetotaxy slightly or not reduced: tibiae I-II with 2 setae; with 3 pairs of anal setae in male and 5-6 pairs in female. Sexual suckers normal.....2

2. Cuticle smooth and shiny. Body setae smooth or with few and short pectinations. Tarsi not especially long and narrow. Male with one pair of adanal suckers and two suckers on each of the tarsi IV.....ACARIDAE 3

Cuticle densely covered with very thin projections and not shiny. Body setae strongly pectinate. Tarsi very long and narrow, especially tarsi IV. Male without adanal and tarsal suckers .....GLYCYPHAGIDAE 5

3. Both solenidia of genua I slightly unequal (ratio 1 : 1.5). Setae *sc i* distinctly longer than *sc e* ; the *ve* pectinate, longer than genu I and situated laterally, slightly behind *vi*. Legs I of male normal, femur without spur ....*Tyrophagus* 4

Both solenidia of genua I strongly unequal (ratio 1 : 4 or 1 : 3). Setae *sc* i only slightly longer than *sc e* ; the *ve* thin and smooth, distinctly shorter than genu I and situated laterally, distinctly behind the level of *vi*. Male with legs I expanded, femur I with a spur (Fig. 63-65).... .....*Acarus siro*

4. Setae *d2* at most twice as long as *d1*. Solenidion ω1 long, slender, tapering distally, the end being either pointed or slightly expanded. No eye spots on propodonotal shield. Setae *s cx* not expanded and with short pectinations. Male : penis long, slender, tapering, only slightly curved and shaped like the spout of a teapot. Lateral sclerites of penis turned inwards (Hughes, 1976) ....*Tyrophagus longiör*

Setae *d2* more than twice as long as *d1*. Solenidion ω1 slightly expanded distally. propodonotal shield with pigmented eyespots. Setae *s cx* flattened with an expanded base bearing stiff lateral projections. Male : penis short, curved twice (S-shaped), shaped like a coffee pot spout (Fig. 62-64). Lateral sclerites supporting the penis turned outwards (Hughes, 1976)..... .....*Tyrophagus putrescentiae*

5. All tarsi are enveloped ventrally by a pectinate scale almost as long as the tarsi and inserted basally. Crista metopica absent. Femur I with a thin smooth seta (Fig. 68-70) .....*Lepidoglyphus destructor*

Tarsi without such scales. Crista metopica present. Femur I with a thick pectinate seta (Fig. 66-68) ....*Glycyphagus domesticus.*

B. MITES CAUSING DERMATITIS OR MANGE

Dermatitis and scabies (or mange), are two different aspects of pruriginous irritation of the skin related to the presence of mites on the skin of man. In dermatitis irritation of the skin is caused by repeated contact with living or dead mites (allergic contact dermatitis) or by the toxic action of saliva injected into the skin by biting or blood sucking mites. In both cases the mites are accidental and temporary invaders and they are not able to permanently colonize or reproduce on the human skin. In scabies (or mange) however, the mite (*Sarcoptes scabiei*) colonizes the corneus layer of the skin. It is a strict parasite and is unable to live in other conditions. In man only one species is able to produce mange, whilst many species may cause dermatitis (Fain, 1984).

1. DERMATITIS ASSIGNED TO *DERMATOPHAGOIDES* SP.

In 1864, Bogdanov described *Dermatophagoides scheremetewskyi* from the skin of several patients suffering from sarcoptic mange or from herpes farinosus (one case). He suggested that, at least in the latter case, this mite was implicated in the etiology of the disease: "L'herpes farinosus peut avoir chez l'homme sa cause dans la présence d'un acarien qui peut être le mâle de *Dermatophagoides*" (Bogdanov, 1864, p. 345).

Traver (1951), in an "auto-observation" expressed the opinion that a chronic dermatitis of the scalp from which she suffered for about 10 years was caused by *Dermatophagoides scheremetewskyi*. During this time she collected from her hair various arthropods (Hymenoptera, Coleoptera, Diptera, Spiders, Oribates, Chiggers) and also a few specimens (about 20) of *Dermatophagoides*. These specimens were identified by E. Baker as *D. scheremetewskyi*. We were able to examine these specimens and found that they actually belong to two species, *D. pteronyssinus* and *D. farinae*. It seems unlikely that these mites were the cause of the scalp dermatitis of Miss Traver. Due to the great frequency and abundance of these mites in house dust and in bedding it is not surprising to find some of these mites in the hair.

Dubinin *et al.* (1956) reported similar cases from the U.S.S.R. They found *D. scheremetewskyi* on the skin, mainly on the head, of patients suffering from seborrheal eczema (7 patients infected among 8 examined) and chronic diffused neurodermatitis (mites were found on 2 out of 6 patients examined).

Probably in all of these cases the mites were simply accidental contaminants. It is also possible that they had been attracted by the large amount of skin scales produced in these skin diseases (Fain, 1969a, 1988b).

2. CONTACT DERMATITIS CAUSED BY STORAGE MITES

Repeated contact with food infested with storage mites, mainly of the families Acaridae and Glycyphagidae, may induce an allergic contact dermatitis in man. It consists of a pruriginous erythema appearing at the sites in contact with the mites. Papules, vesicles or pustules may appear. In some cases the lesions resemble eczema. These skin reactions are generally considered as occupational acarine dermatitis. The most frequent are grocer's itch caused by *Glycyphagus domesticus* and *Tyrophagus putrescentiae* ; baker's itch and cheese-mite dermatitis caused by *Acarus siro* ; copra itch caused by *Tyrophagus putrescentiae* and *Cosmoglyphus laarmani* ; dried-fruit dermatitis caused by *Carpoglyphus lactis* (Baker *et al.*, 1956; Fain, 1984).

3. CONTACT DERMATITIS CAUSED BY *CHEYLETIELLA* SPP.

The genus *Cheyletiella* includes three species which cause contact dermatitis in man. The most important is *Ch. yasguri* Smiley (Fig. 71), which causes mange in dogs. Contact with an infected dog may cause development of an allergic dermatitis in man, which can last for months or years if the true origin of the itch is not recognised. Diagnosis is often difficult because the mites do not attach to the human skin and are generally not found on man ; it is essentially based on the discovery of the mites on dogs. The treatment of dogs with an acaricide results in a prompt cure of the patient (Fain *et al.*, 1982).

4. OTHER TYPES OF DERMATITIS CAUSED BY MITES INJECTING TOXIC SALIVA

Several groups of mites may attack man and attach temporarily to the skin for sucking blood or tissue

fluids. Prior to sucking they inject their toxic saliva which may cause local or general irritation of the skin, resembling contact dermatitis. It is possible that in some cases allergic phenomena also occur. The most important are :

A. Families Dermanyssidae and Macronyssidae (Mesostigmata) :

Dermanyssus gallinae : the "chicken mite". Cosmopolitan

Allodermanyssus sanguineus : the "house mouse mite". Also cosmopolitan

Ornithonyssus bursa : the "tropical fowl mite"

Ornithonyssus bacoti : the "tropical rat mite"

B. Ticks : they attach to skin for several days causing local irritation.

C. Larvae of Trombiculidae (Chiggers) : About a dozen species are known to attack man. They attach to the skin and feed upon the host tissues which they partly digest with their saliva. They remain fixed for several days and then drop off. They cause severe seasonal dermatitis in man.

D. *Pyemotes* spp. (Pyemotidae). These mites are also called straw, hay or grain itch mites. Some species feed on larvae of insects which attack grain and seeds. Persons in contact with grains or sleeping in straw may be attacked by these mites. They may cause a severe dermatitis.

5. SARCOPTIC MANGE

Sarcoptic mange is a cosmopolitan chronic disease of skin affecting man and animals (mammals) and caused by *Sarcoptes scabiei* (L.). It consists of superficial burrows produced by the mites and a resultant violent itching. The scratching is accompanied by scaling, thickening of the skin and secondary infection. The pruritus is mainly caused by allergy (Mellanby, 1944).

The genus *Sarcoptes* includes only one species, *S. scabiei* (L.) infecting both man and animals (Fain, 1968 and 1978). (Fig. 72-74).

ACKNOWLEDGEMENTS

I wish to thank all my colleagues for their help in providing material and information about the geographical distribution of the Pyroglyphidae. I am especially grateful to Professor Y. Coineau, director of Acarologia, who allowed me to reproduce in this book some of my drawings published in Acarologia from 1966 to 1974.

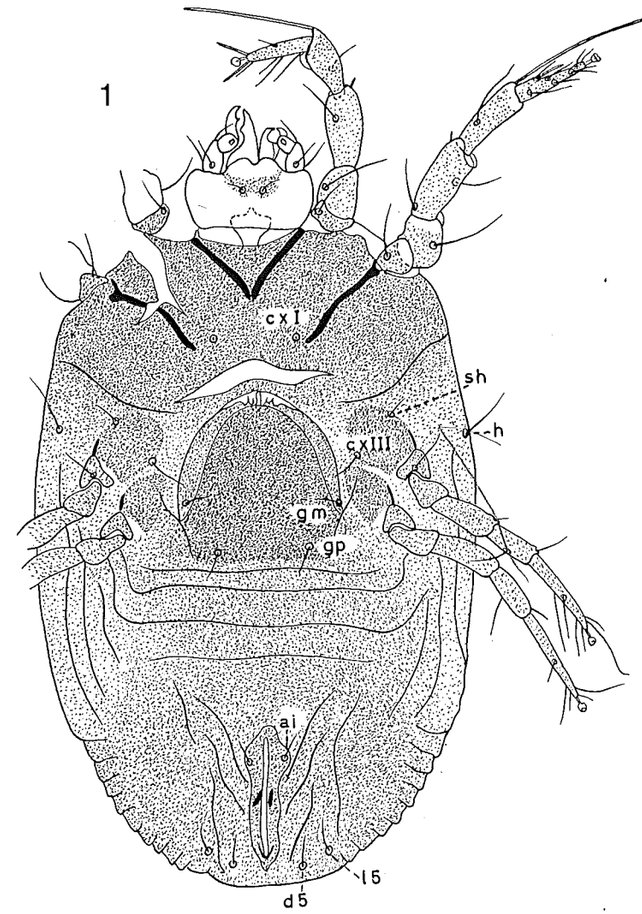


Fig. 1 *Pyroglyphus morlani* Cunliffe : Female in ventral view

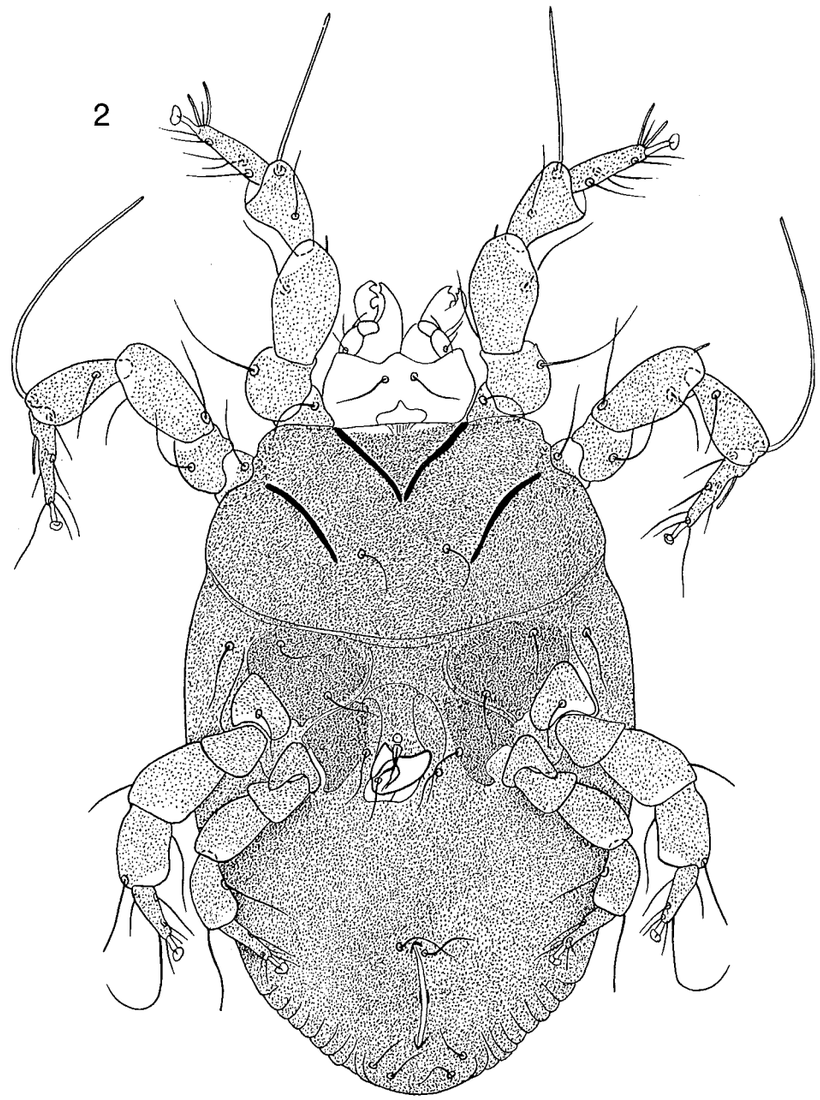


Fig. 2 *Pyroglyphus morlani* Cunliffe : Male in ventral view

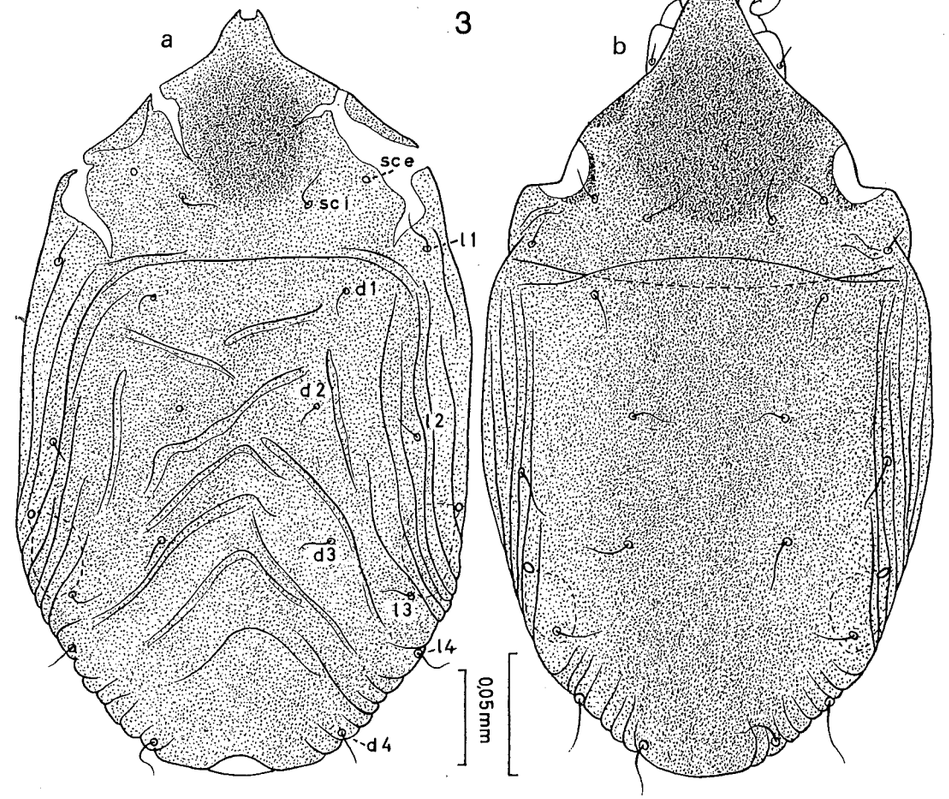


Fig. 3 *Pyroglyphus morlani* Cunliffe : Female (a) and male (b) in dorsal view

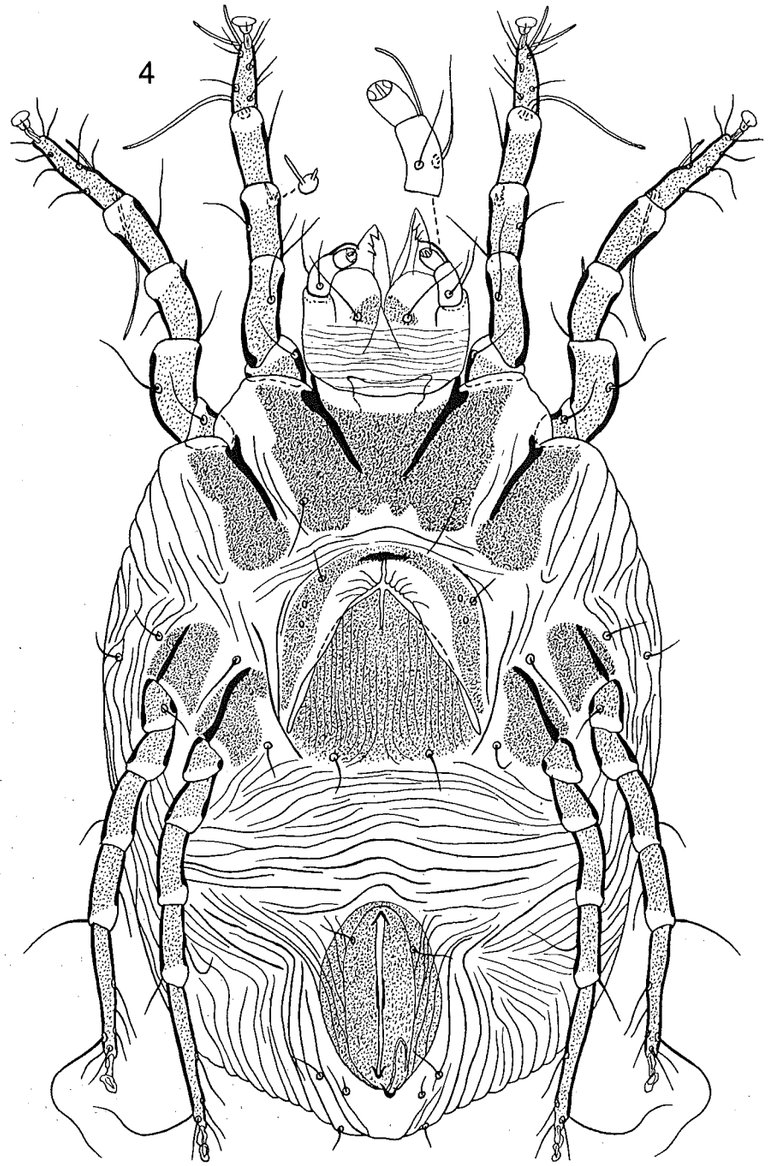


Fig. 4 *Hughesiella africana* (Hughes) : Female in ventral view

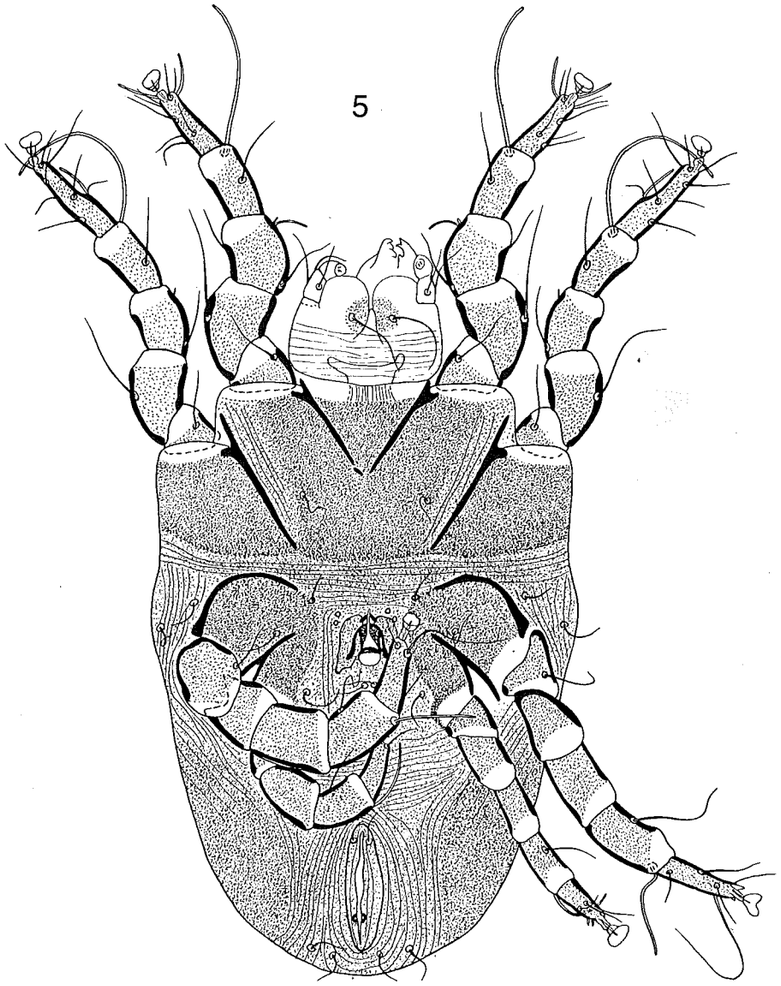


Fig. 5 *Hughesiella africana* (Hughes) : Male in ventral view

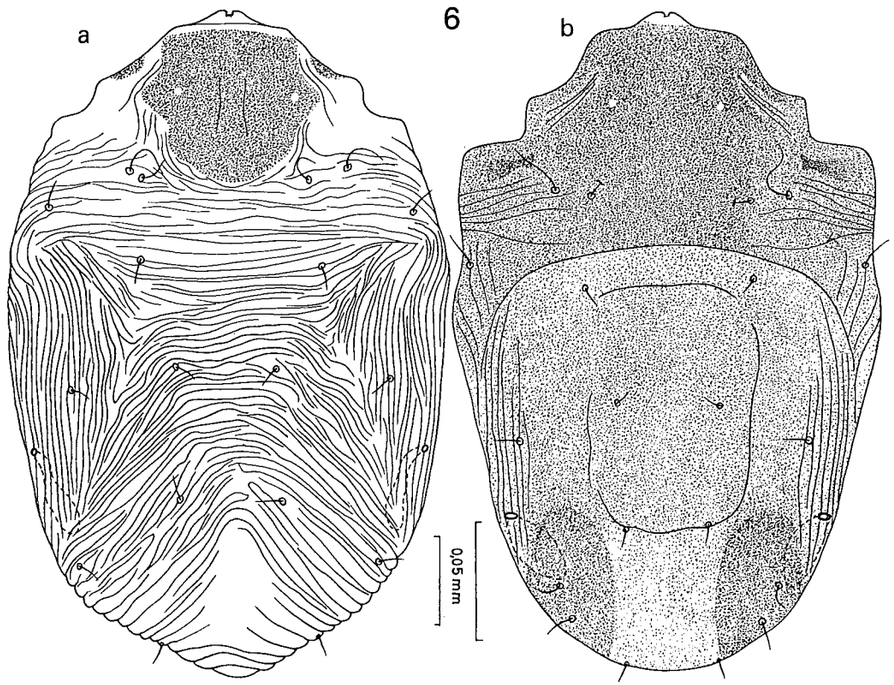


Fig. 6 *Hughesiella africana* (Hughes) : Female (a) and male (b) in dorsal view

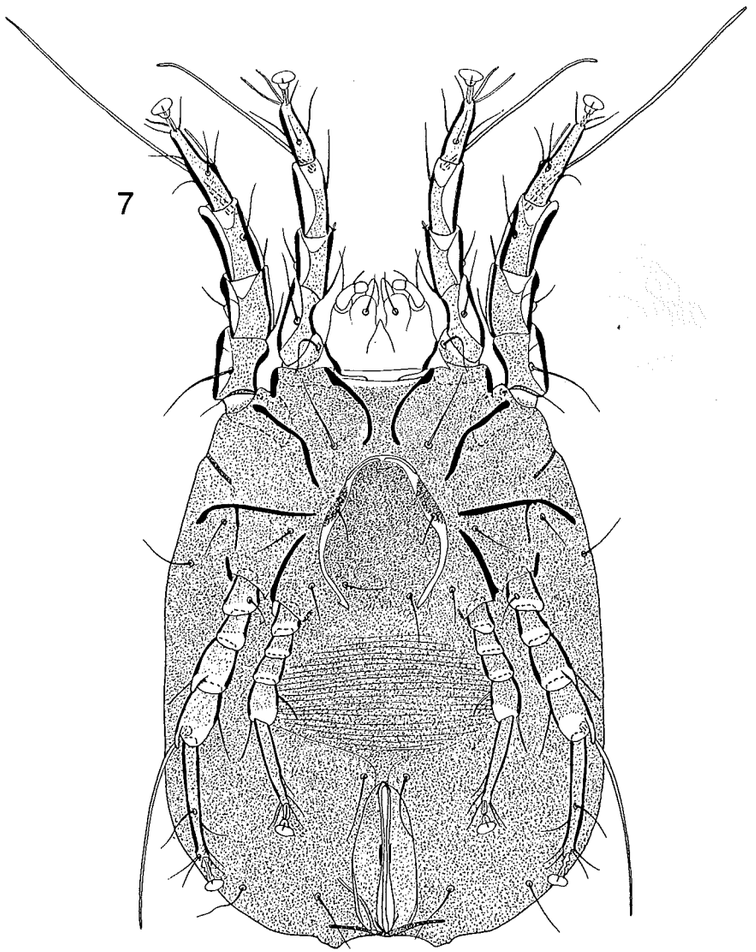


Fig. 7 *Bontiella bouilloni* Fain : Female in ventral view

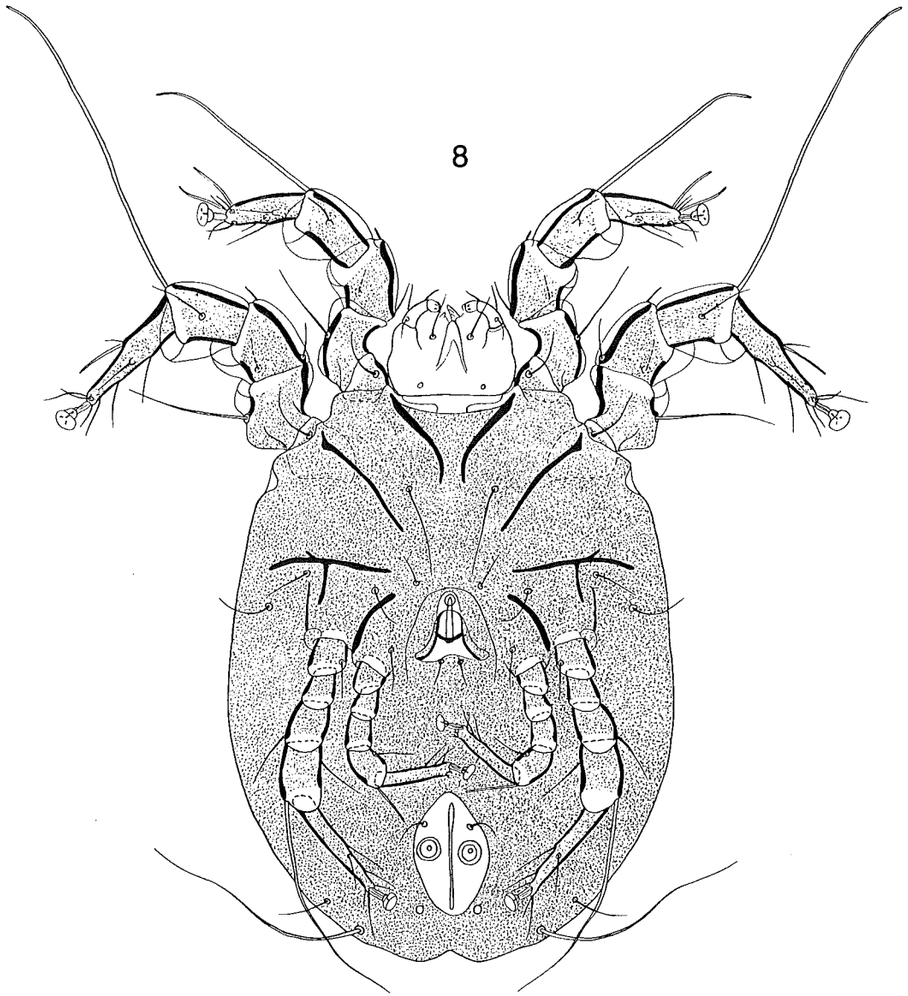


Fig. 8 *Bontiella bouilloni* Fain : Male in ventral view

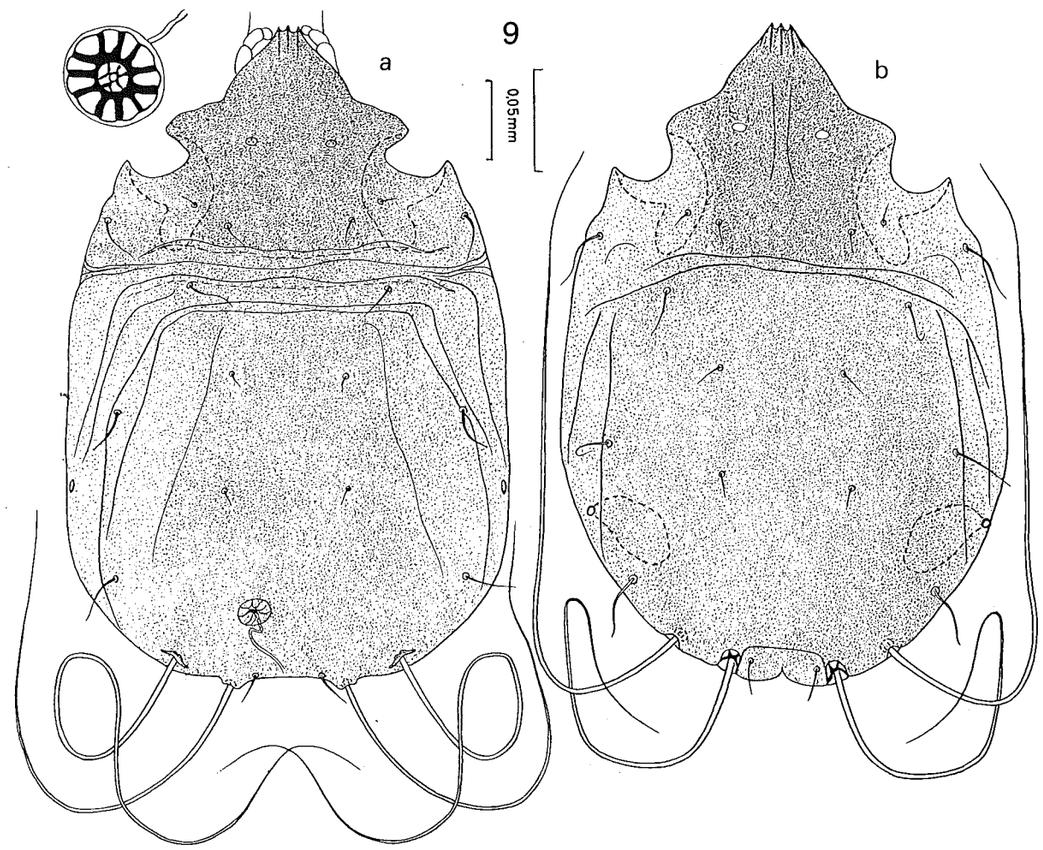


Fig. 9 *Bontiella bouilloni* Fain : Female (a)and male (b) in dorsal view

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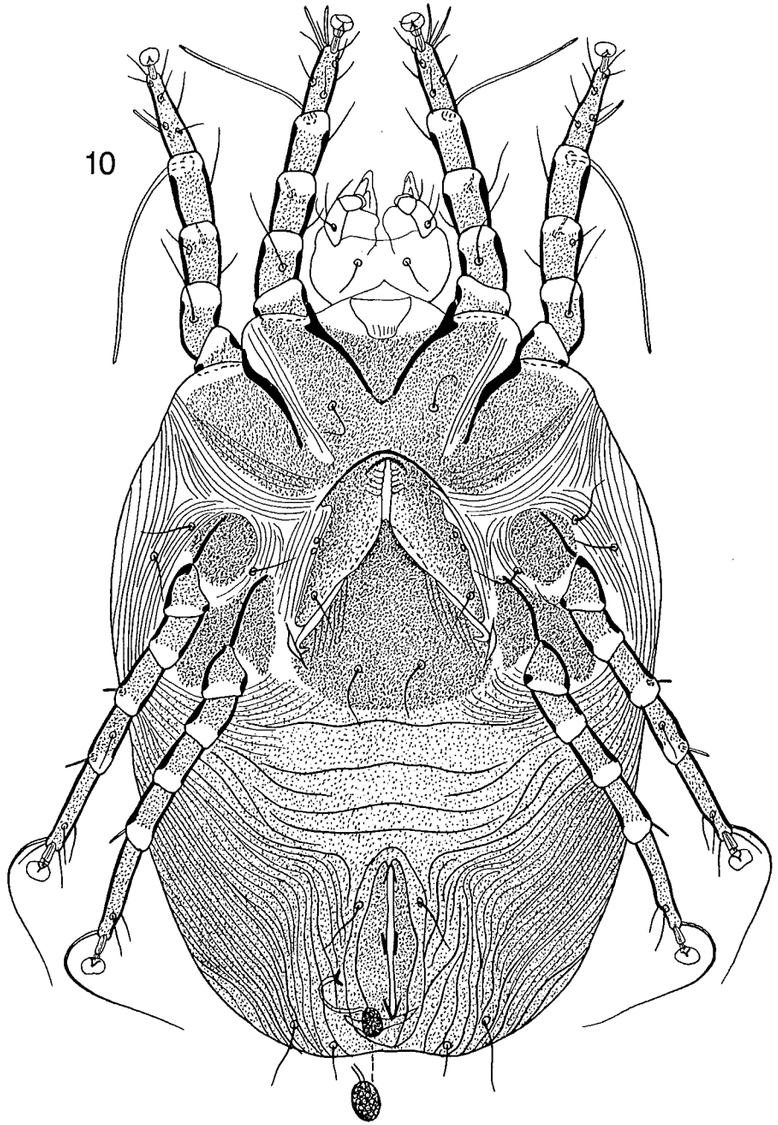

Fig. 10 *Euroglyphus maynei* (Cooreman) : Female in ventral view

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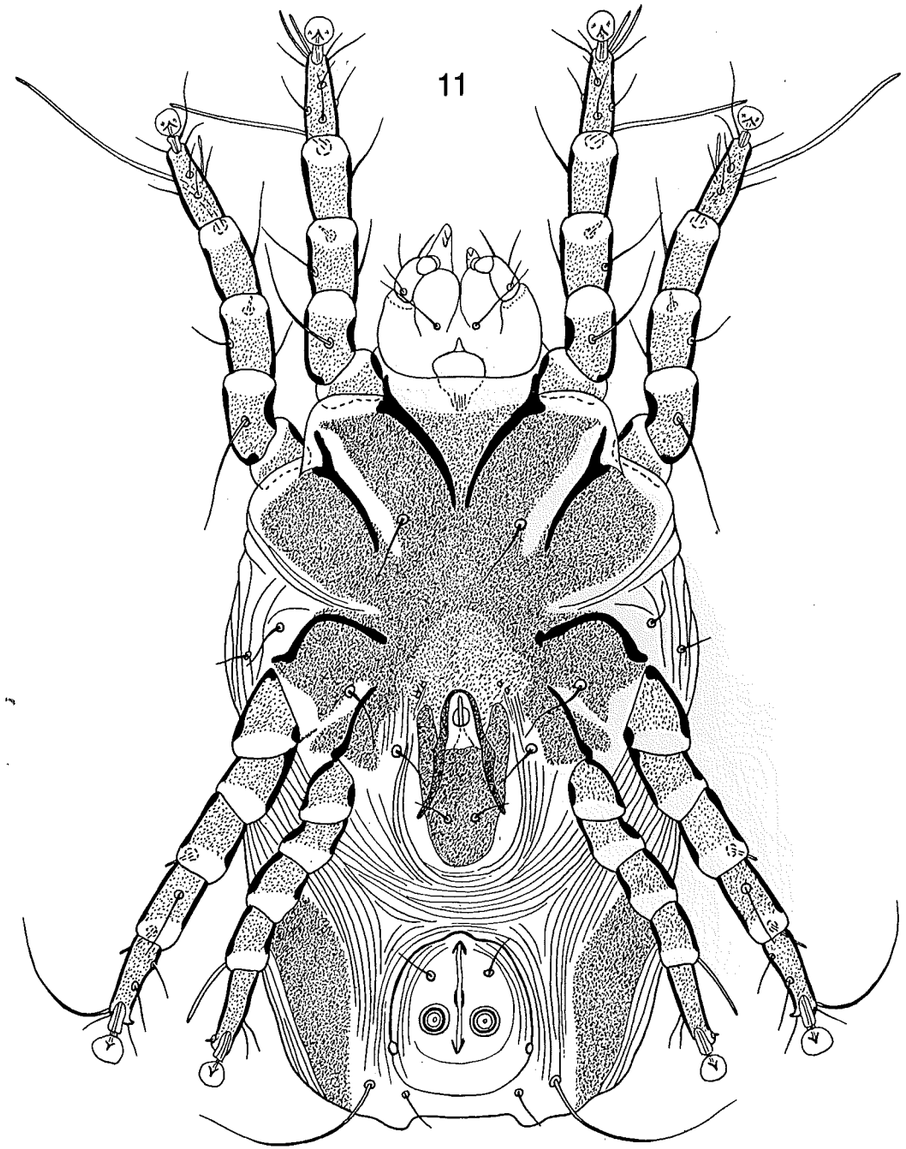

Fig. 11 *Euroglyphus maynei* (Cooreman) : Male in ventral view

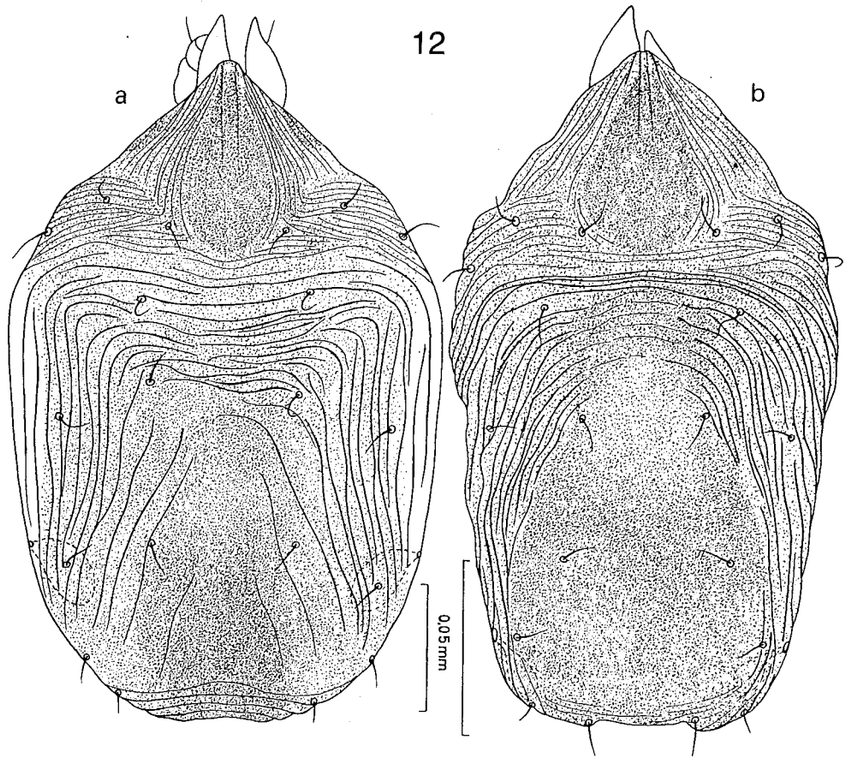

Fig. 12 *Euroglyphus maynei* (Cooreman) : Female (a) and male (b) in dorsal view

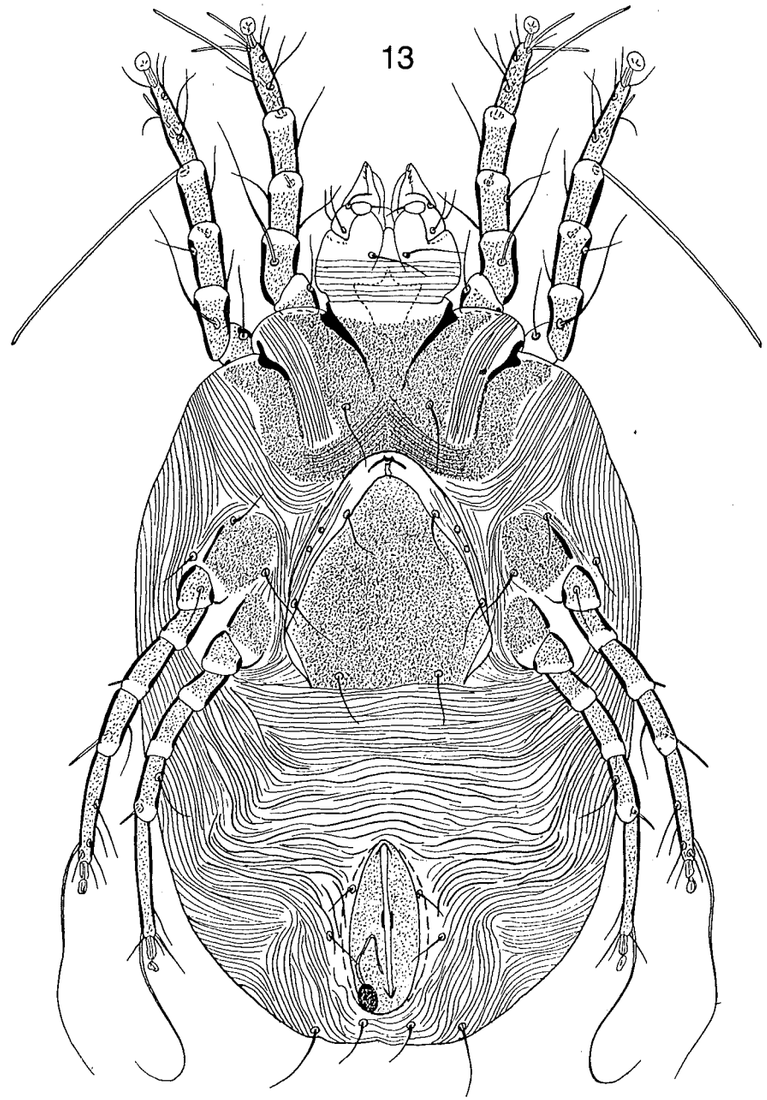

Fig. 13 *Gymnoglyphus longior* (Trouessart) : Female in ventral view

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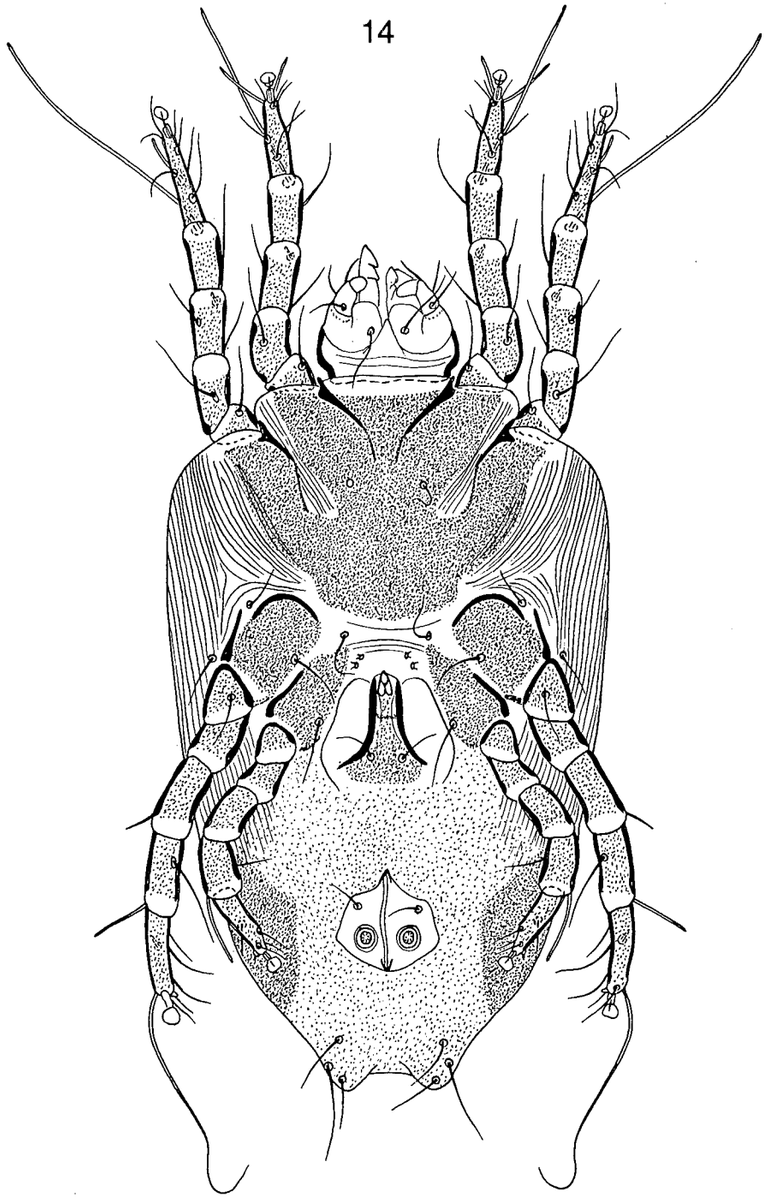

Fig. 14 *Gymnoglyphus longior* (Trouessart) : Male in ventral view

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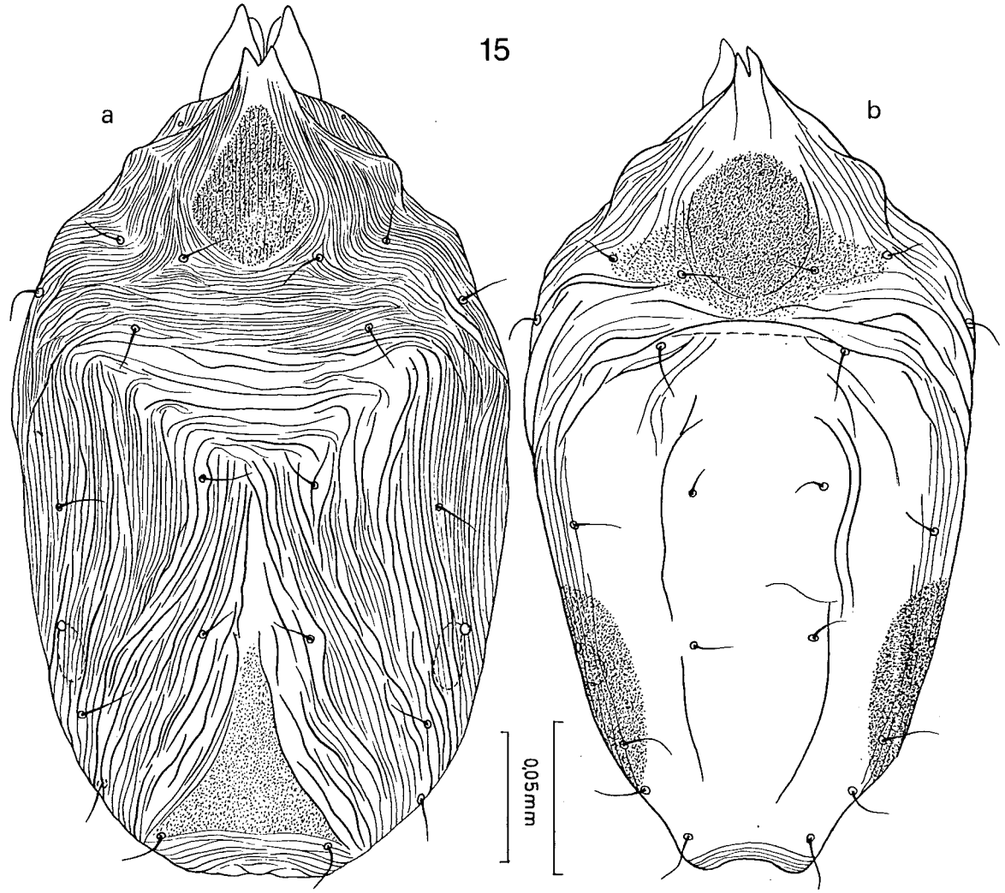

Fig. 15 *Gymnoglyphus longior* (Trouessart) : Female (a) and male (b) in dorsal view

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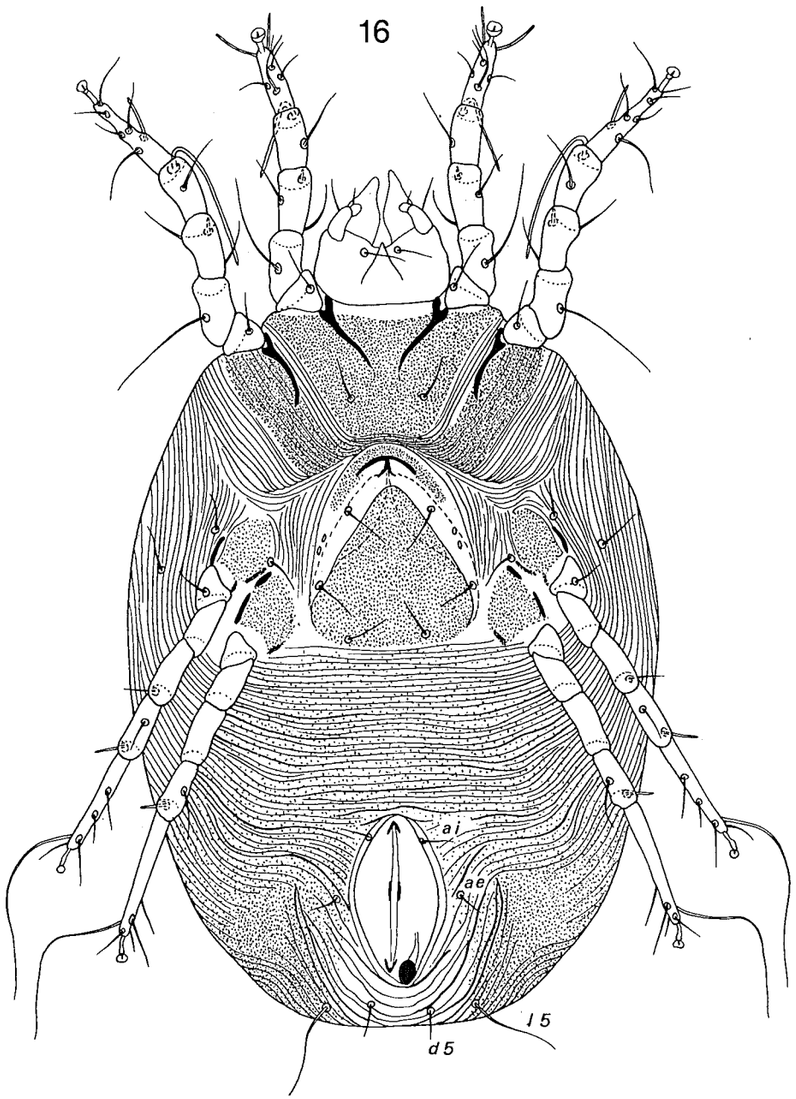

Fig. 16 *Gymnoglyphus osu* Fain and Johnston : Female in ventral view

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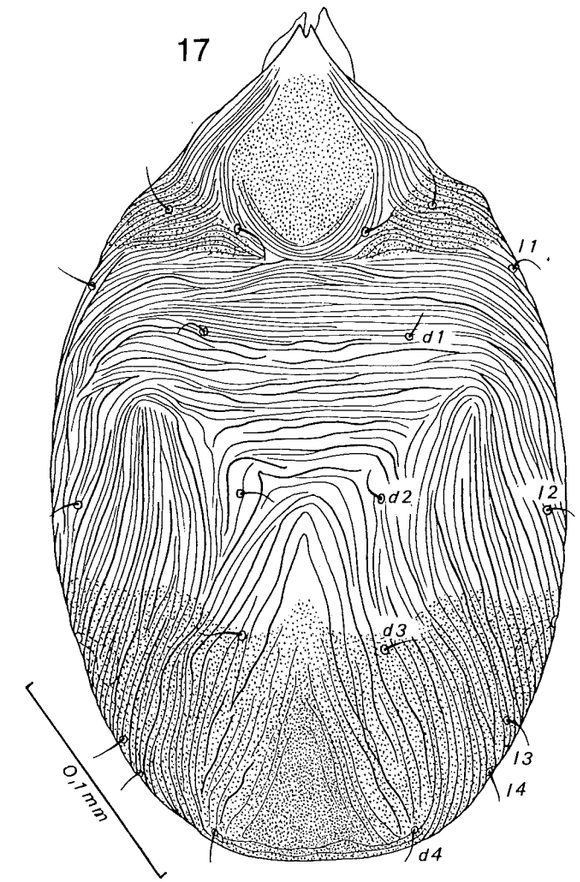

Fig. 17 *Gymnoglyphus osu* Fain and Johnston : Female in dorsal view

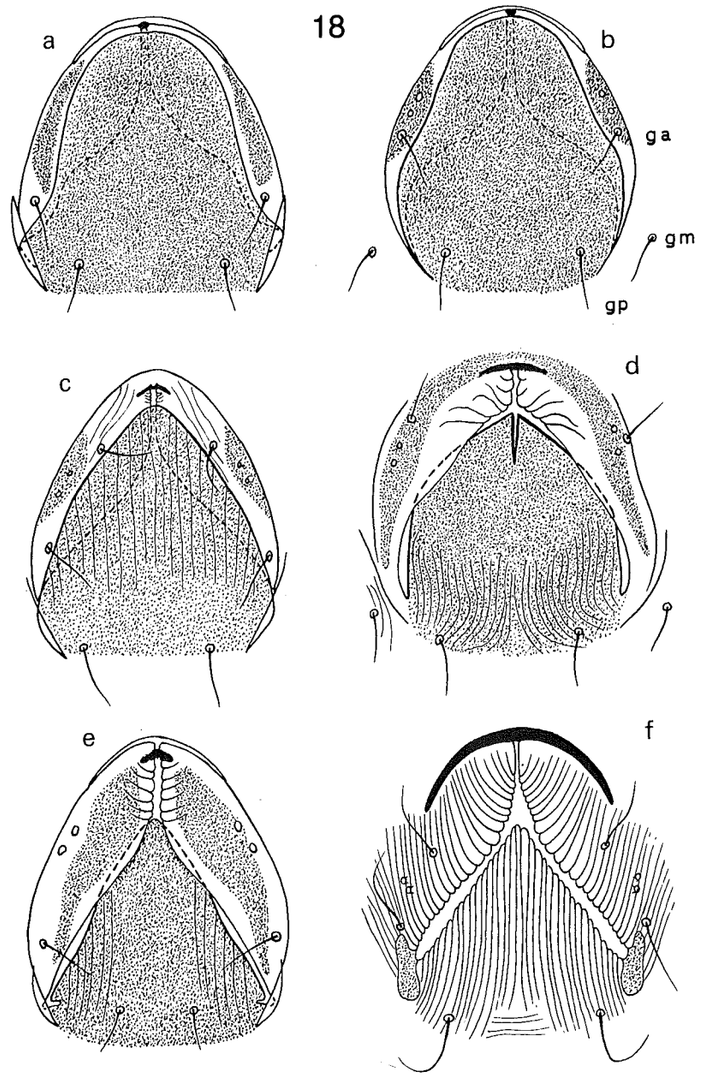

Fig. 18 Vulva in: *Pyroglyphus morlani* Cunliffe (a) ; *Bontiella bouilloni* Fain (b) ; *Gymnoglyphus longior* (Trouessart) (c) ; *Hughesiella africana* (Hughes) (d) ; *Euroglyphus maynei* (Cooreman) (e) *Dermatophagoides pteronyssinus* (Trouessart) (f)

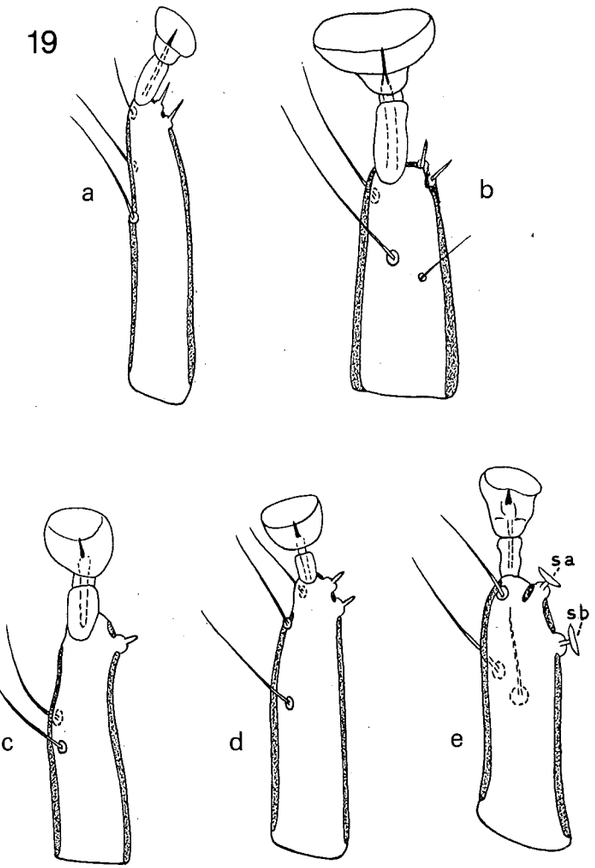

Fig. 19 Tarsus IV in the males of : *Bontiella bouilloni* Fain (a) ; *Hughesiella africana* (Hughes) (b) ; *Euroglyphus maynei* (Cooreman) (c) ; *Gymnoglyphus longior* (Trouessart) (d) ; *Dermatophagoides pteronyssinus* (Trouessart) (e)

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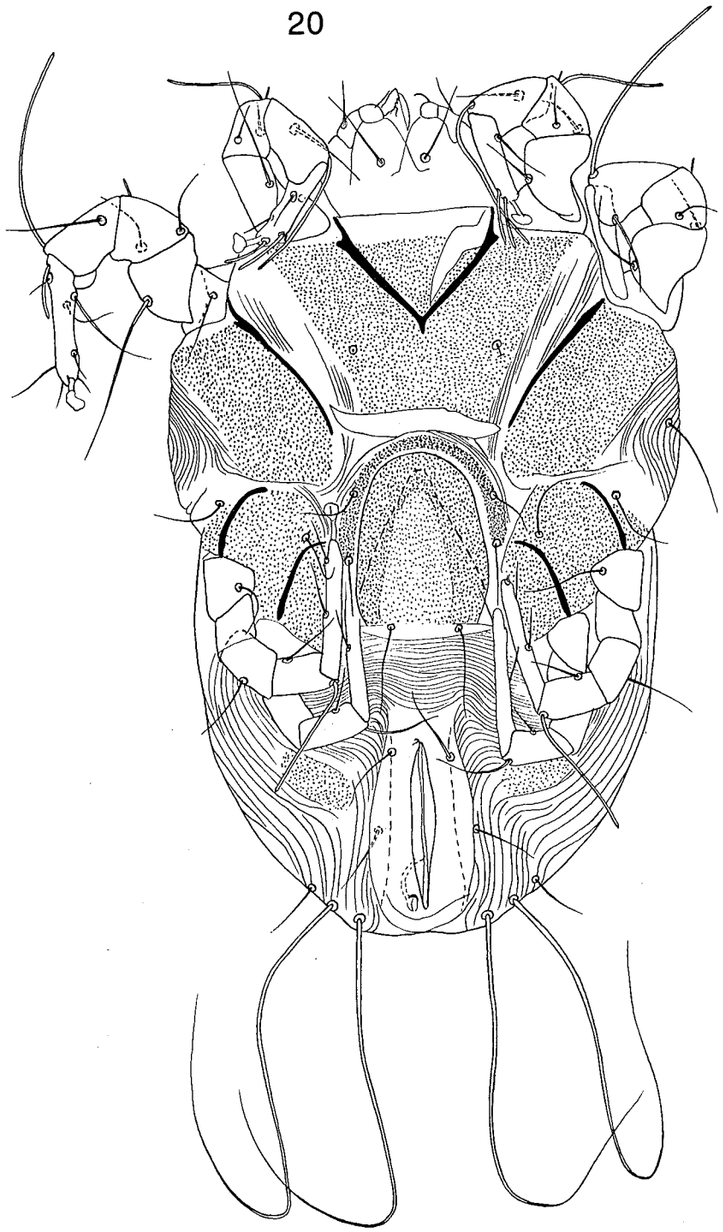

Fig. 20 *Weelawadjia australis* Fain and Lowry : Female in ventral view

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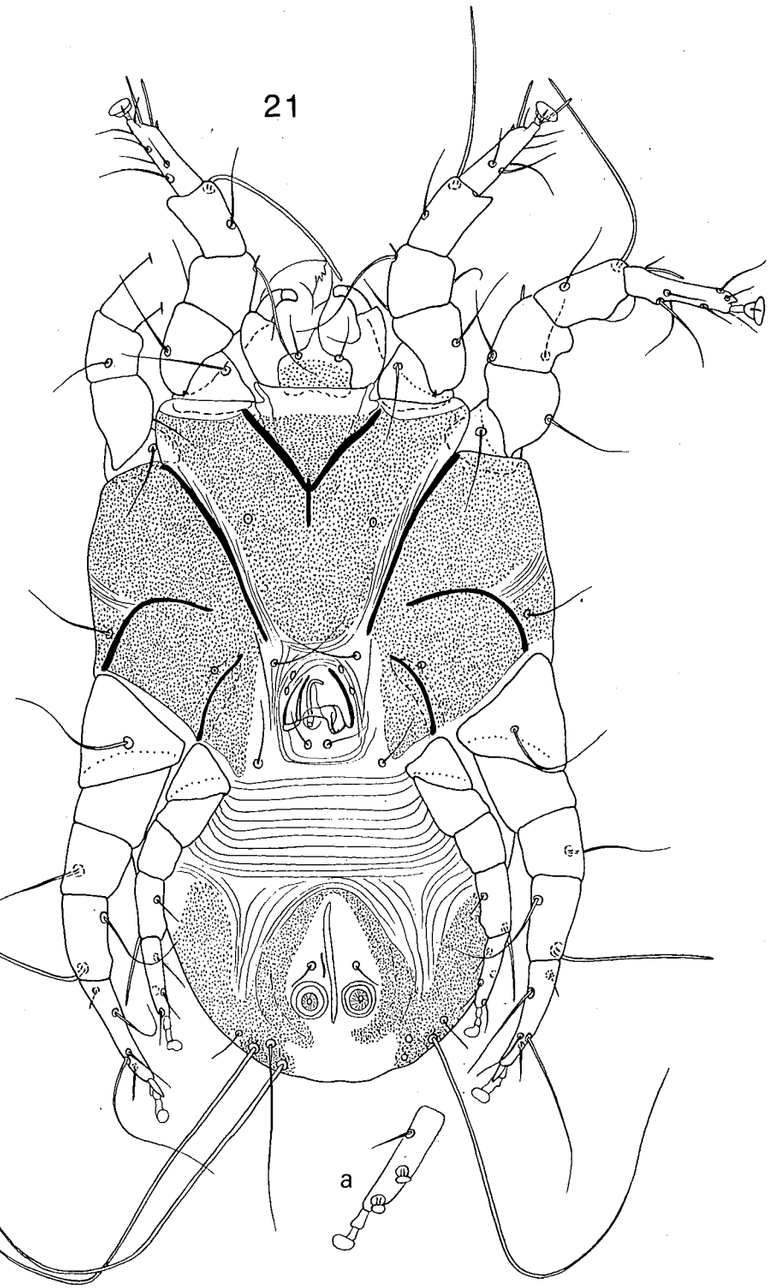

Fig. 21 *Weelawadjia australis* Fain and Lowry : Male in ventral view. Tarsus IV in dorsal view (a)

22

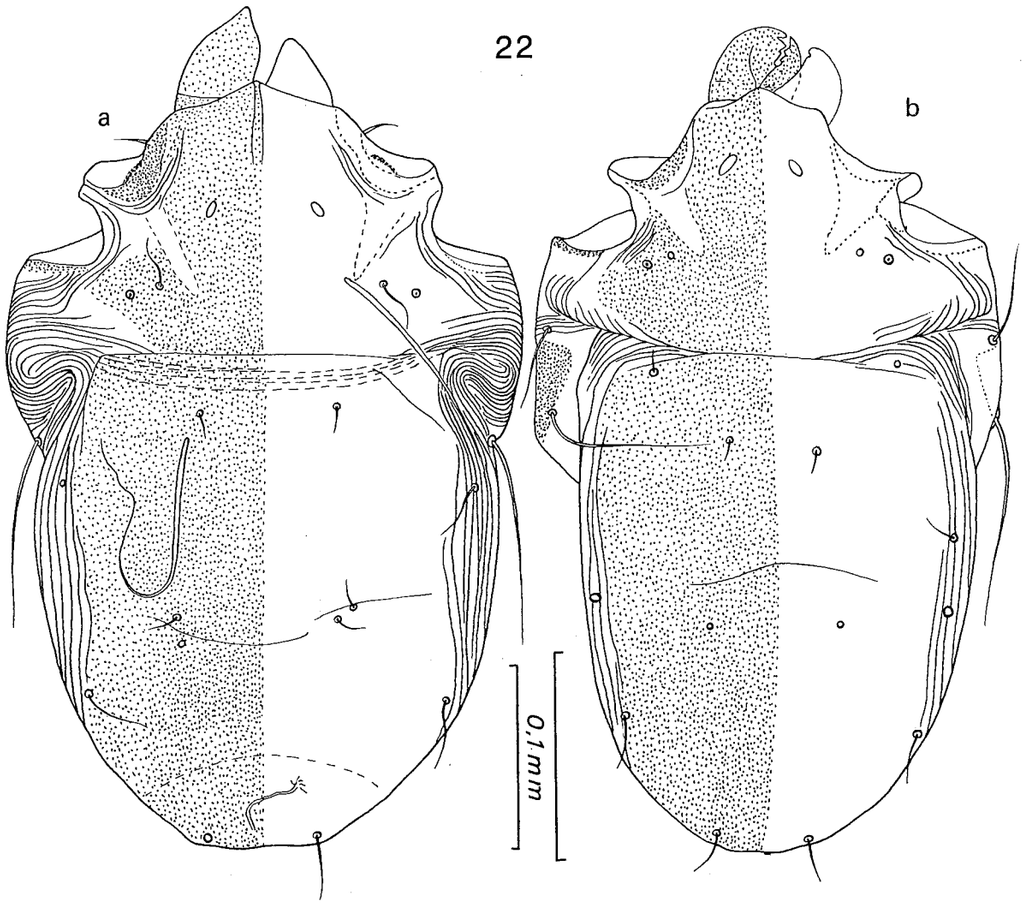

Fig. 22 *Weelawadjia australis* Fain and Lowry : Female (a) and male (b) in dorsal view

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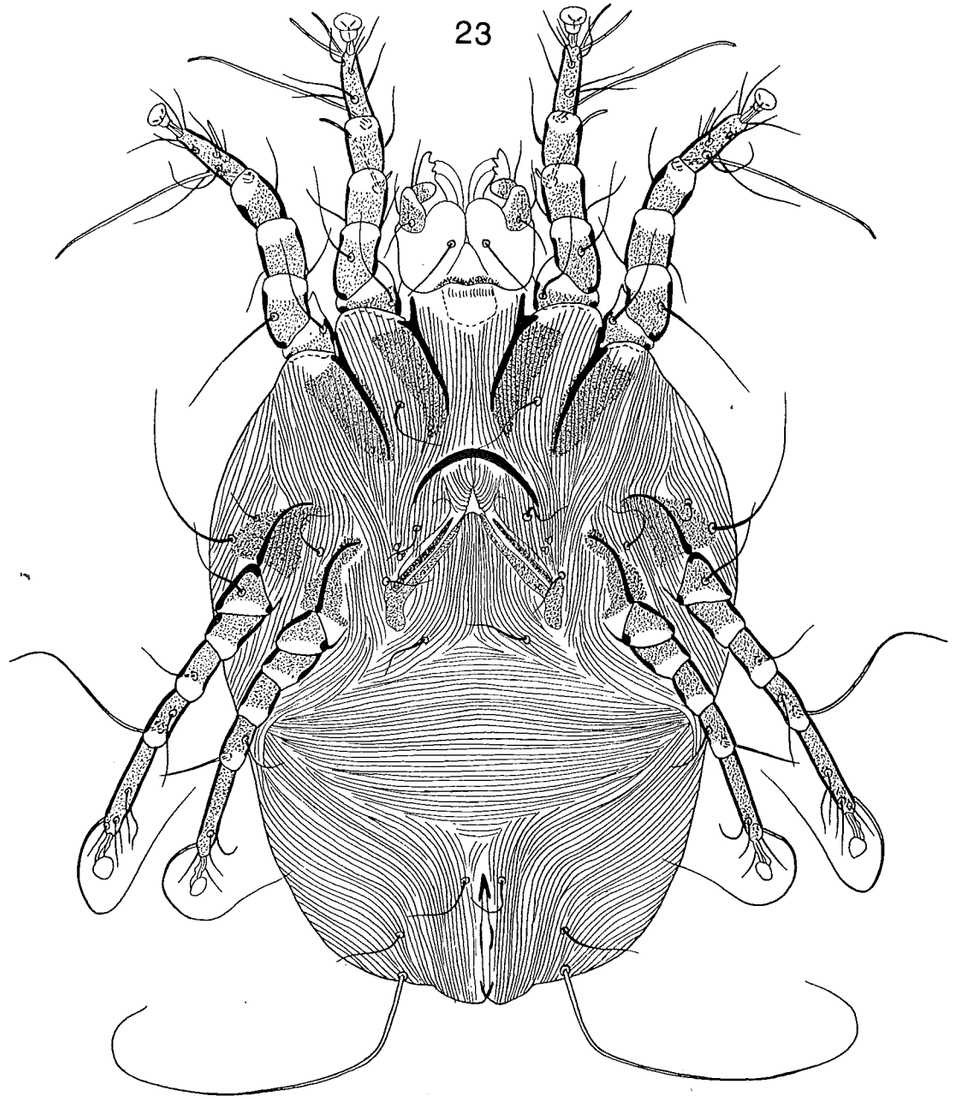

Fig. 23 *Dermatophagoides pteronyssinus* (Trouessart) : Female in ventral view

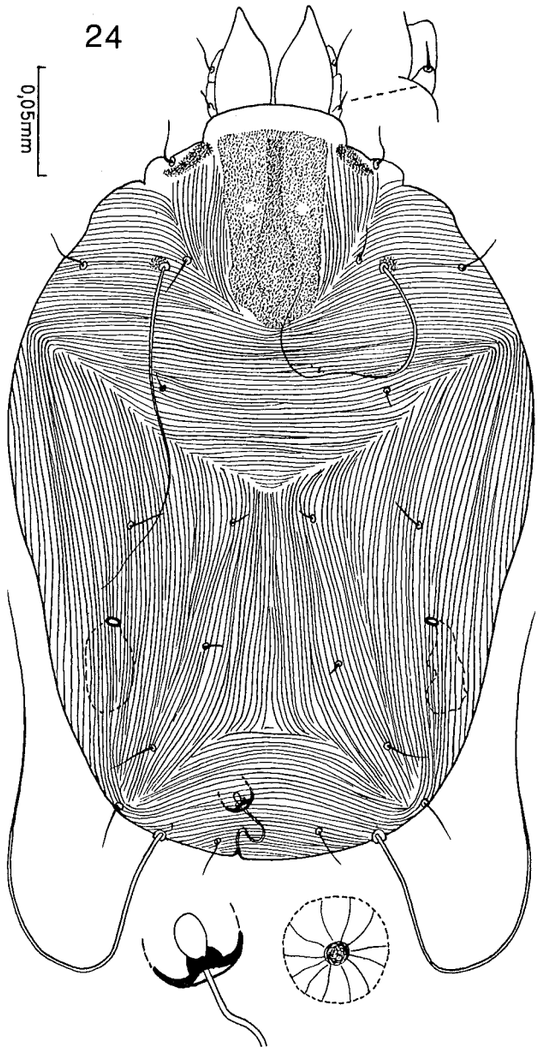

Fig. 24 *Dermatophagoides pteronyssinus* (Trouessart) : Female in dorsal view

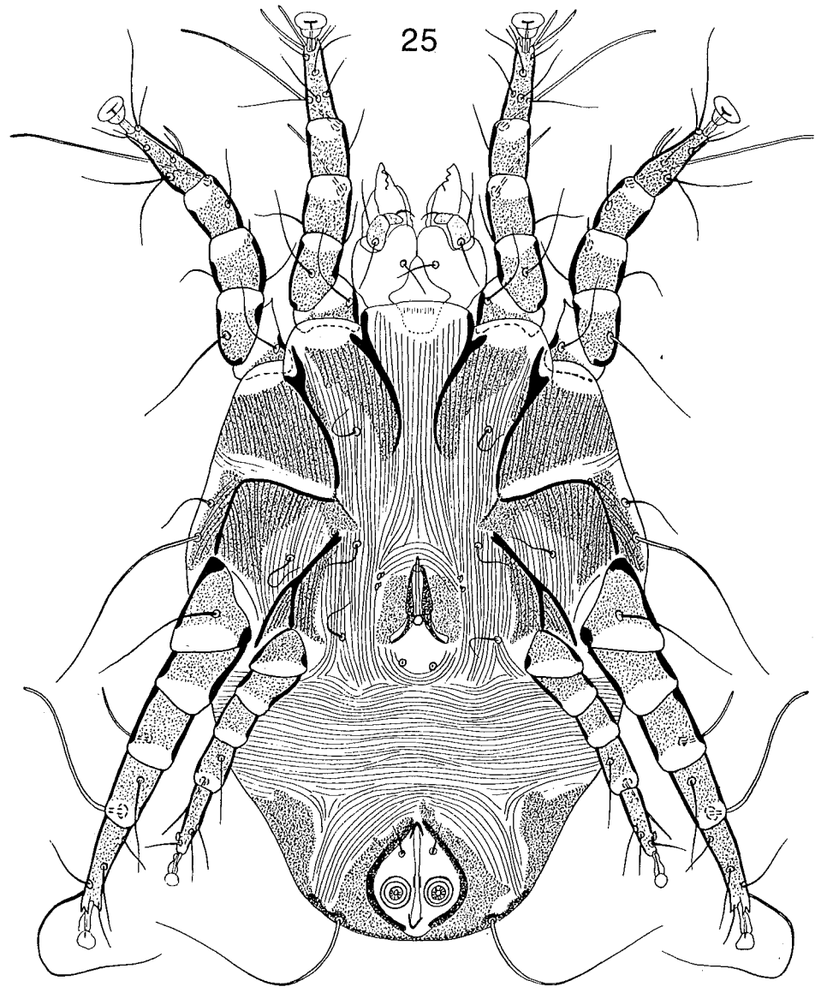

Fig. 25 *Dermatophagoides pteronyssinus* (Trouessart) : Male in ventral view

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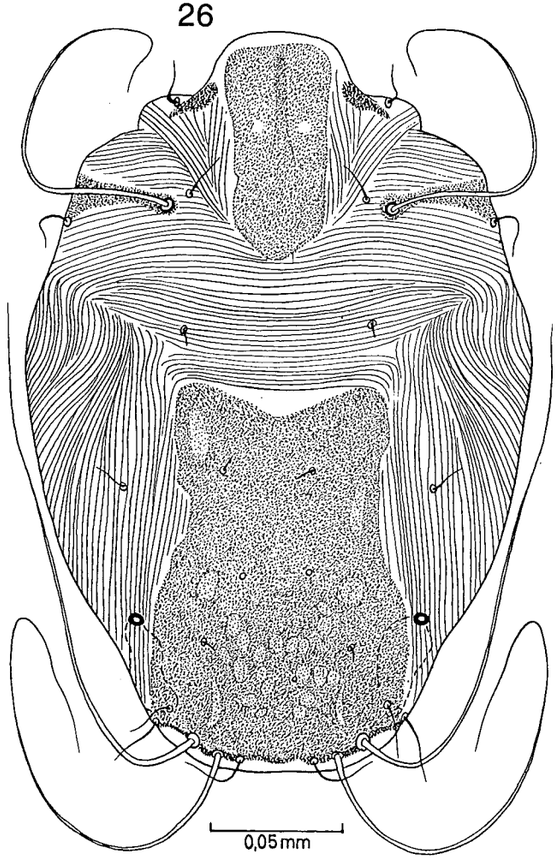

Fig. 26 *Dermatophagoides pteronyssinus* (Trouessart) : Male in dorsal view

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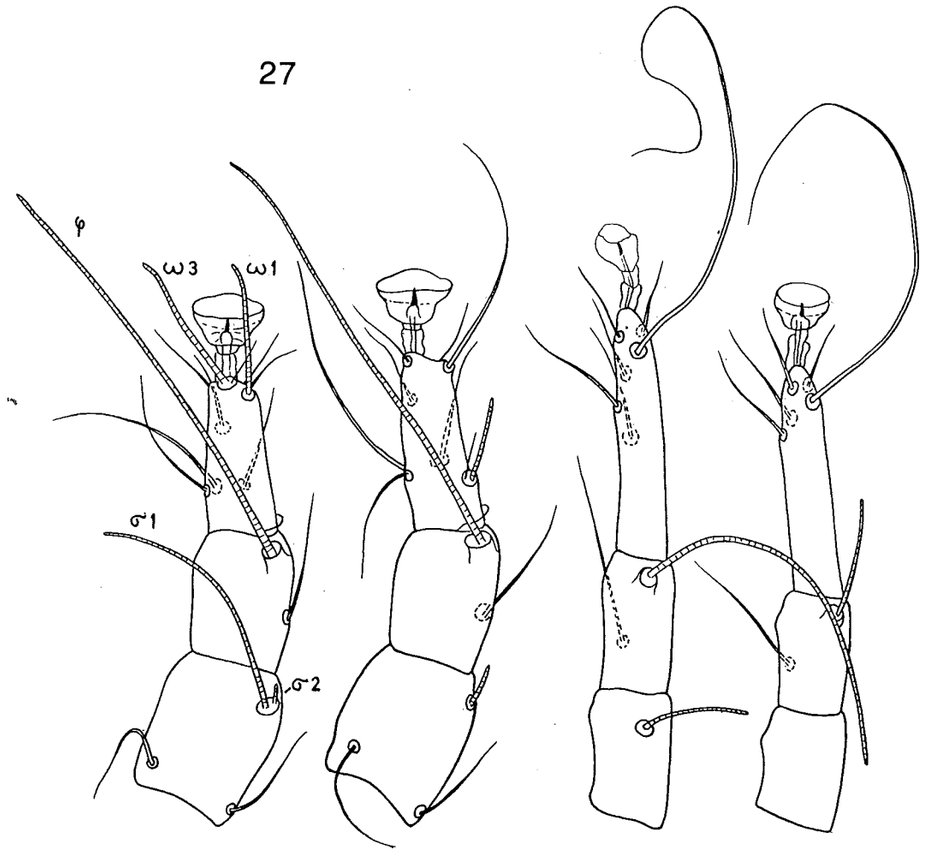

Fig. 27 *Dermatophagoides pteronyssinus* (Trouessart) : Legs I to IV (from left to right) (3 apical segments) in the female

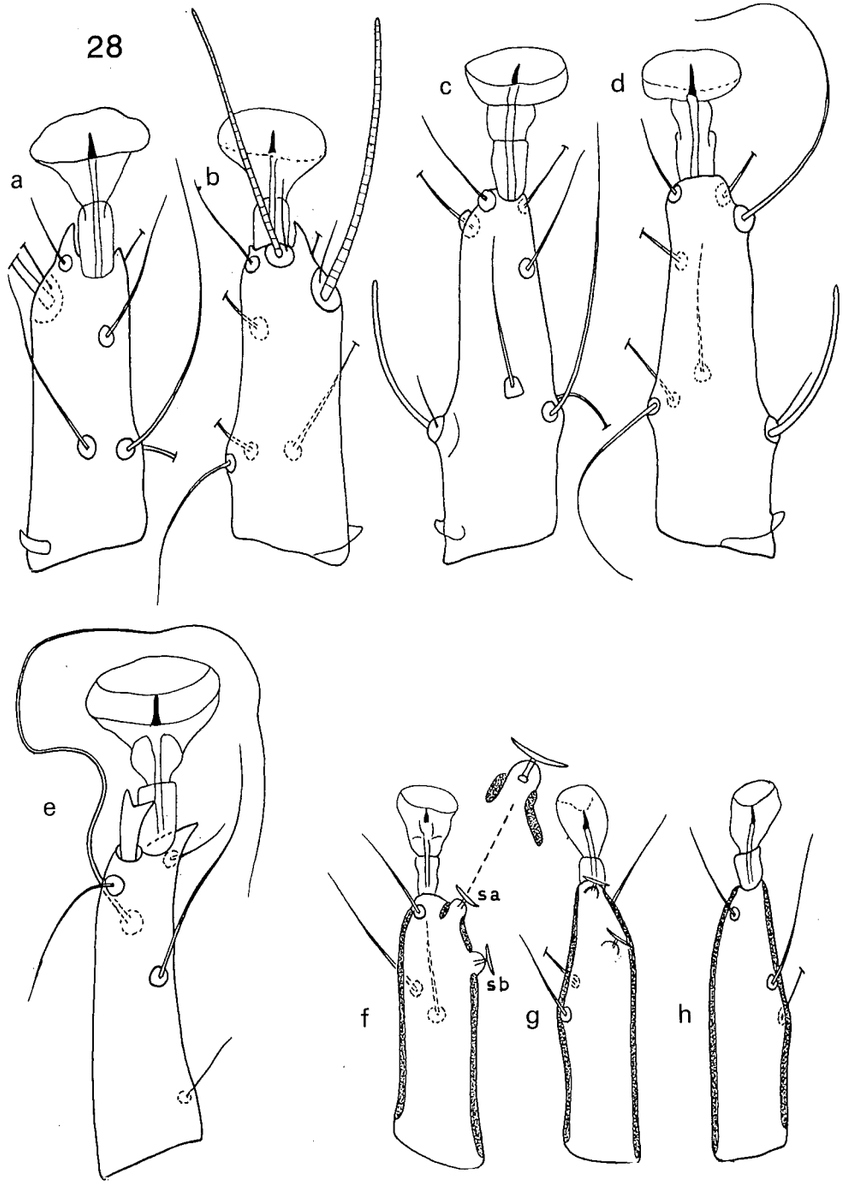

Fig. 28 *Dermatophagoides pteronyssinus* (Trouessart) : Male : Tarsi I (a and b), II (c and d), III (e) and IV (f, g and h)

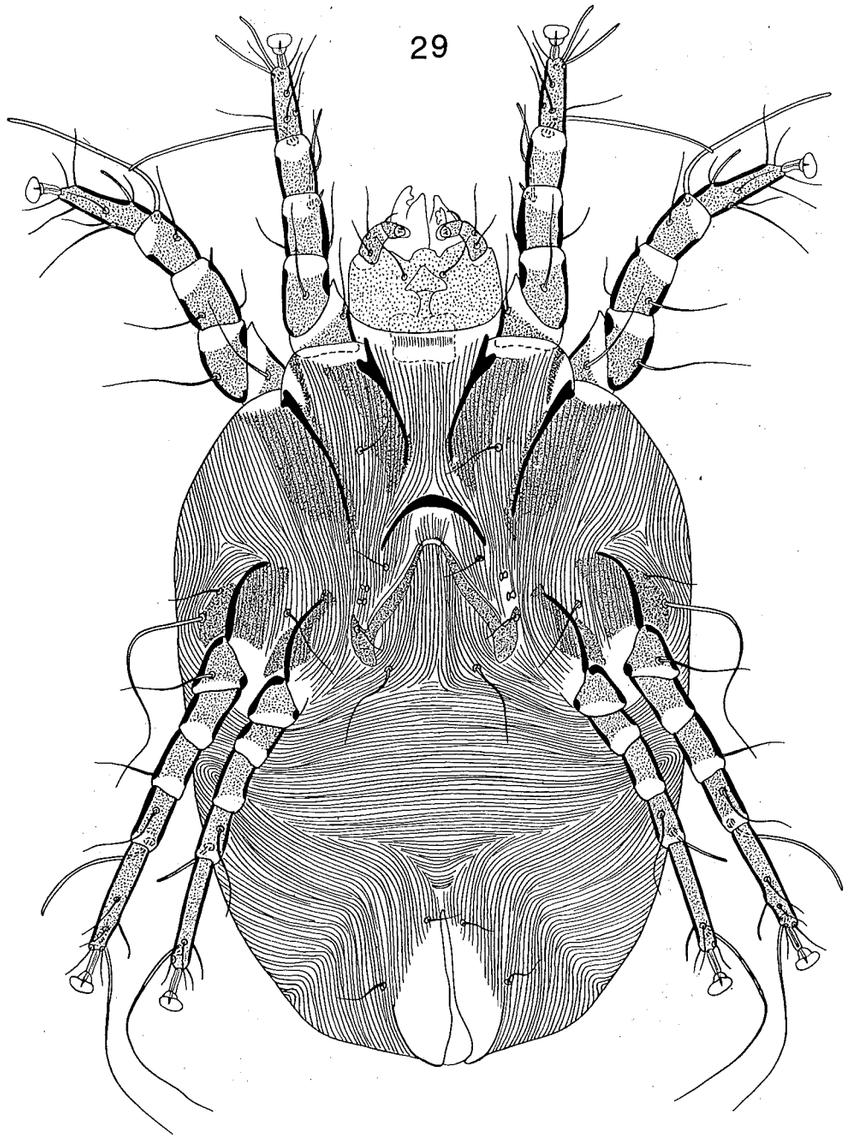

Fig. 29 *Dermatophagoides evansi* Fain, Hughes and Johnston : Female in ventral view

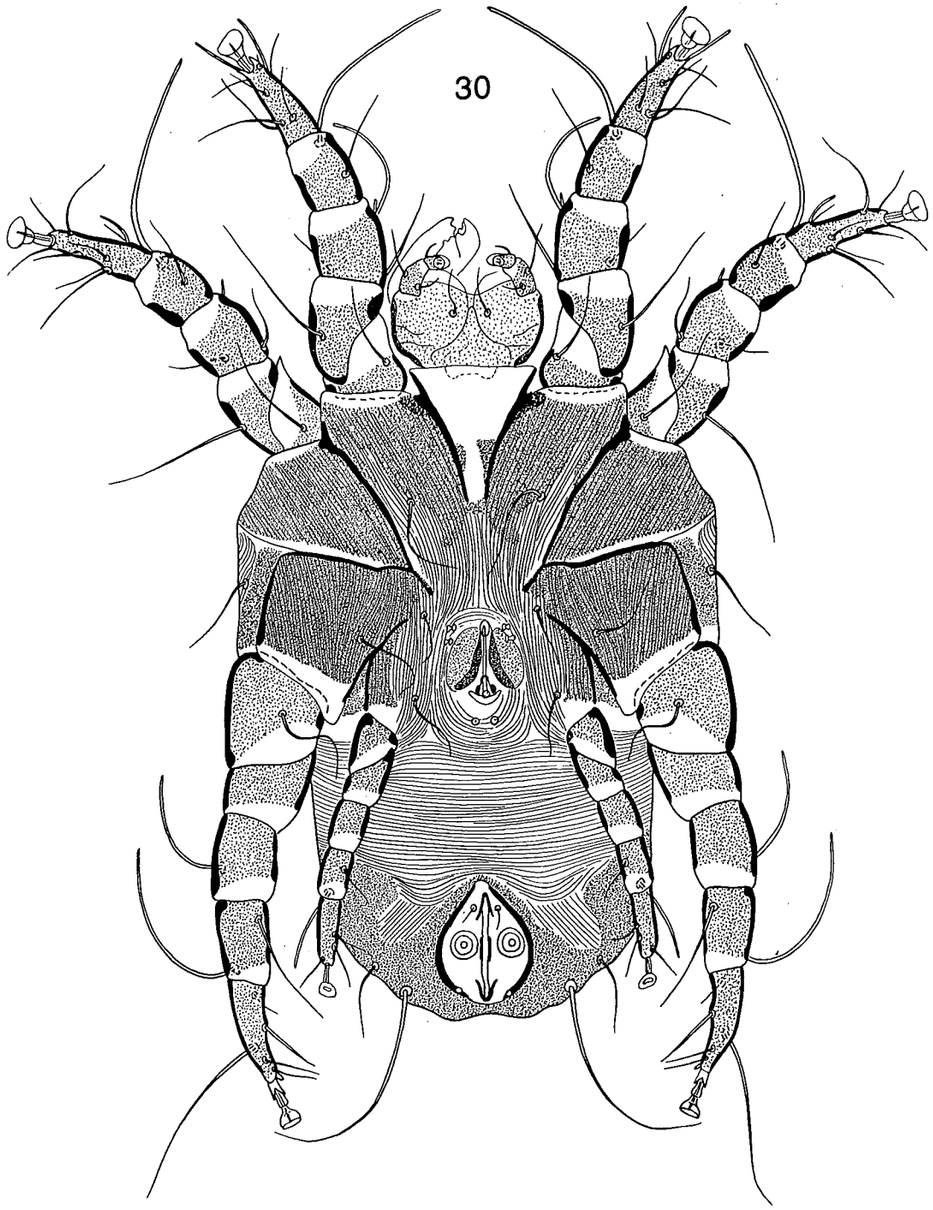

Fig. 30 *Dermatophagoides evansi* Fain, Hughes and Johnston : Male in ventral view

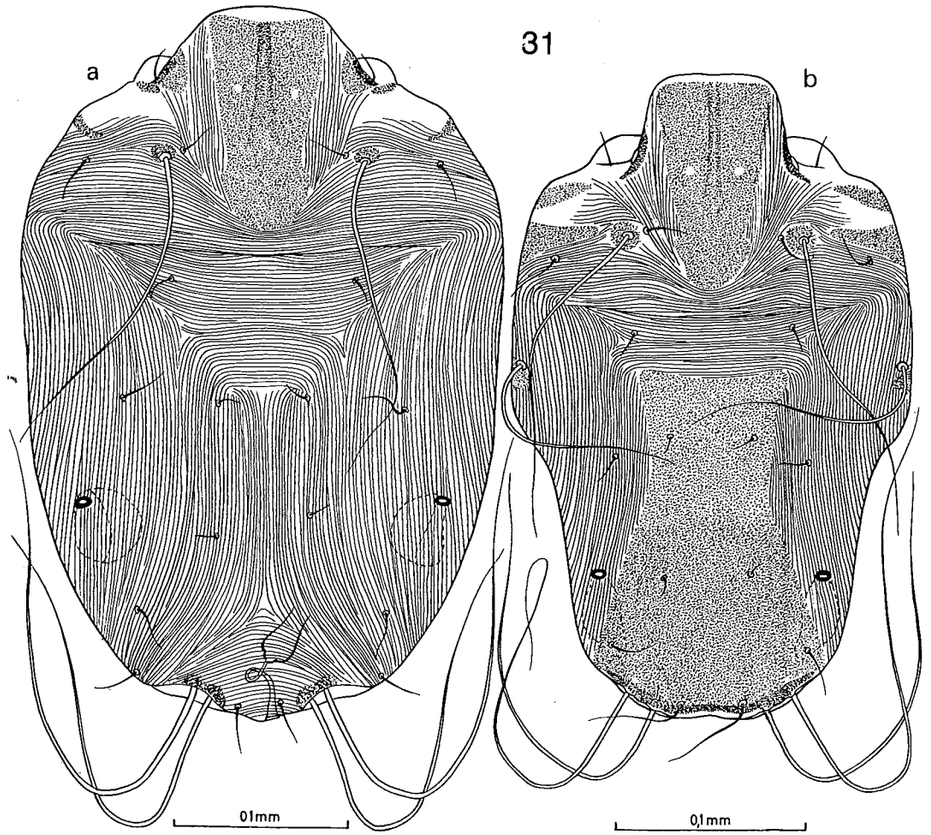

Fig. 31 *Dermatophagoides evansi* Fain, Hughes and Johnston : Female (a) and male (b) in dorsal view

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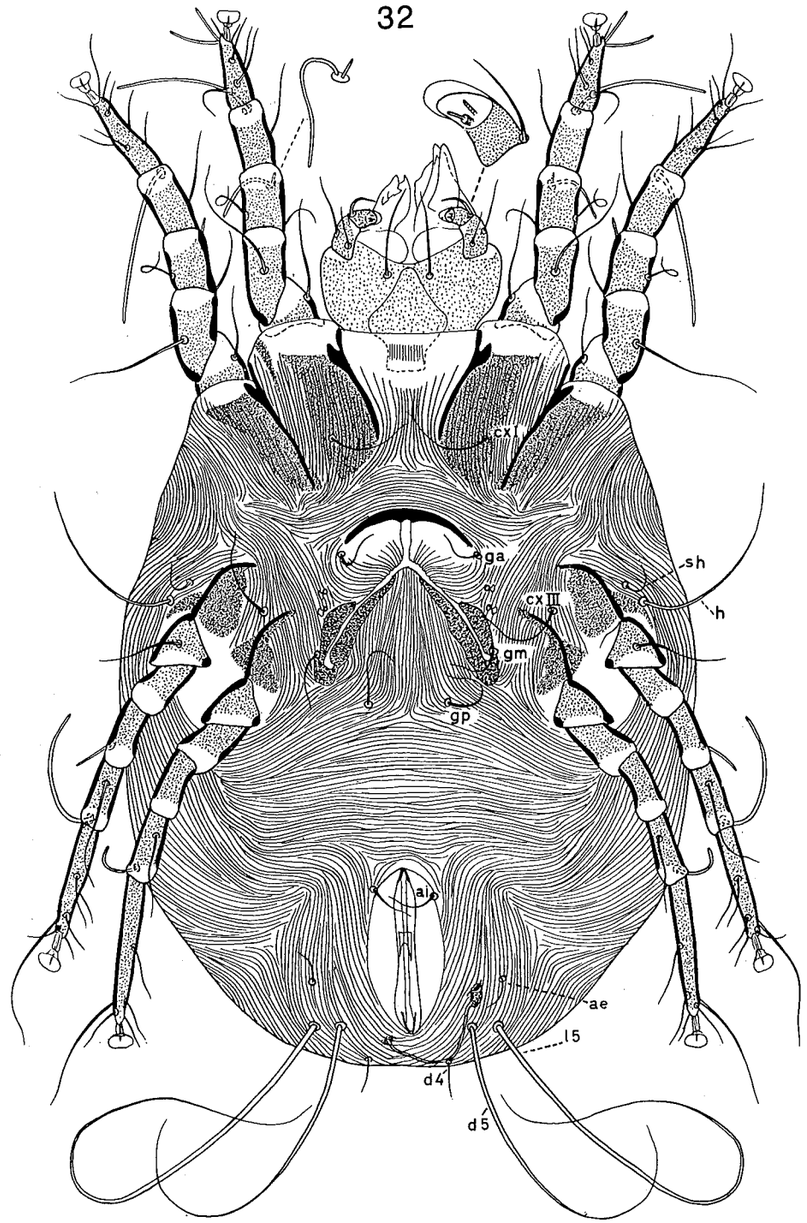

Fig. 32 *Dermatophagoides farinae* Hughes : Female in ventral view

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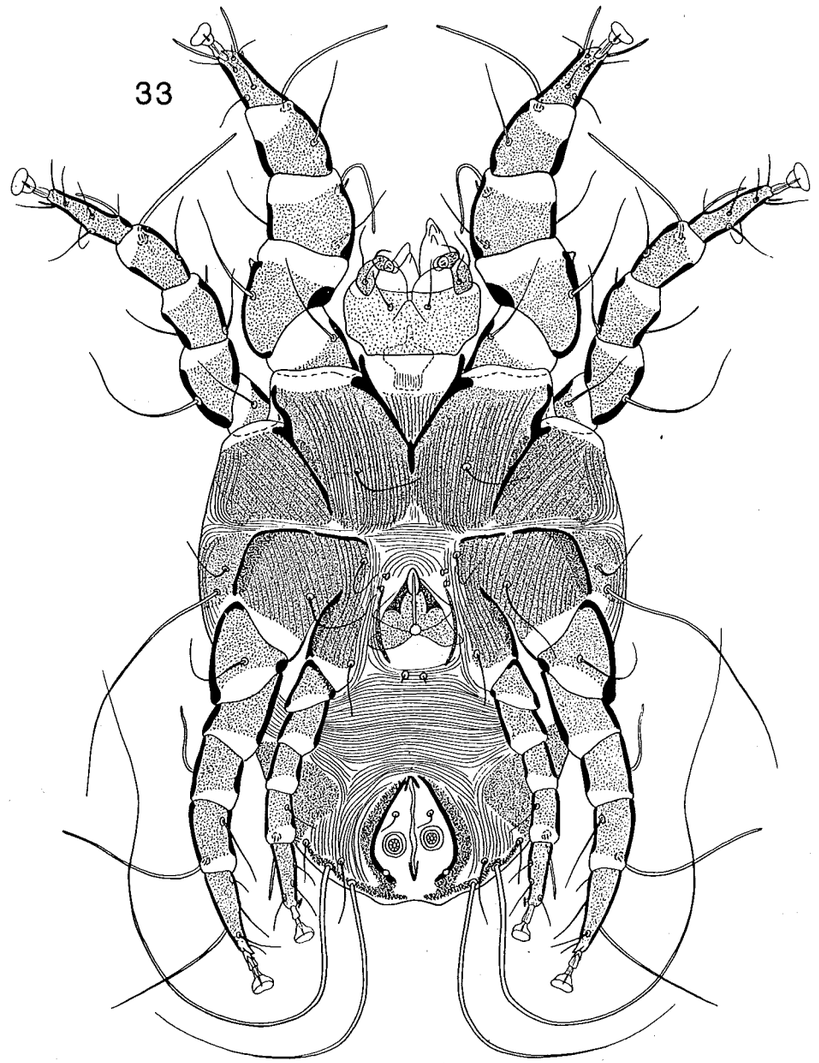

Fig. 33 *Dermatophagoides farinae* Hughes : Heteromorphic male in ventral view

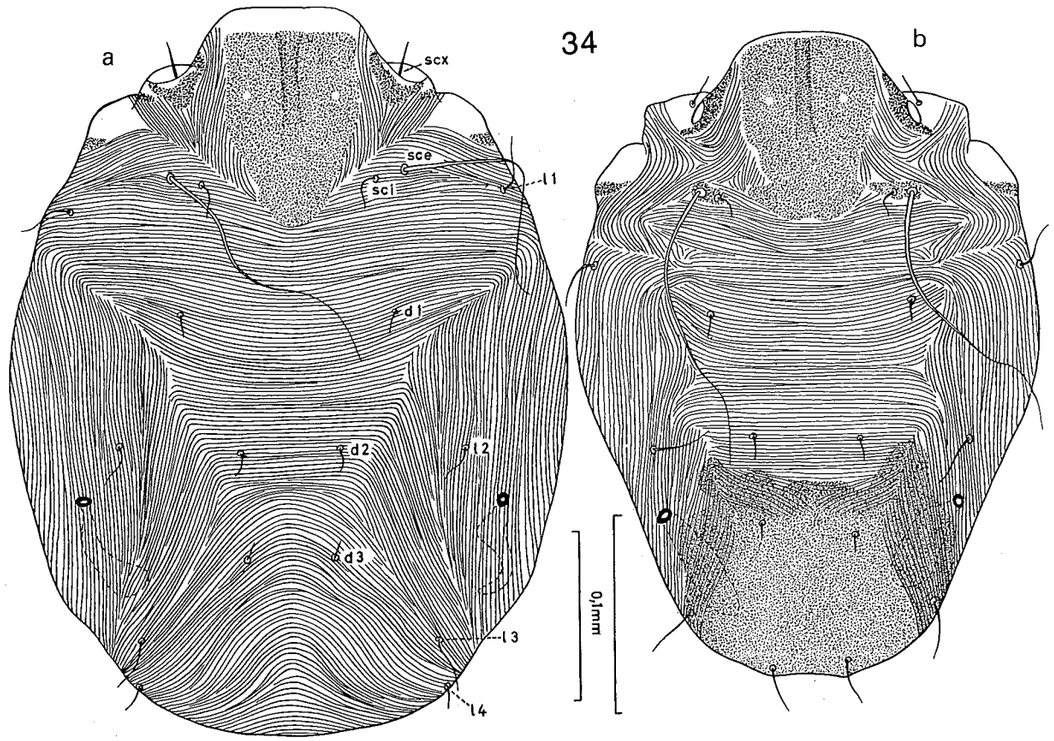

Fig. 34 *Dermatophagoides farinae* Hughes : Female (a) and male (b) in dorsal view

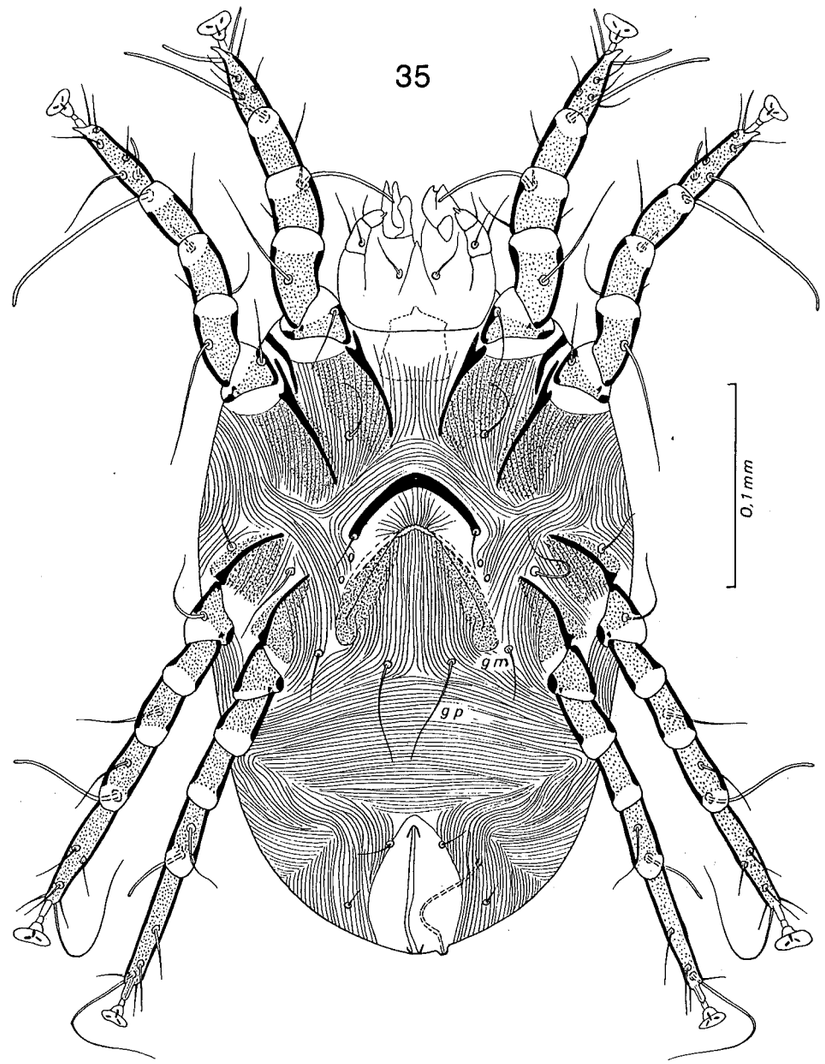

Fig. 35 *Dermatophagoides neotropicalis* Fain and Van Bronswijk : Female in ventral view

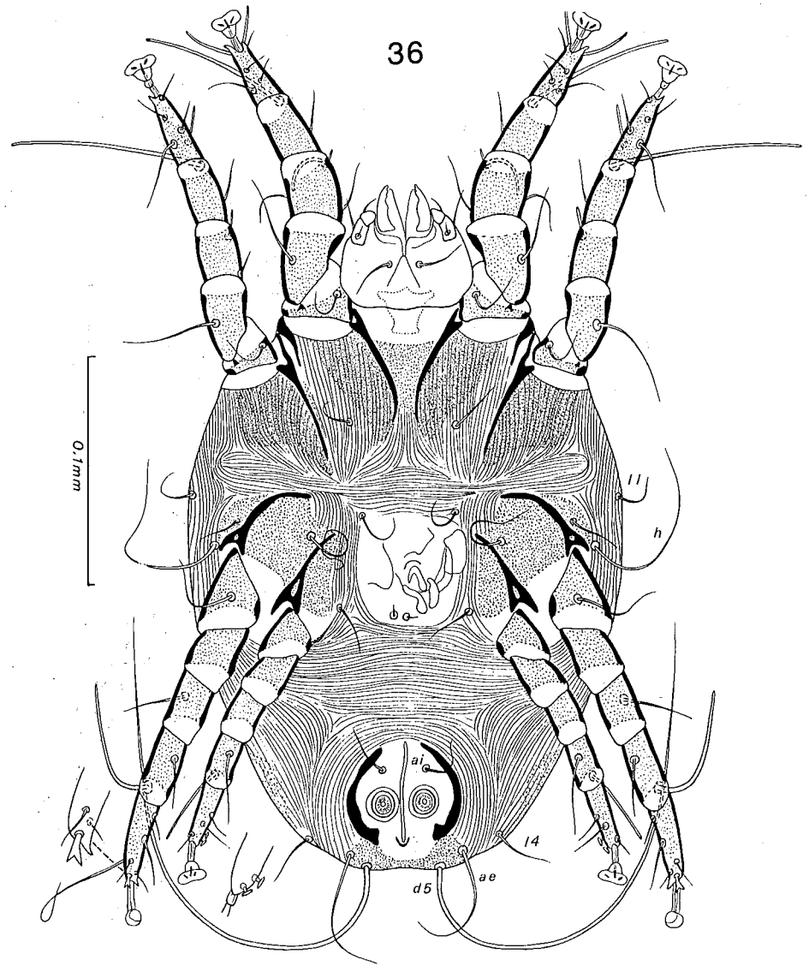

Fig. 36 *Dermatophagoides neotropicalis* Fain and Van Bronswijk : Male in ventral view

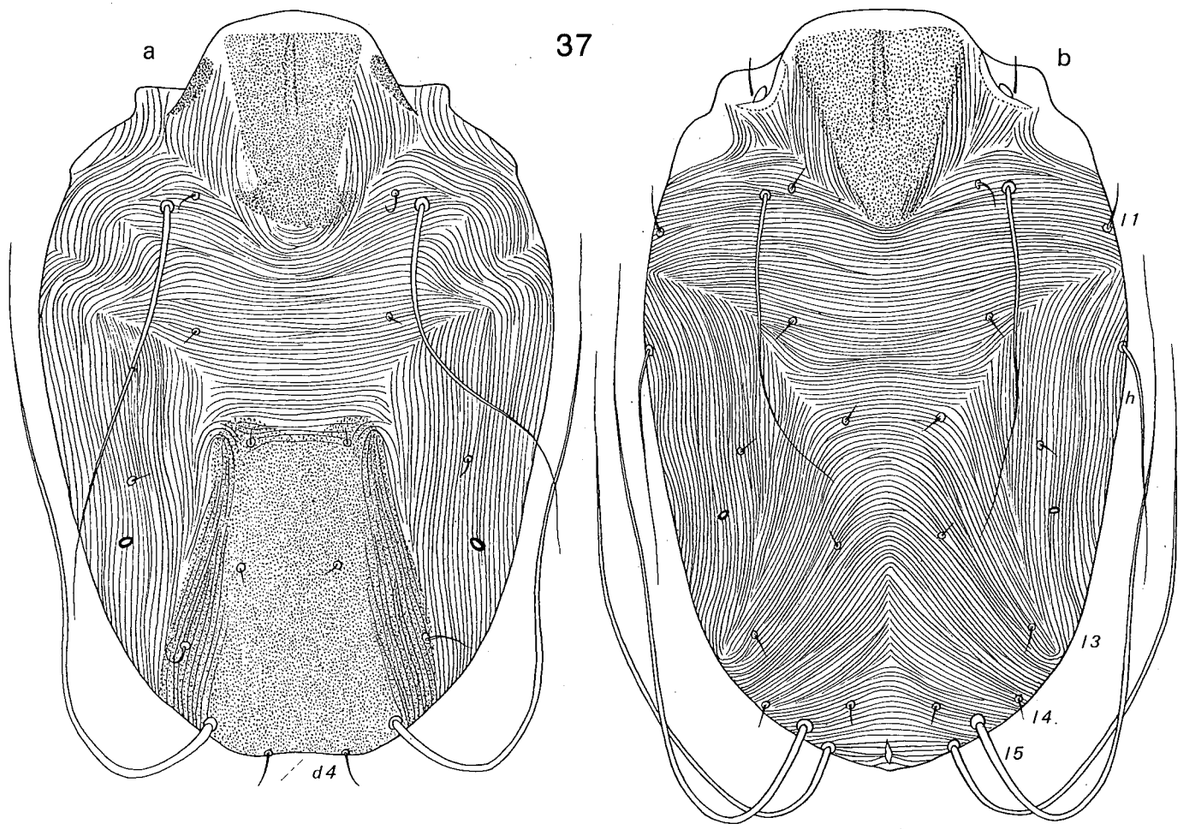

Fig. 37 *Dermatophagoides neotropicalis* Fain and Van Bronswijk : Male (a) and female (b) in dorsal view

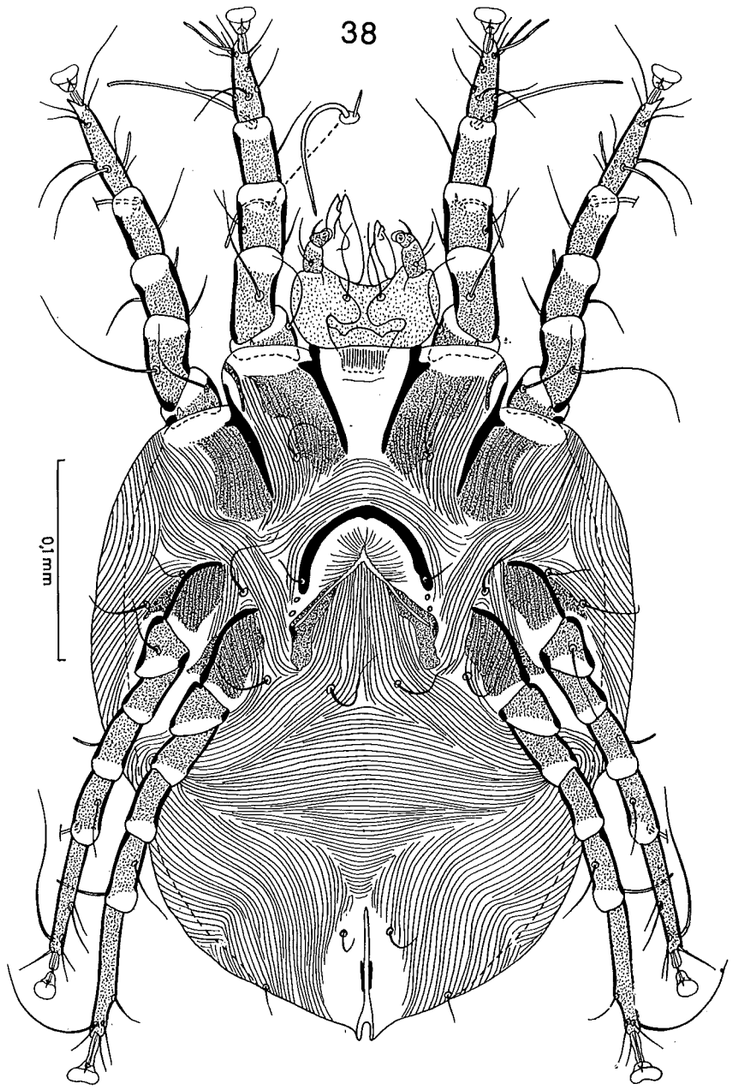

Fig. 38 *Dermatophagoides rwandae* Fain : Female in ventral view

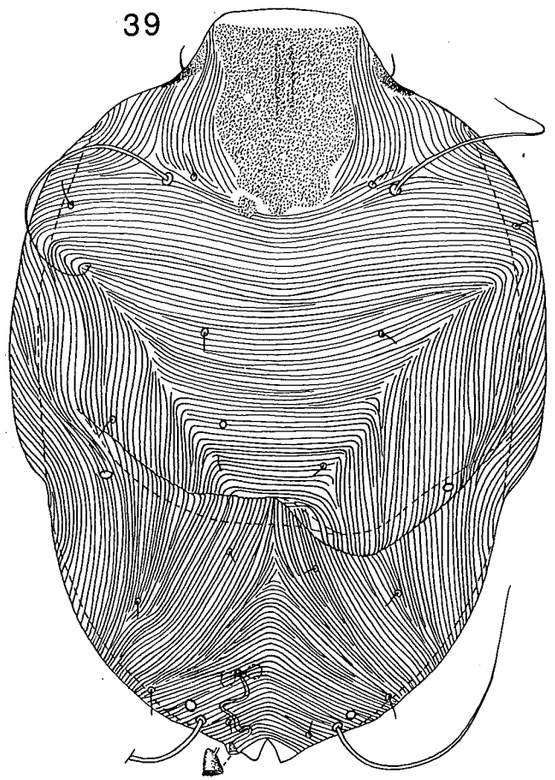

Fig. 39 *Dermatophagoides rwandae* Fain : Female in dorsal view

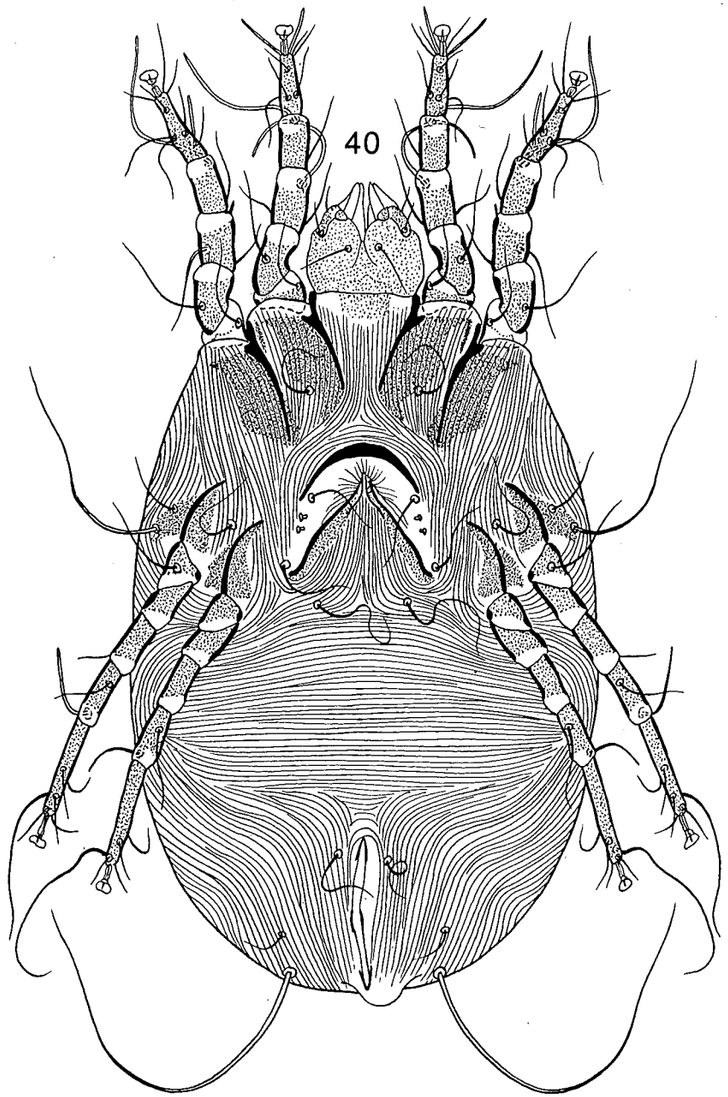

Fig. 40 *Dermatophagoides aureliani* Fain : Female in ventral view

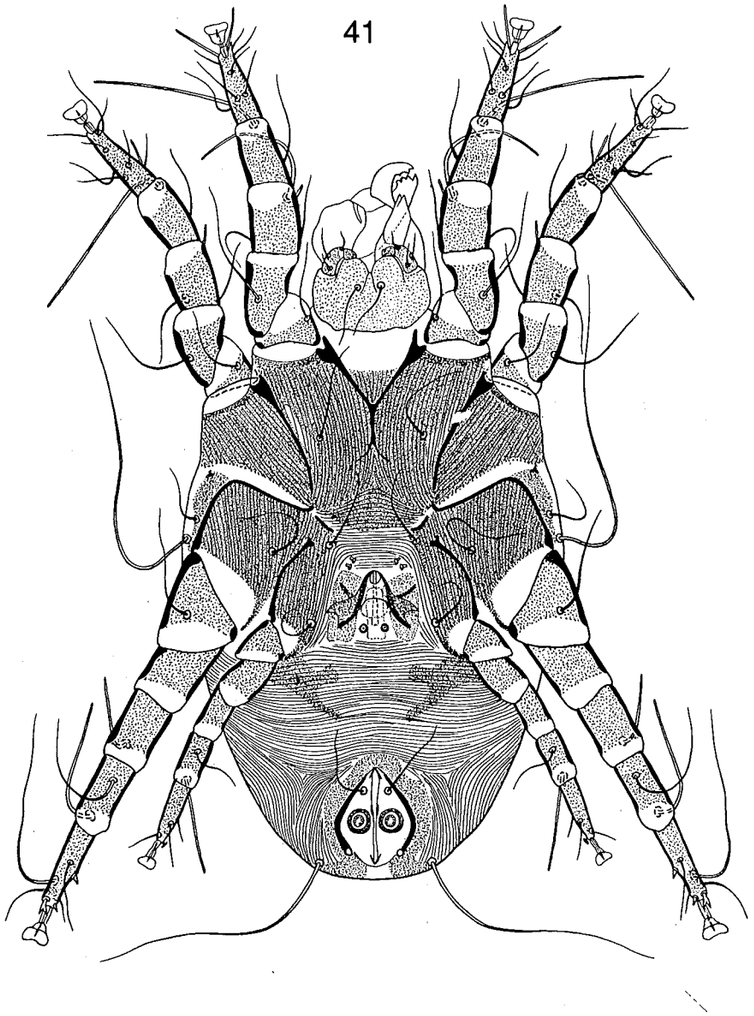

Fig. 41 *Dermatophagoides aureliani* Fain : Male in ventral view

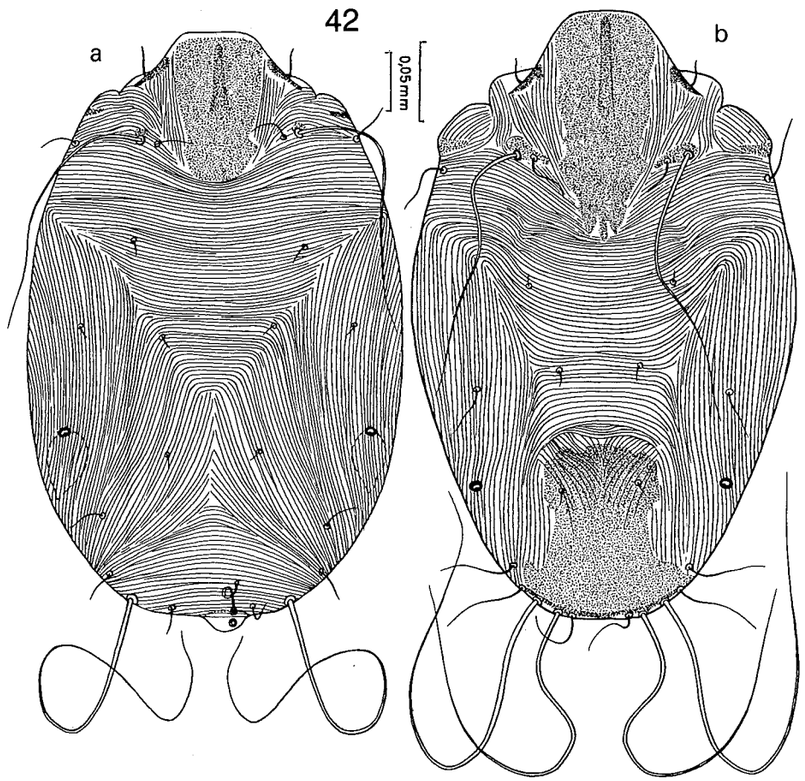

Fig. 42 *Dermatophagoides aureliani* Fain : Female (a) and male (b) in dorsal view

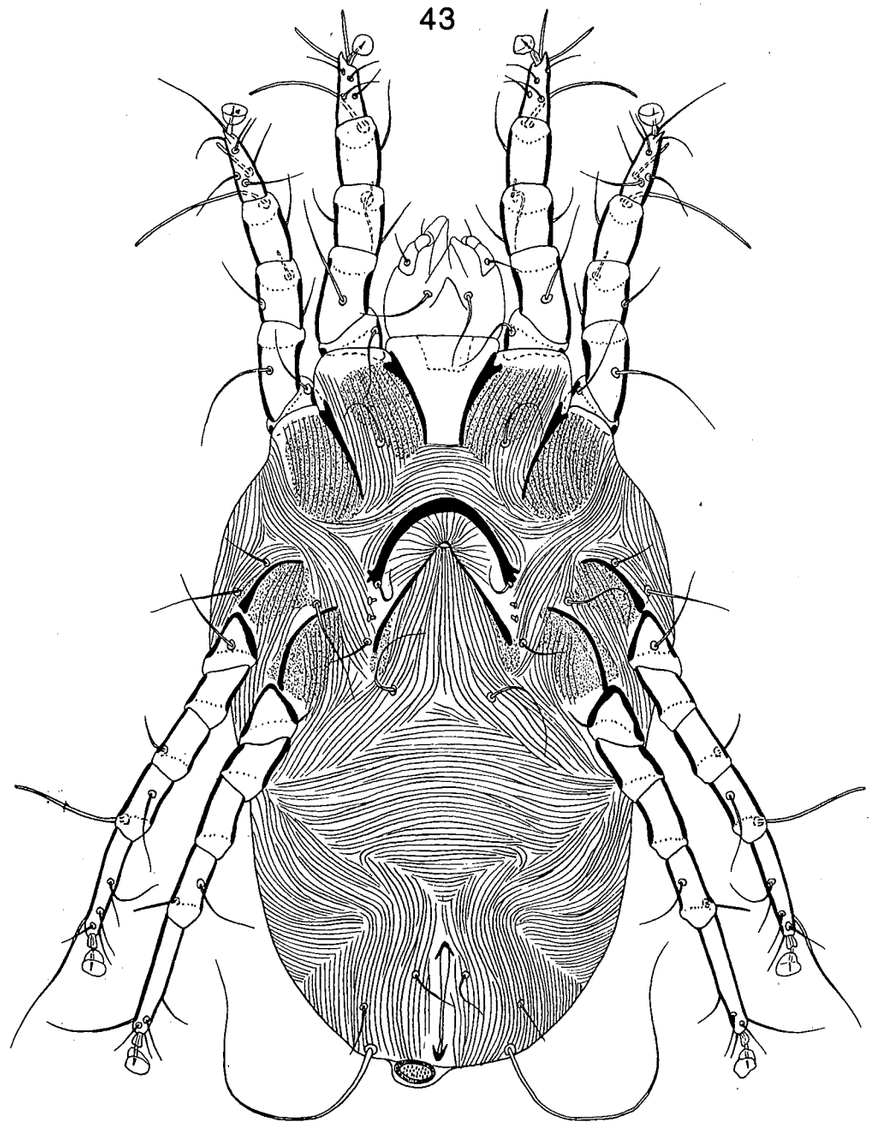

Fig. 43 *Dermatophagoides sclerovestibulatus* Fain : Female in ventral view

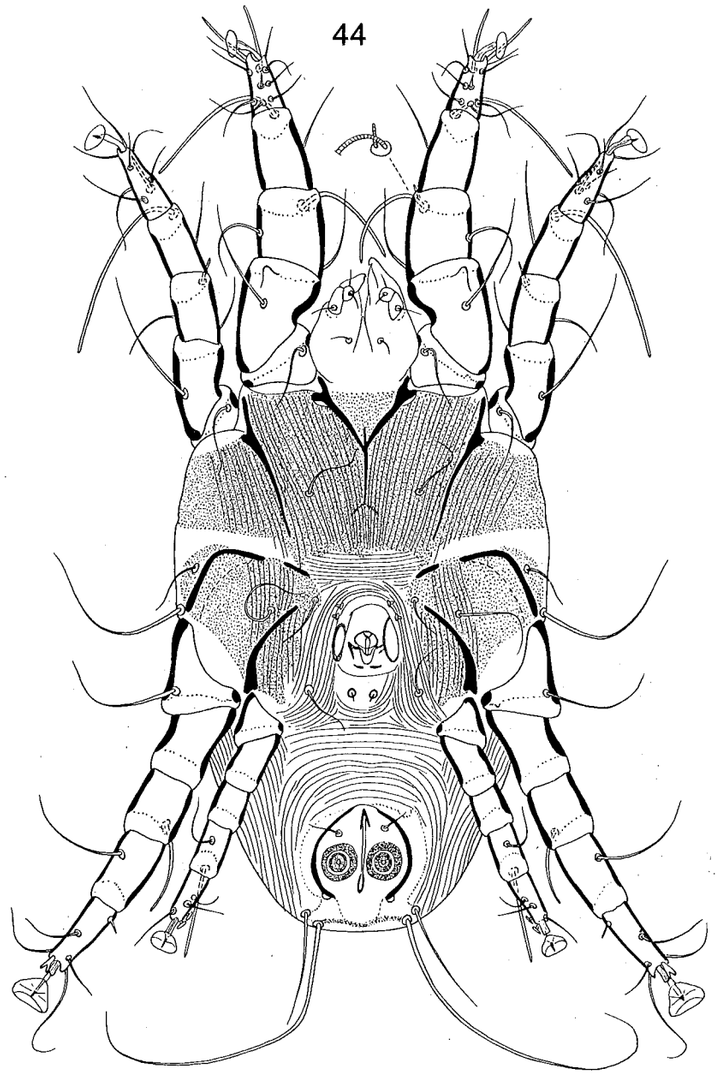

Fig. 44 *Dermatophagoides sclerovestibulatus* Fain : Male in ventral view

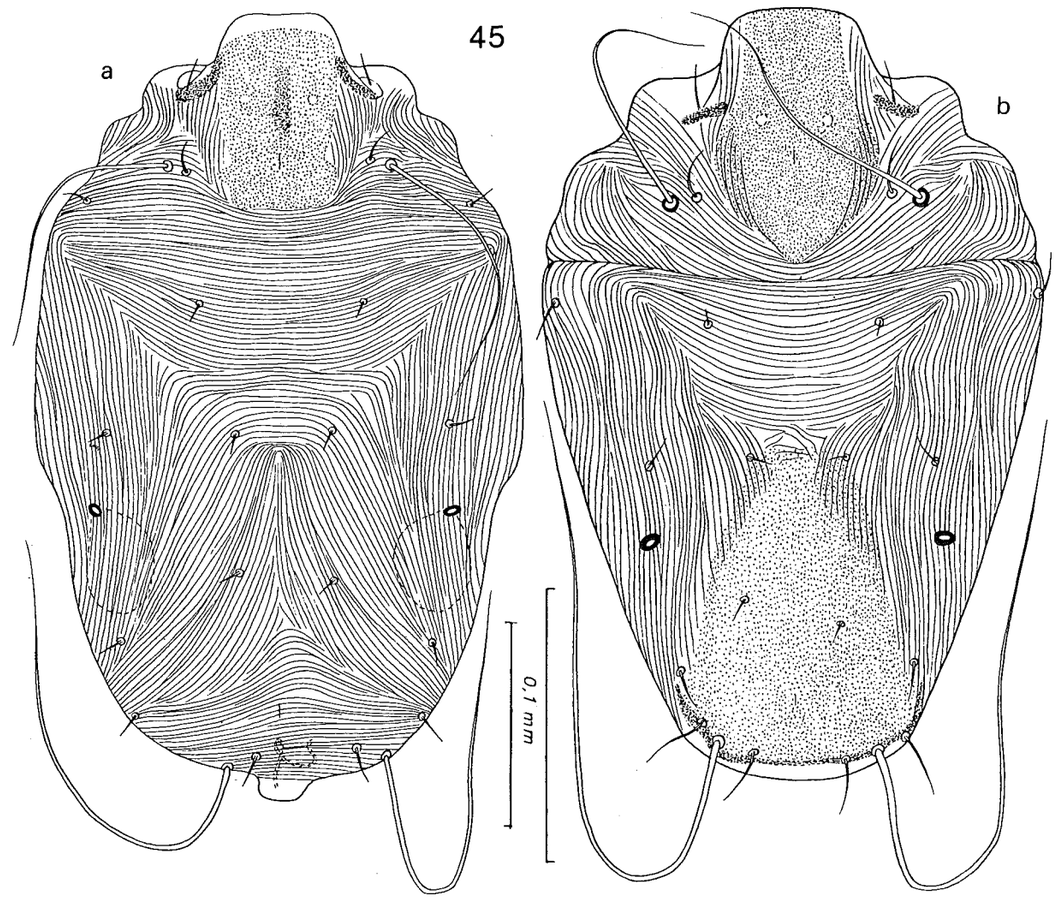

Fig. 45 *Dermatophagoides sclerovestibulatus* Fain : Female (a) and male (b) in dorsal view

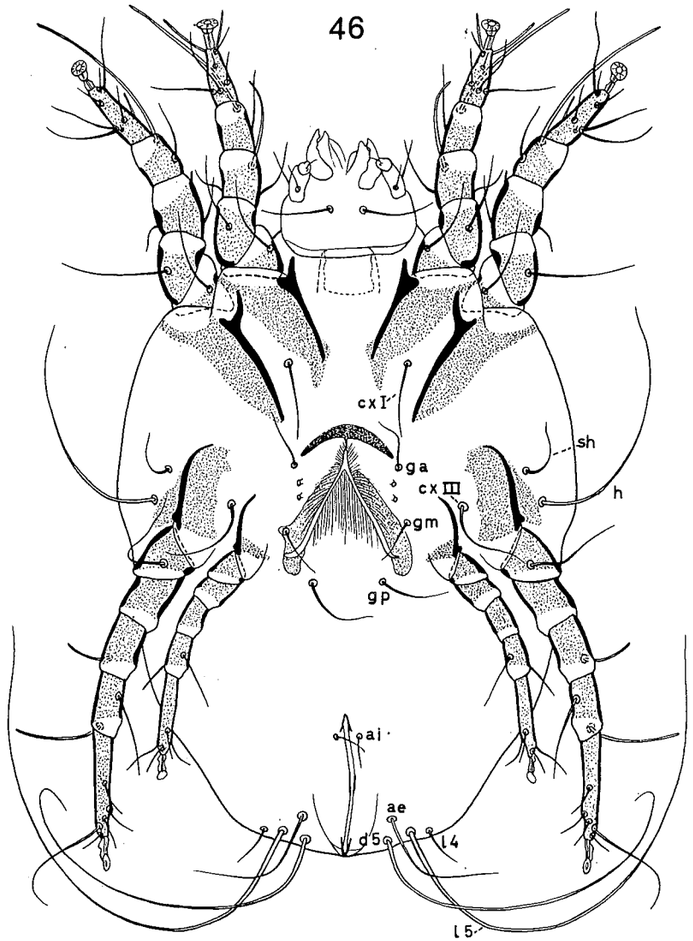

Fig. 46 *Hirstia passericola* (Fain) : Holotype female in ventral view

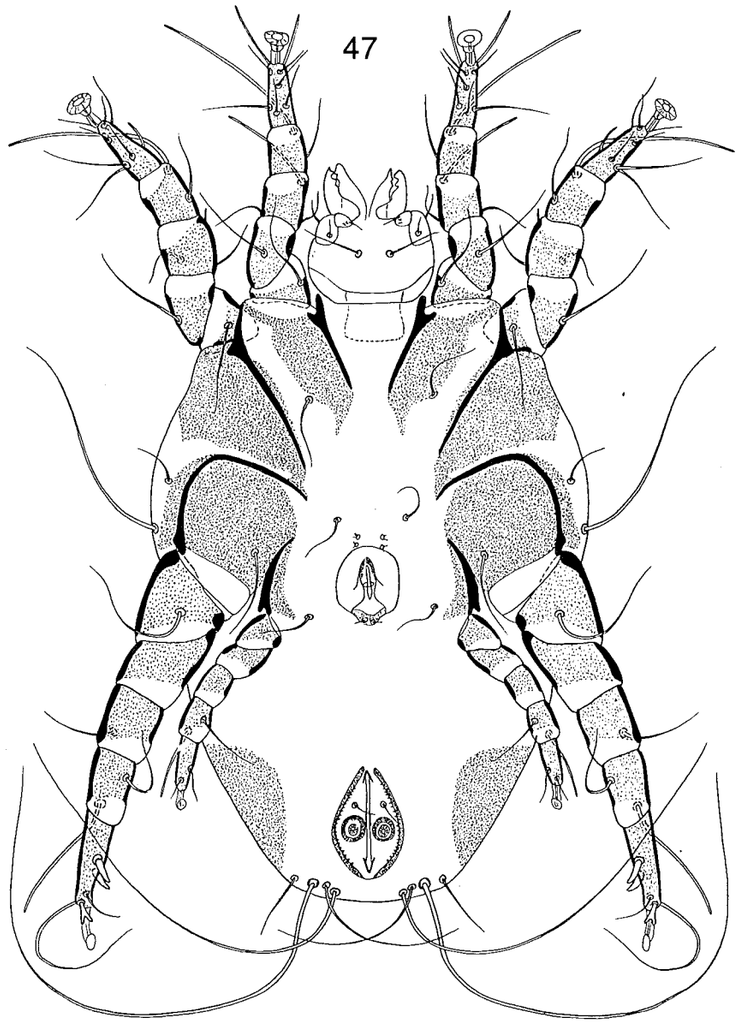

Fig. 47 *Hirstia passericola* (Fain) : Male (paratype) in ventral view

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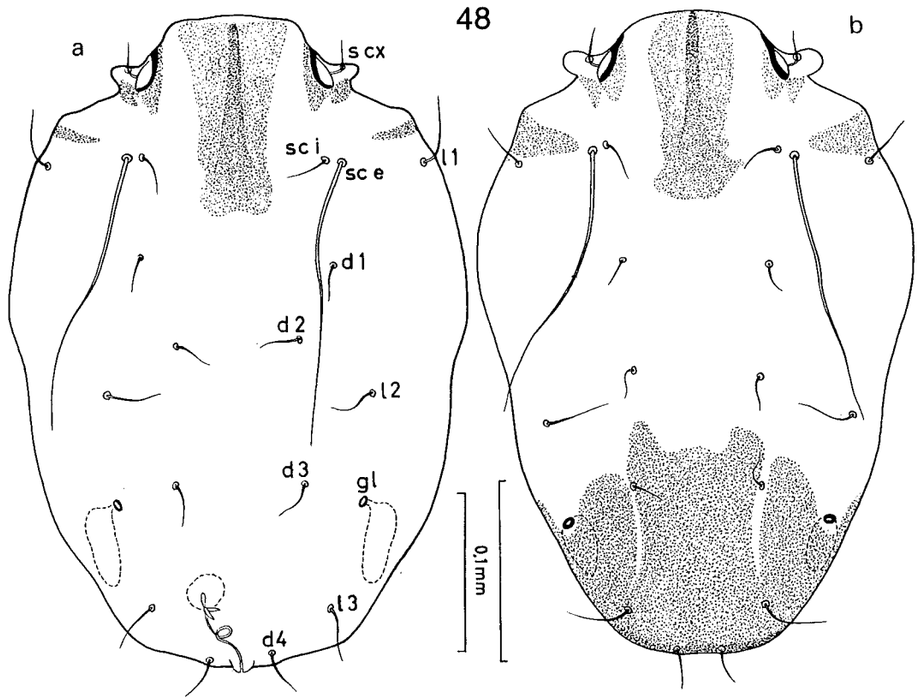

Fig. 48 *Hirstia passericola* (Fain) : Female (holotype) (a) and male (paratype) (b) in dorsal view

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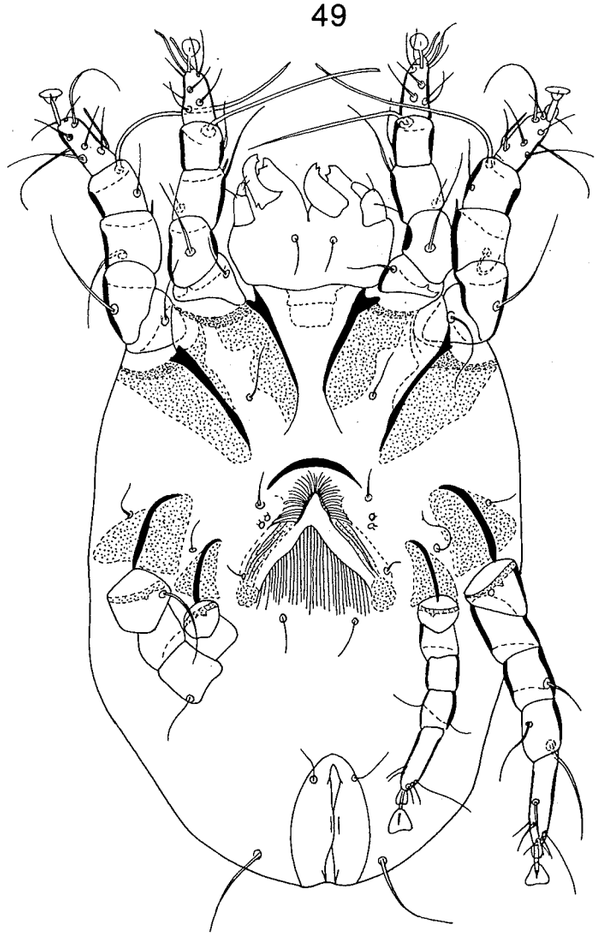

Fig. 49 *Hirstia domicola* Fain, Oshima and Van Bronswijk : Female in ventral view

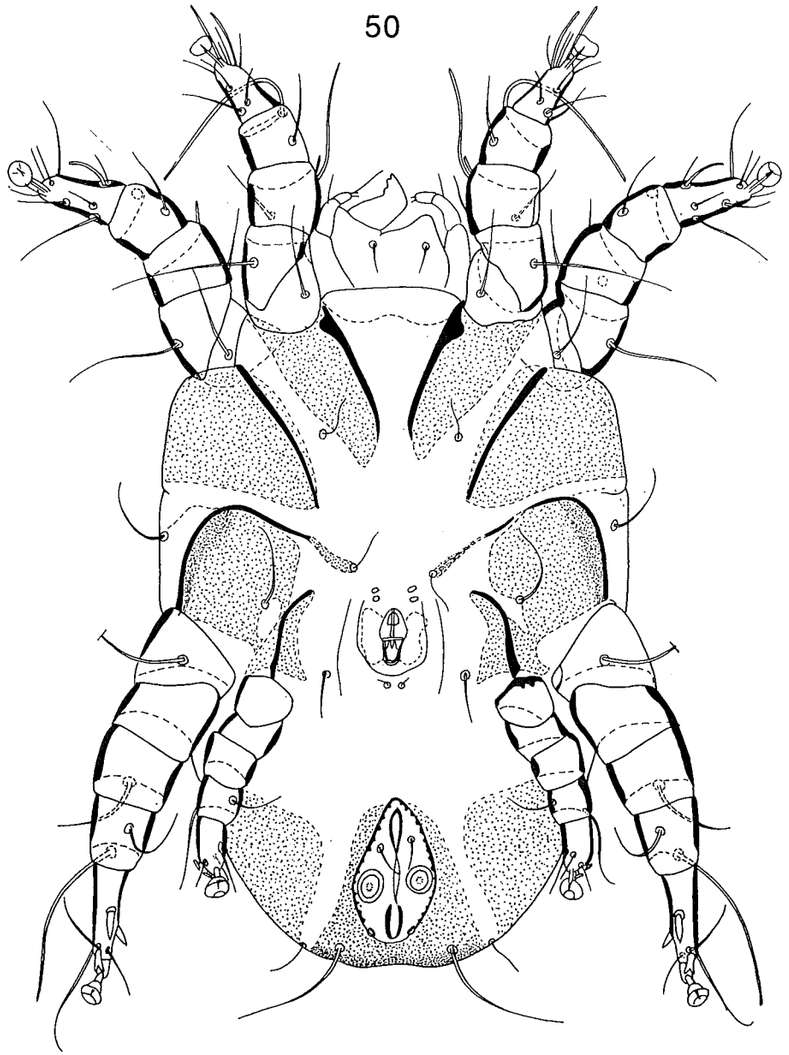

Fig. 50 *Hirstia domicola* Fain, Oshima and Van Bronswijk : Male in ventral view

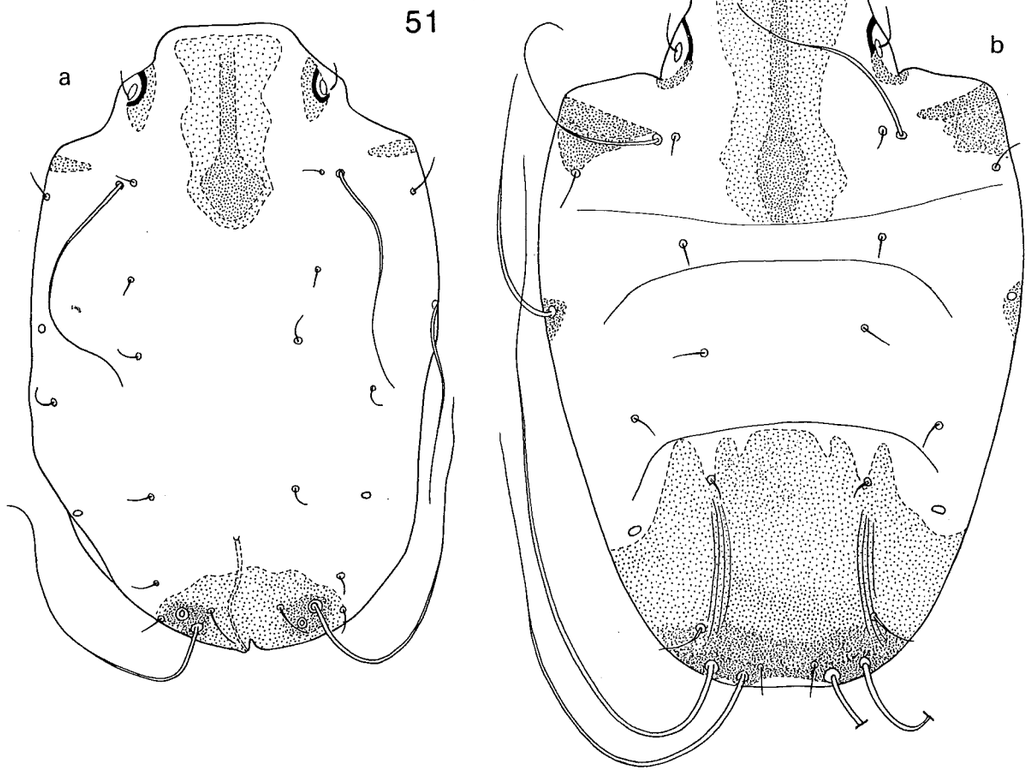

Fig. 51 *Hirstia domicola* Fain, Oshima and Van Bronswijk : Female (a) and male (b) in dorsal view

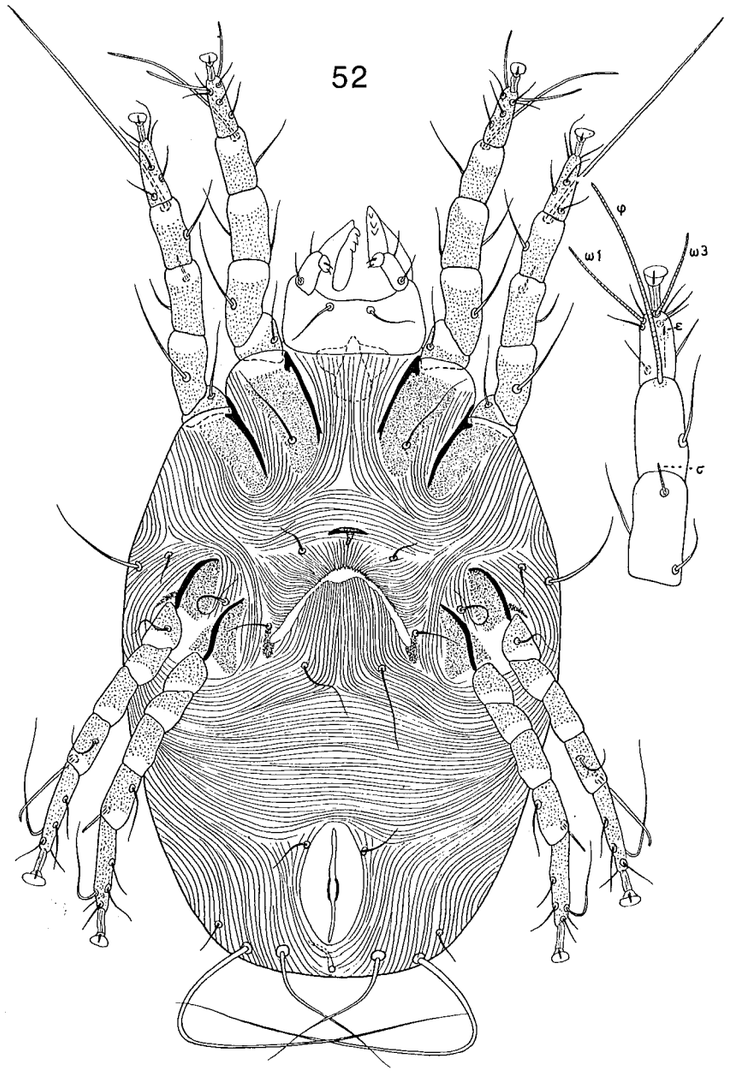

Fig. 52 *Malayoglyphus intermedius* Fain, Cunnington and Spieksma : Female in ventral view with leg I enlarged (a)

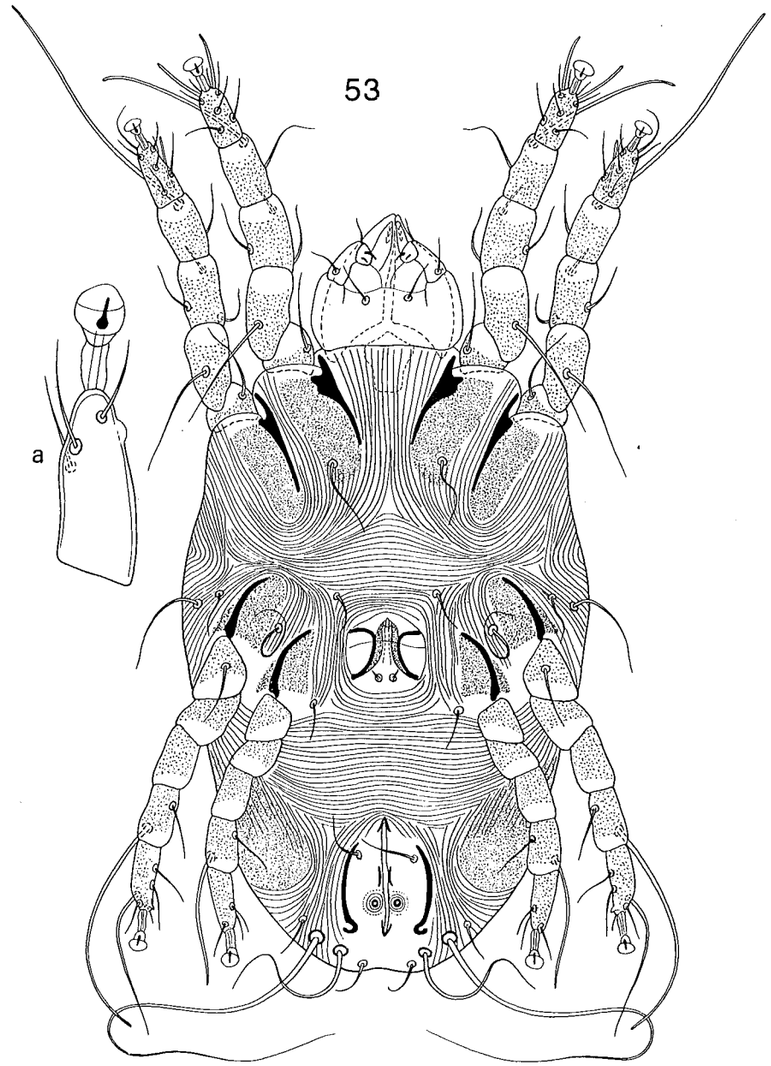

Fig. 53 *Malayoglyphys intermedius* Fain, Cunnington and Spieksma : Male in ventral view, with tarsus IV enlarged (a)

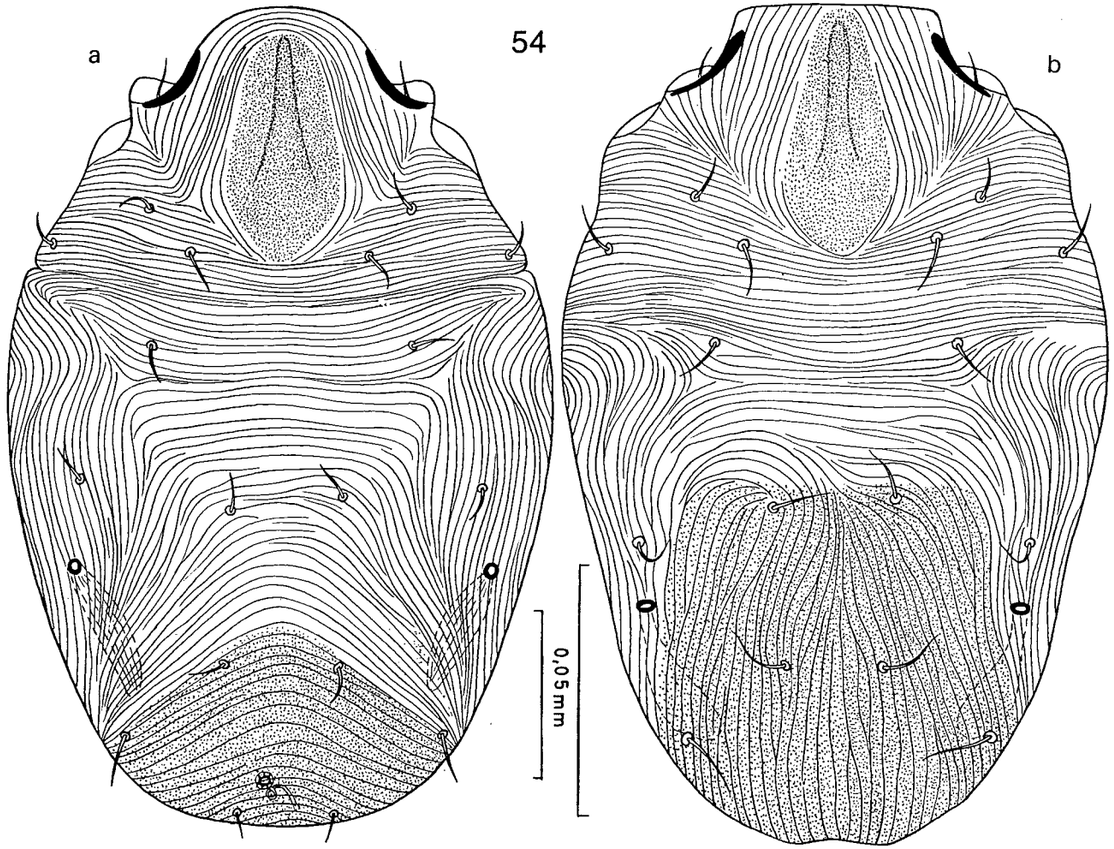

Fig. 54 *Malayoglyphus intermedius* Fain, Cunnington and Spieksma : Female (a) and male (b) in dorsal view

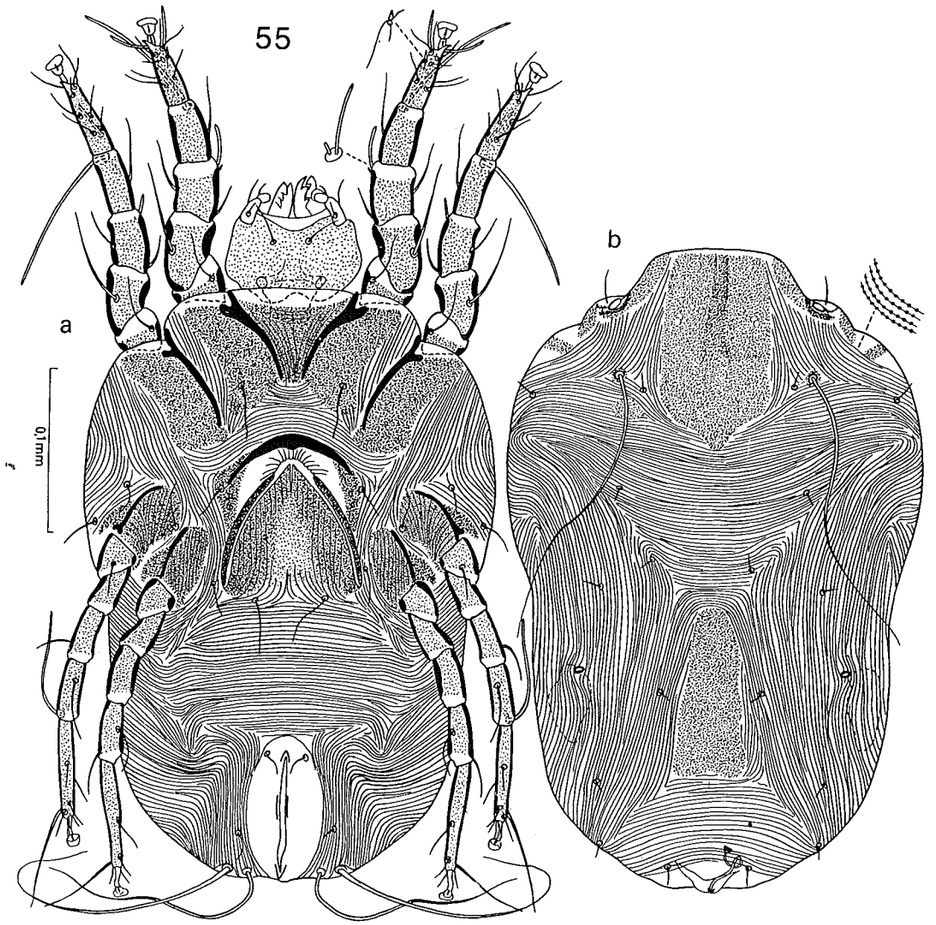

Fig. 55 *Sturnophagoides bakeri* Fain : Female in ventral (a) and dorsal (b) view

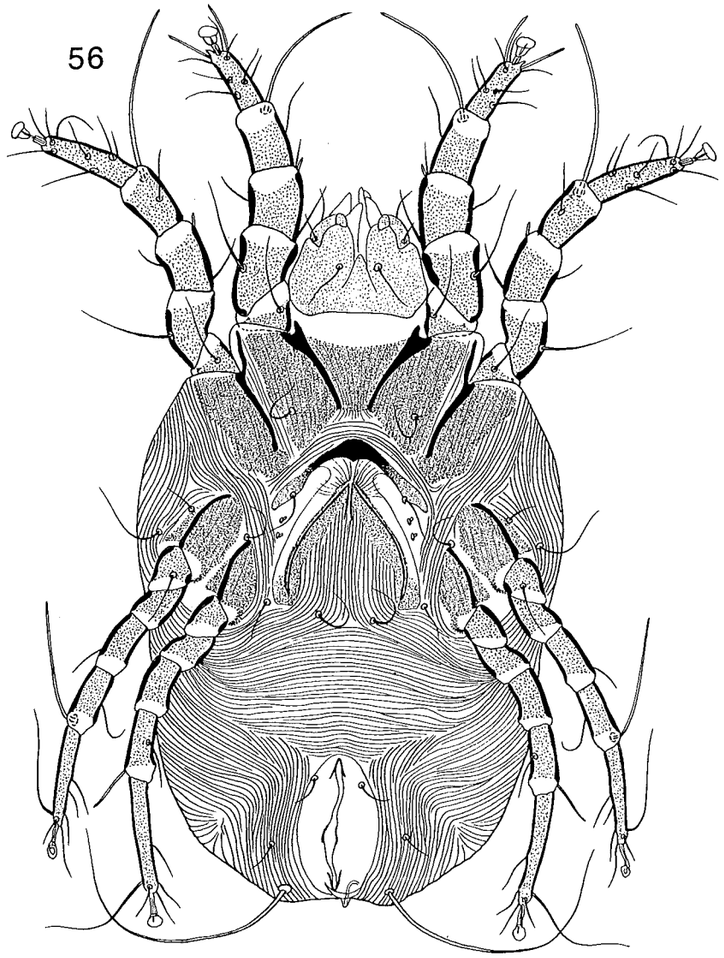

Fig. 56 *Sturnophagoides brasiliensis* Fain : Female in ventral view

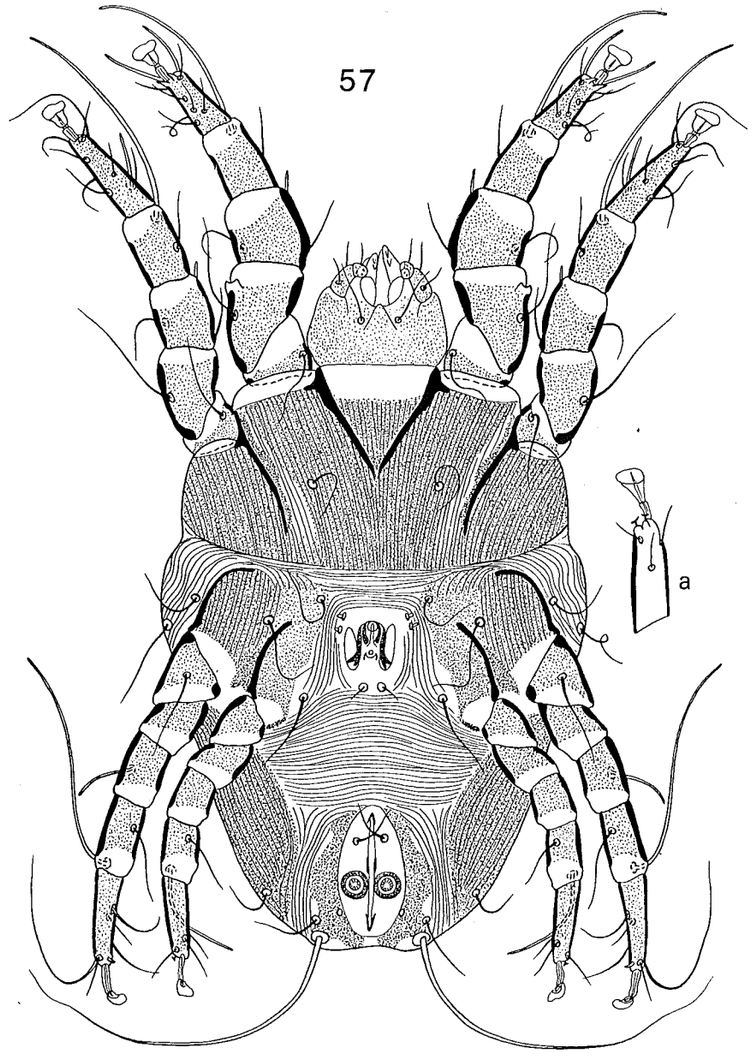

Fig. 57 *Sturnophagoides brasiliensis* Fain : Male in ventral view, with tarsus IV enlarged (a)

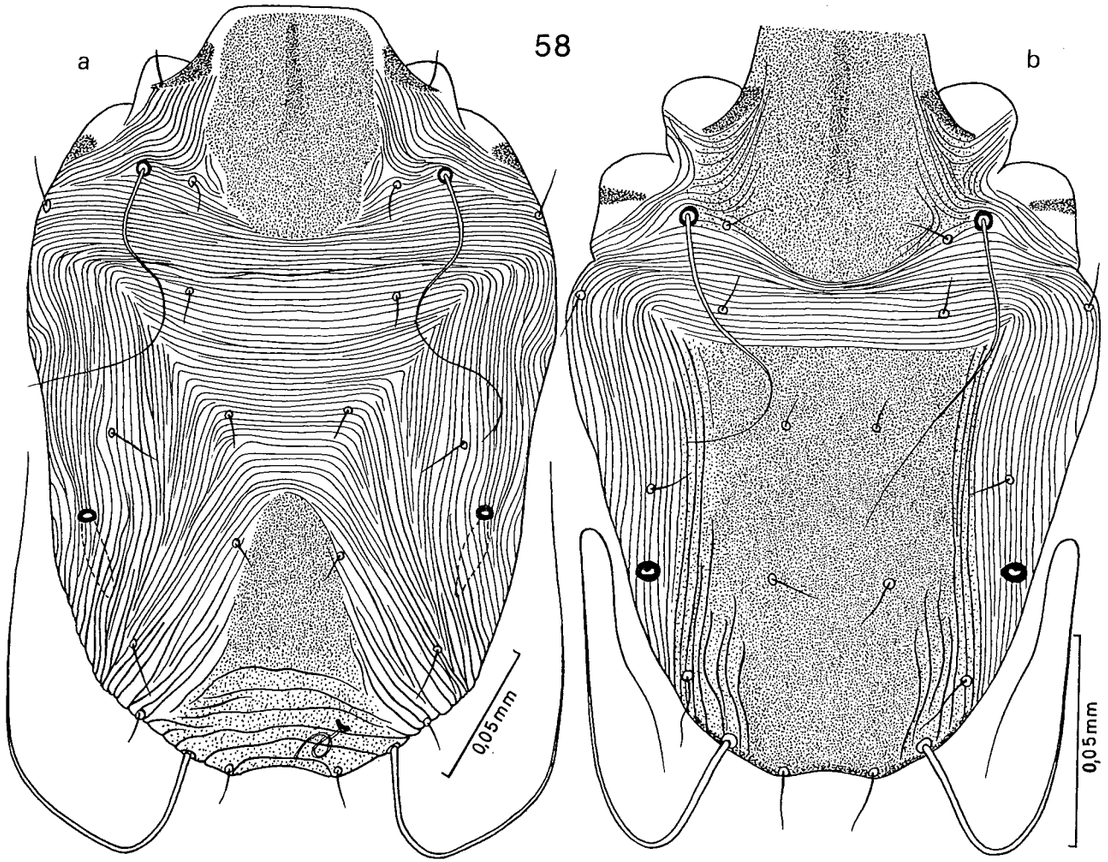

Fig. 58 *Sturnophagoides brasiliensis* Fain : Female (a) and male (b) in dorsal view

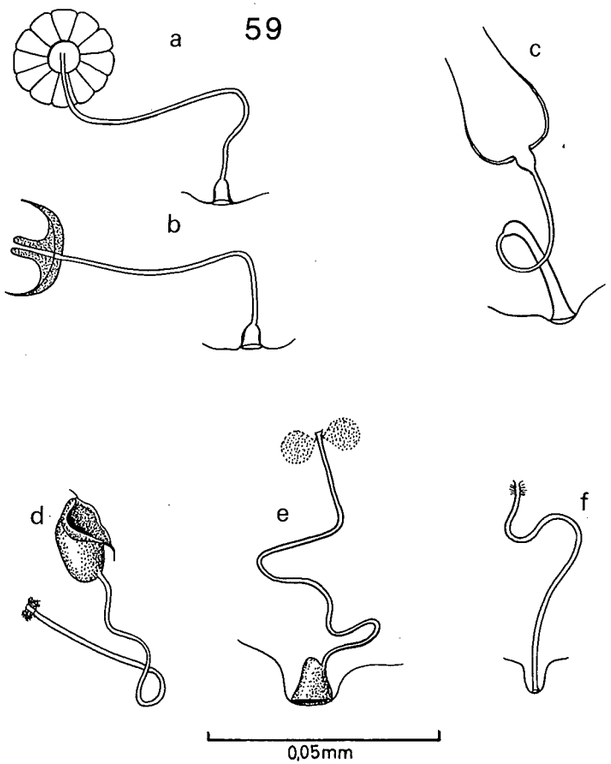

Fig. 59 Bursa copulatrix in : *Dermatophagoides pteronyssinus* (Trouessart) in two different positions (a et b) ; *D. evansi* Fain, Hughes and Johnston (c) ; *D. farinae* Hughes (d) ; *D. rwandae* Fain (e) ; *Hirstia passericola* Fain (f)

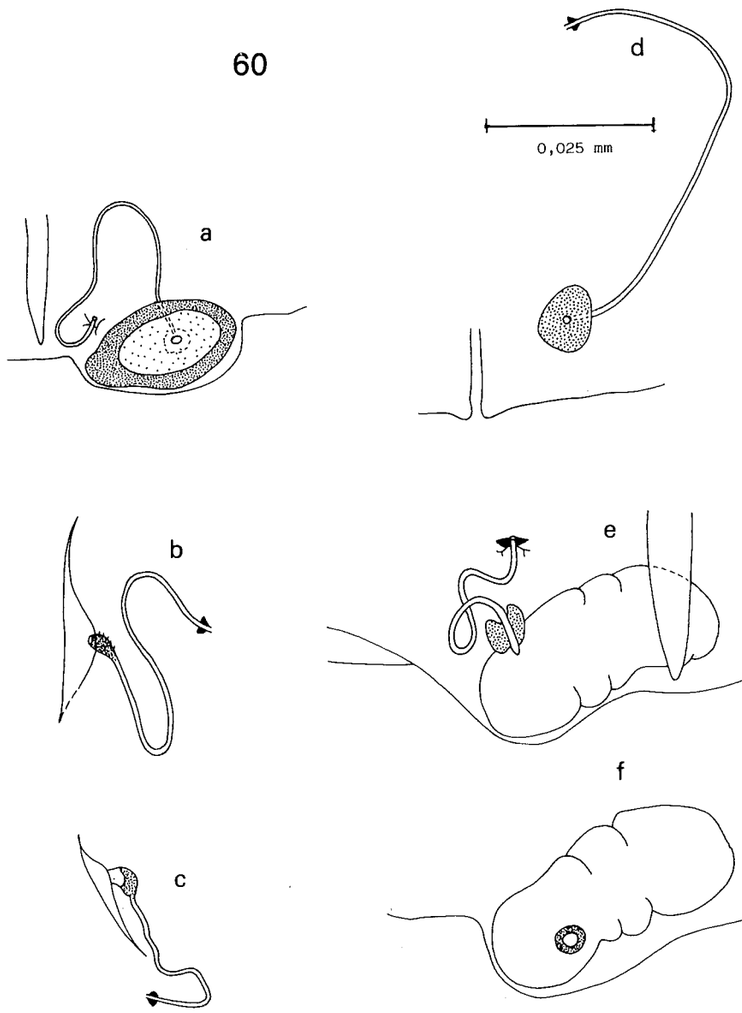

Fig. 60 Bursa copulatrix in : *Dermatophagoides sclerovestibulatus* Fain (a) ; *D. microceras* Griffiths and Cunnington (b) ; *D. siboney* Dusbabek, Cuervo and Cruz (c) ; *D. simplex* Fain and Rosa (d) ; *D. aureliani* Fain, in ventral (e) and dorsal view (f)

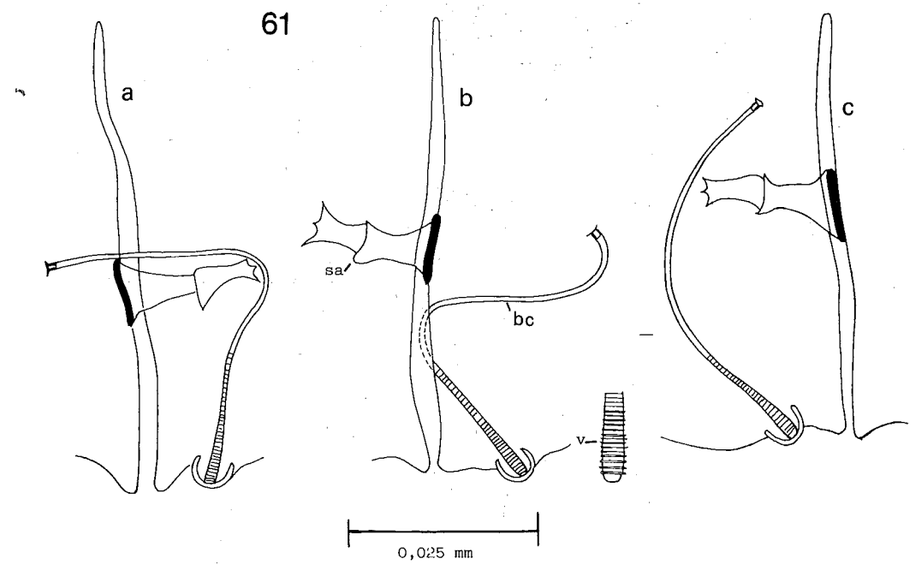

Fig. 61 Bursa copulatrix (bc) and anal sclerite (sa) in 3 females of *D. neotropicalis* Fain and Van Bronswijk : Holotype of *D. deanei* Galvao and Neide (= syn. of *D. neotropicalis*) (a) ; 2 paratypes of *D.neotropicalis* (b et c). (v = distal part of bursa enlarged)

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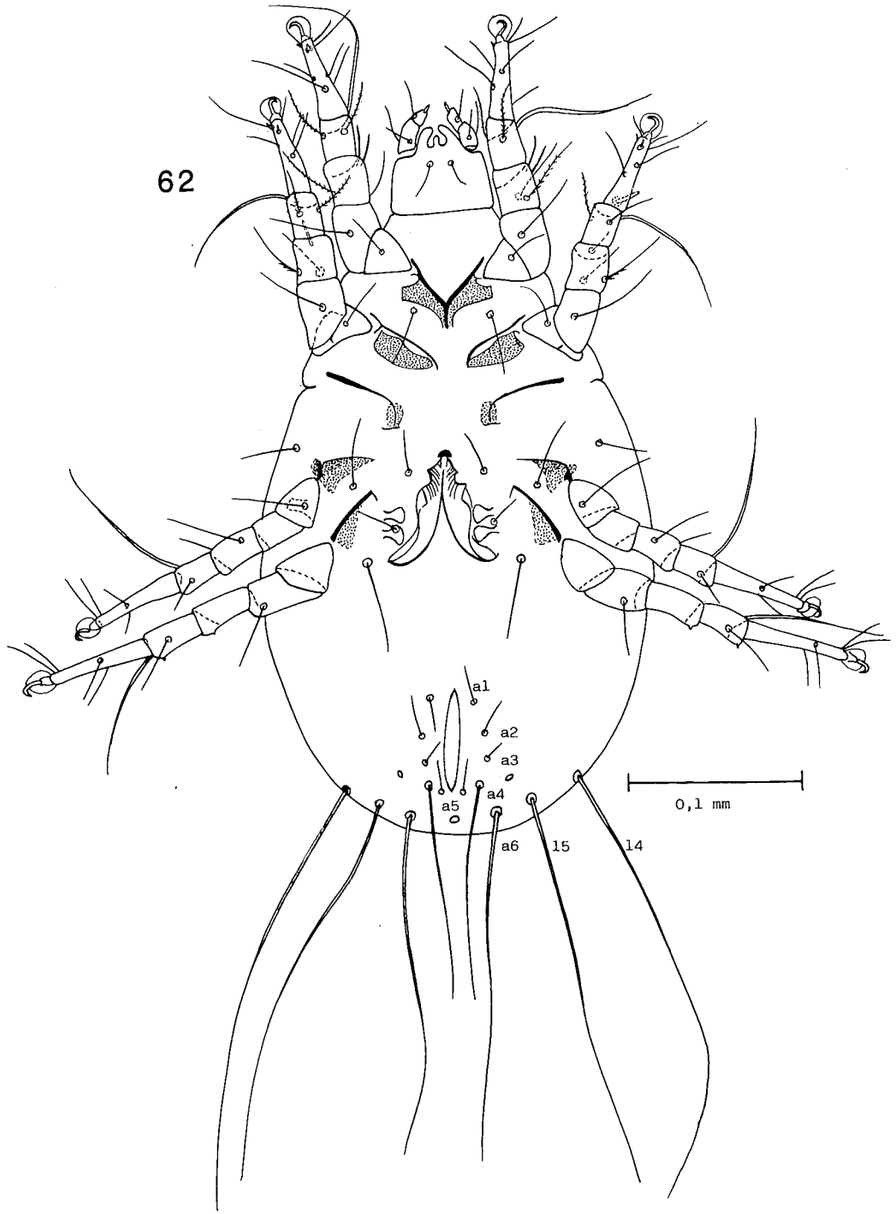

Fig. 62 *Tyrophagus putrescentiae* (Schrank) : Female in ventral view

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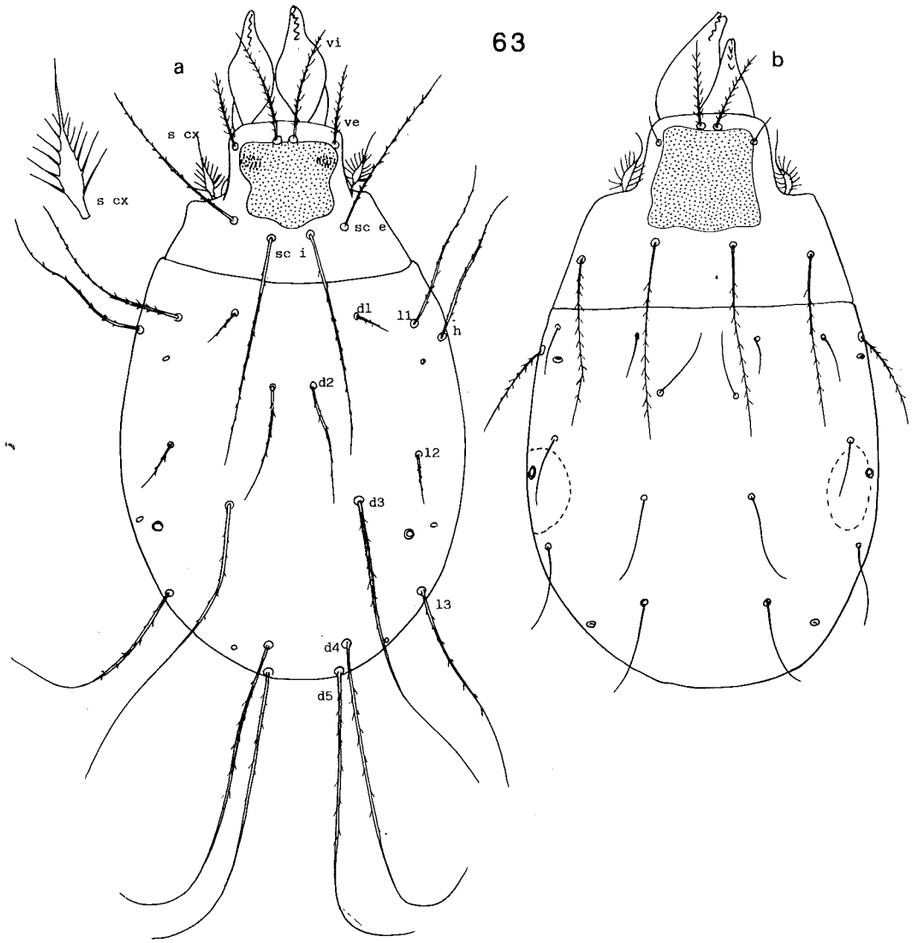

Fig. 63 *Tyrophagus putrescentiae* (Schrank) (a) and *Acarus siro* L. (b) : Females in dorsal view

Fig. 64 *Tyrophagus putrescentiae* (Schrank) (a) and *Acarus siro* L. (b) : Males in ventral view. Penis of *T. putrescentiae* in lateral view (c)

Fig. 65 *Acarus siro* L. : Female in ventral view

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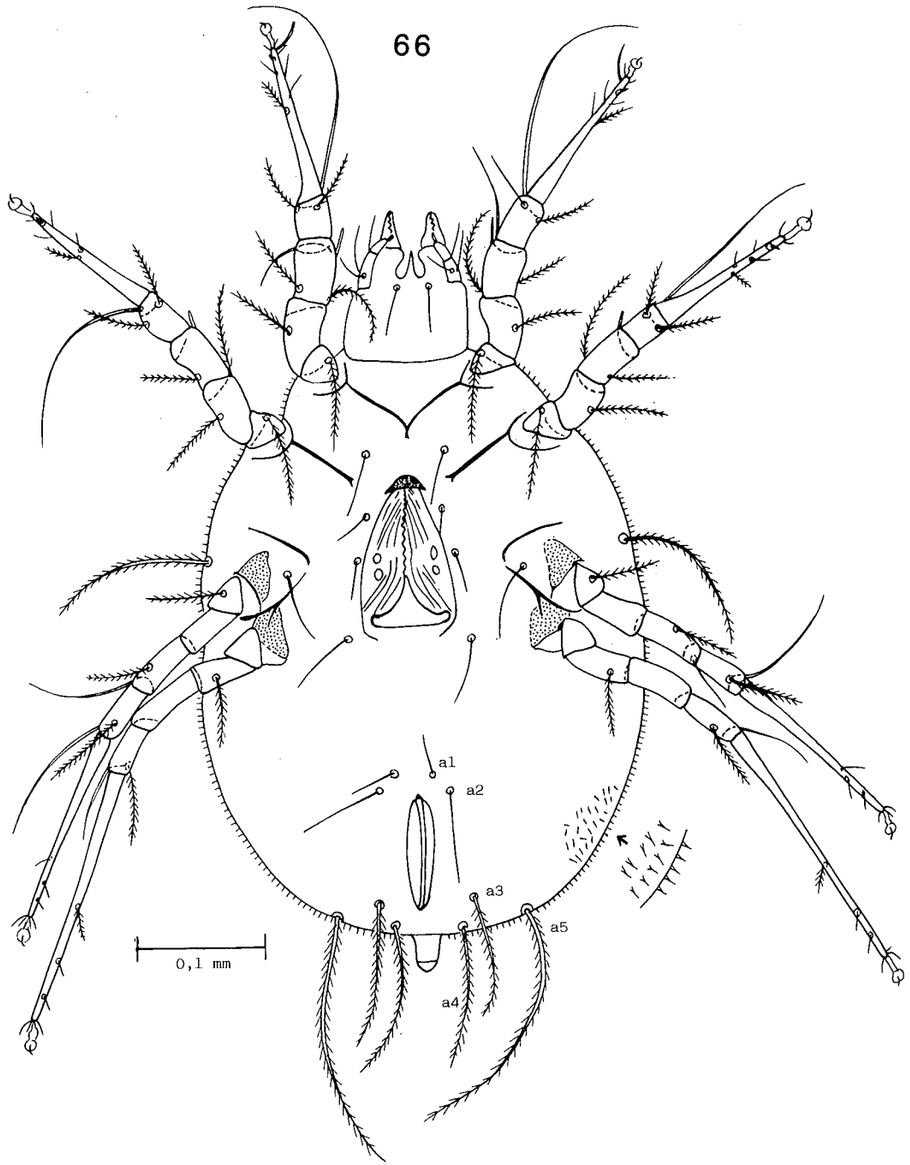

Fig. 66 *Glycyphagus domesticus* (De Geer) : Female in ventral view

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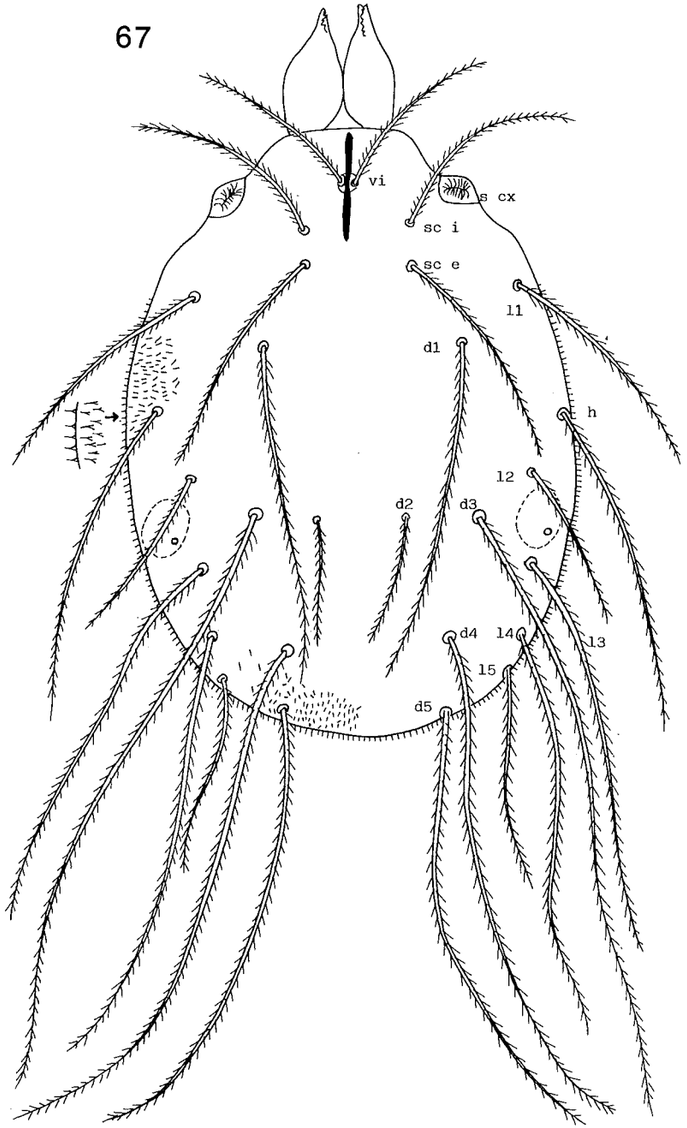

Fig. 67 *Glycyphagus domesticus* (De Geer) : Female in dorsal view

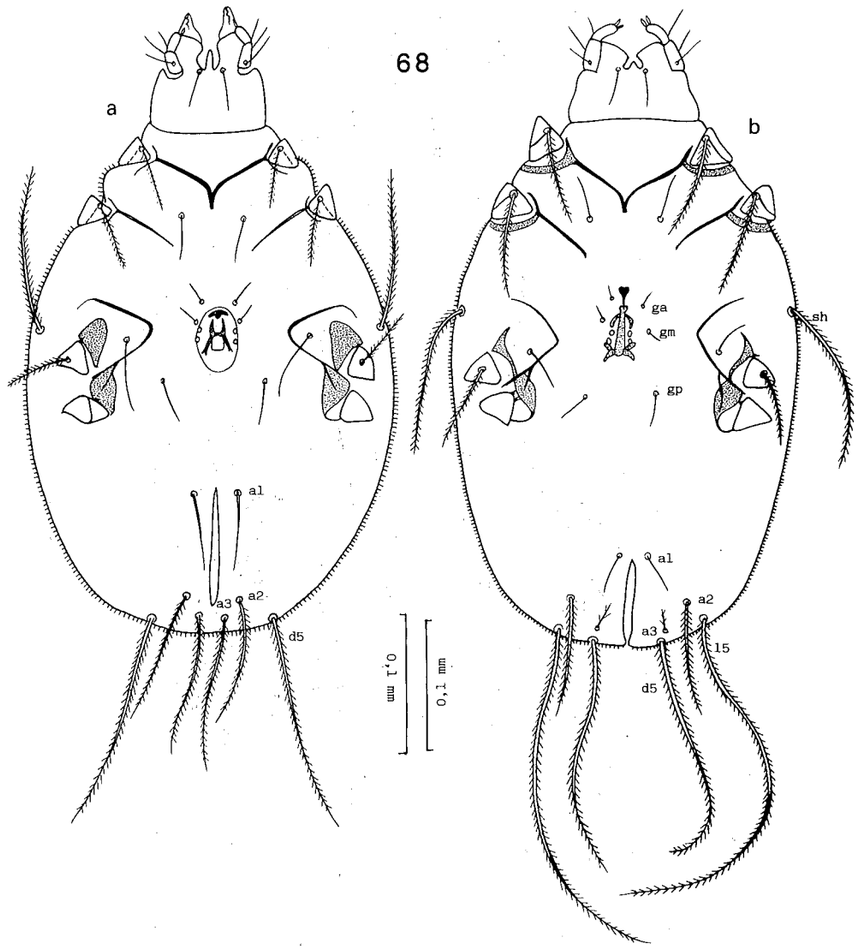

Fig. 68 *Glycyphagus domesticus* (De Geer) (a) and *Lepidoglyphus destructor* (Schrank) (b) : Males in ventral view

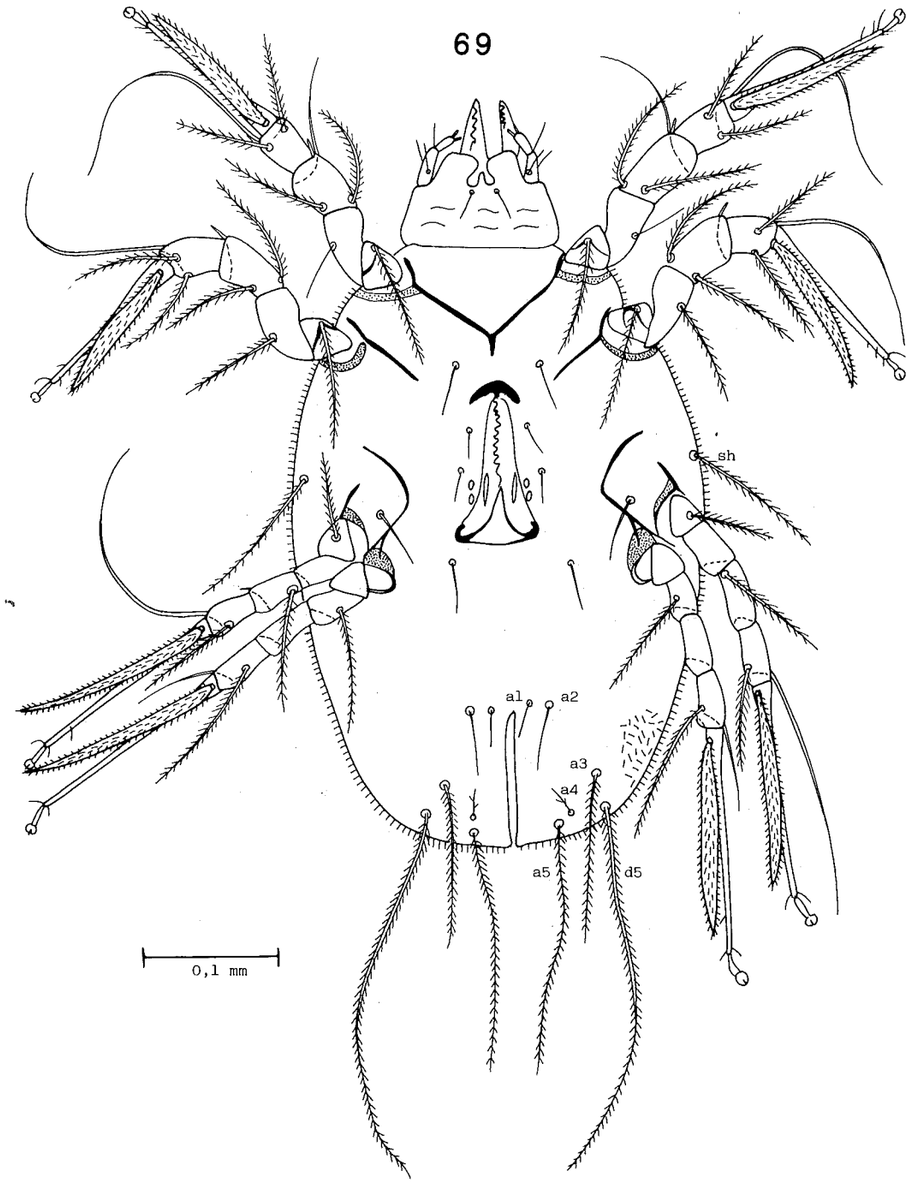

Fig. 69 *Lepidoglyphus destructor* (Schrank) : Female in ventral view

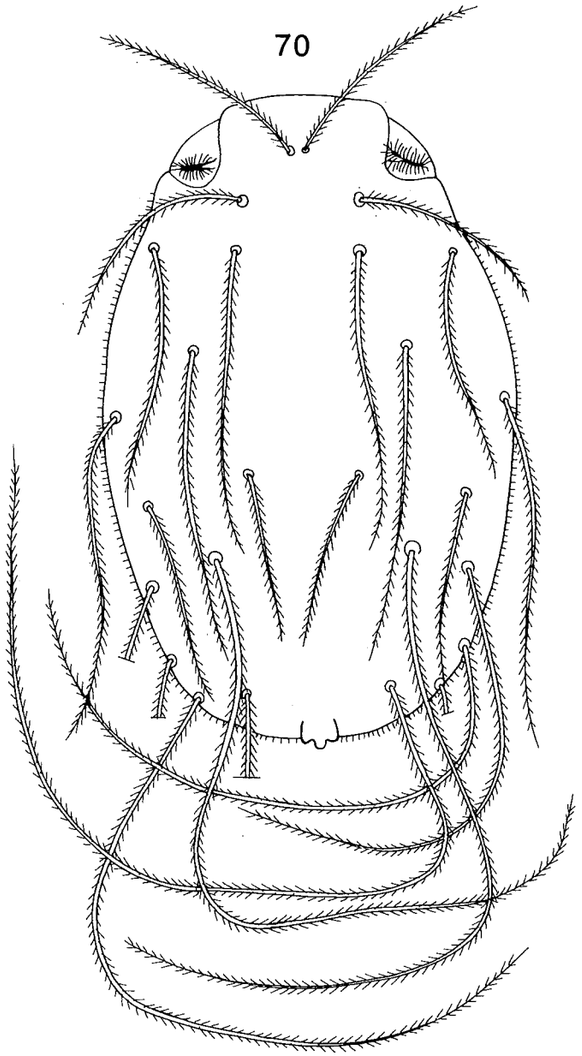

Fig. 70 *Lepidoglyphus destructor* (Schrank) : Female in dorsal view

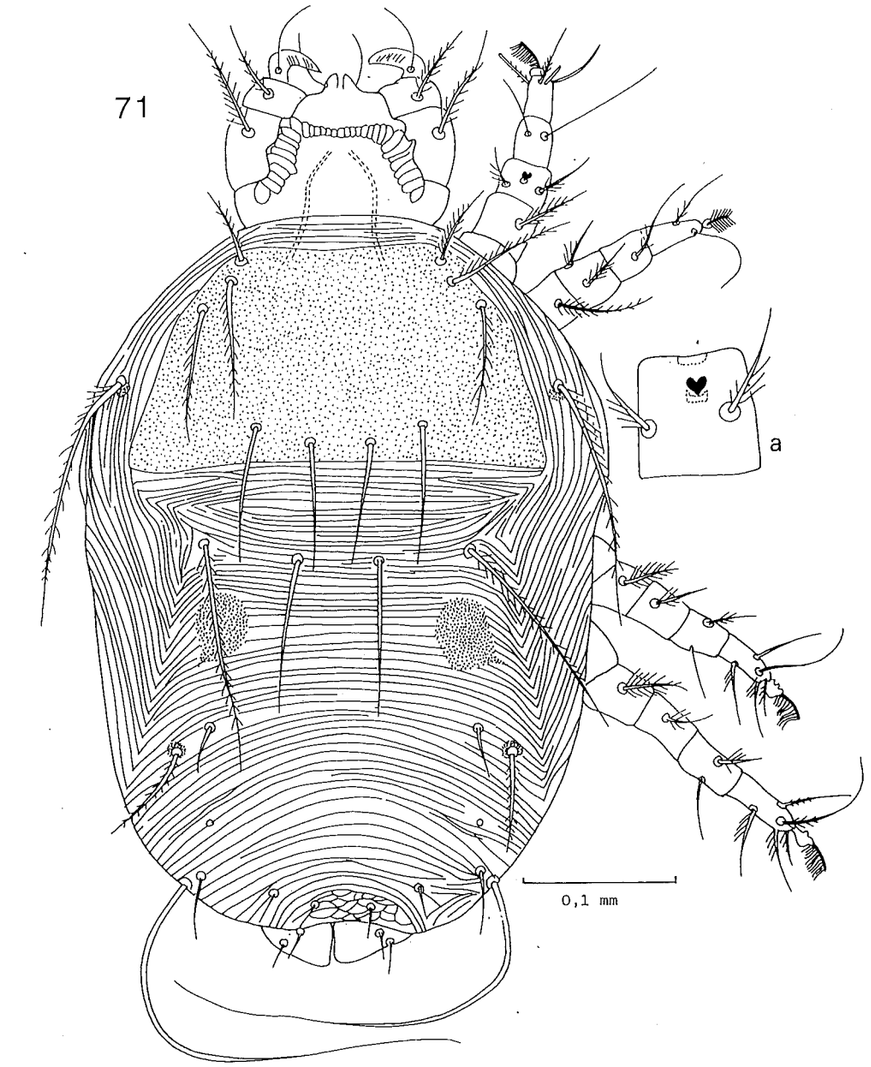

Fig. 71 *Cheyletiella yasguri* Smiley : Female in dorsal view, with genu I enlarged (a)

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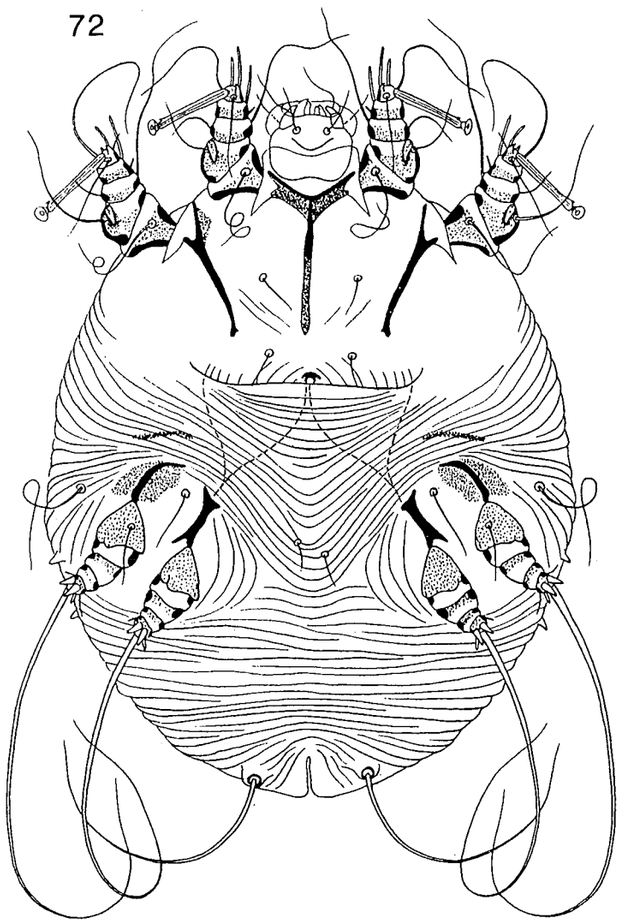

Fig. 72 *Sarcoptes scabiei* (L.) : Female in ventral view

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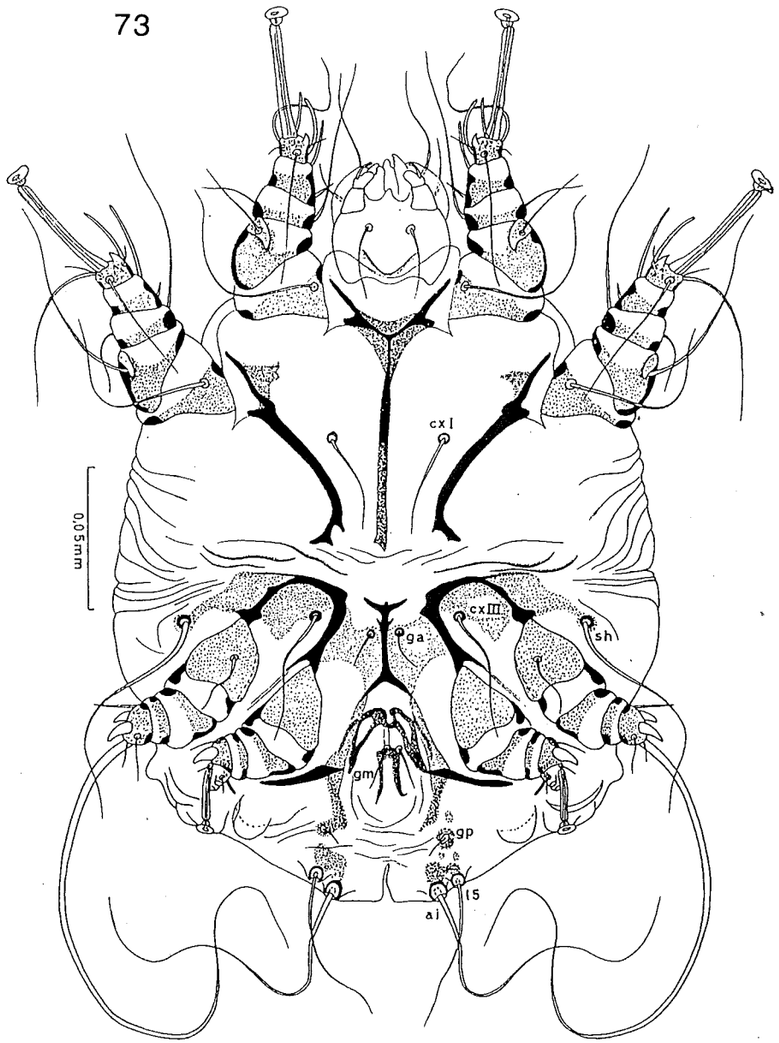

Fig. 73 *Sarcoptes scabiei* (L.) : Male in ventral view

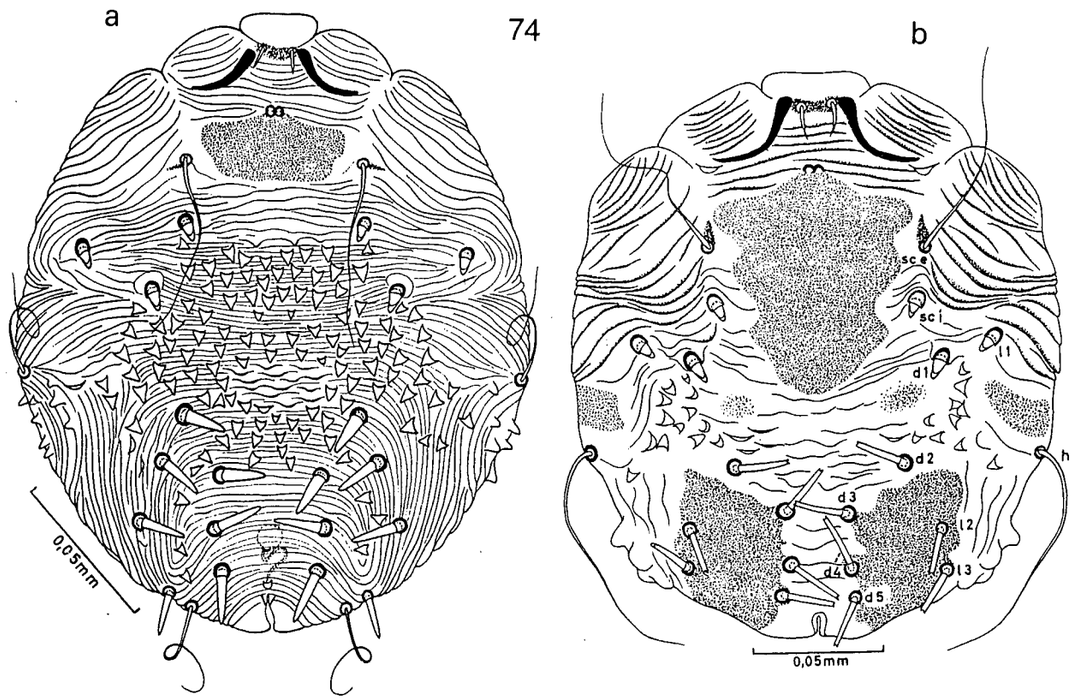

Fig. 74 *Sarcoptes scabiei* (L.) : Female (a) and male (b) in dorsal view

CHAPTER II

Ecology and biology of allergenic mites

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Introduction

The discovery in 1964 of asthma provoking house dust mites (Voorhorst *et al.*, 1964) resulted in widespread interest in every aspect of these mites, including their ecology and biology. Many studies in these particular areas have been embarked upon, usually with a view to finding some feature which may be exploited in the control of house dust mites. As a result, we now have concrete indications of the ecological factors which influence the numbers and species of mites present in house dust, e.g. season, temperature, humidity, predators, fungi etc. In addition, various studies have elucidated the life cycle, temperature, humidity and nutritional requirements of a number of dust mite species when reared in the laboratory.

To date, these studies have primarily involved the two most common species of dust mites, *Dermatophagoides pteronyssinus* and *Dermatophagoides farinae*, and the ecology and biology of these mites has been extensively reviewed by Bronswijk and Sinha (1971) and Wharton (1976). Nevertheless, research done since these reviews has provided further information on these species. More recently, another Pyroglyphid mite, *Euroglyphus maynei*, has been found to have a widespread distribution in e.g. Europe, Asia, Africa and Australia and has increasingly been considered as an important source of house dust allergens. Unfortunately, however, this species is extremely difficult to culture in laboratory conditions and consequently, to date, information on the biology and also the allergenicity of this species is extremely limited. Nevertheless, laboratory cultures have now been established, thus enabling the first studies on the biology (Nannelli *et al.*, 1983; Hart & Fain, 1988) and also the allergenicity (Hage-Hamsten & Johansson, 1989) of this species. Many other species of Pyroglyphidae, such as *Dermatophagoides microceras, Dermatophagoides evansi, Hirstia domicola, Malayoglyphus intermedius* and various other species which are often found in dust samples are described in Chapter I, however information on their biology, ecology and allergenicity is extremely limited (Griffiths & Cunnington, 1971; Lind, 1986).

In addition to allergenic Pyroglyphidae, house dust and stored products contain various mites in the families Acaridae and Glycyphagidae, of which *Glycyphagus domesticus, Lepidoglyphus destructor, Tyrophagus putrescentiae* and *Acarus siro* are known to be allergenic. Despite their medical and economic importance, information on these mites is limited (Sinha, 1964; Hughes, 1976; Arlian *et al.*, 1984; Eaton *et al.*, 1985a; Hage-Hamsten *et al.*, 1987) and further research is required to complete our knowledge of the biology, ecology and immunology of these mites in order to determine the relative importance of each species in the aetiology of allergic disease. This knowledge could in turn be employed in formulating methods of prevention or control of allergic disease.

The mite *Sarcoptes scabiei* causes the disease scabies in humans and other animals. These mites reside in the lower stratum corneum of the epidermis and their presence provokes a cell-mediated and humoral response in the host. Investigations of the humoral response have yet to unequivocally determine the importance of allergic IgE responses in scabietic patients. This topic will not, however, be covered in this chapter as an excellent 'status of the art' review of the biology, ecology, physiology and immunology of *S. scabiei* has recently been published (Arlian, 1989).

This chapter does not attempt to provide a complete review of the ecology and biology of allergenic mites, but rather aims to provide practical information to those unaccustomed to working with these mites. Various aspects of the ecology of these mites are described in Chapter I and this information is supplemented in the present chapter by sections on the collection of dust samples, extraction of mites from dust, their identification and quantification. Areas of the biology of these mites relevant to their role in the aetiology of dust mite allergies are detailed, in addition to laboratory methods for culturing allergenic mites to provide material for biological and immunological studies. Areas for further investigation are highlighted, in the hope of stimulating research which will enhance our understanding of the biology and ecology of all mites involved in respiratory allergies, and thus contribute to the development of effective prevention or control measures against allergenic mites.

I. ECOLOGY

1. GENERAL ECOLOGY OF DUST MITES

The habitat of house dust mites

The majority of mites in the family Pyroglyphidae inhabit the nests of various birds and mammals and, therefore, the mites of this group which inhabit house dust have probably evolved from nidicolous nest inhabiting mites, having become adapted to the environment, or 'nest', of man. In this environment, pyroglyphid mites do not normally come into direct contact with man, but rather they survive, develop and feed in house dust. House dust is a heterogeneous mixture including synthetic and natural fibres, dander, minerals, salt, ash, pollen, fungi and insect fragments. Chemical analysis of a heterogeneous floor dust demonstrates a high mineral content and also significant quantities of proteins and carbohydrates, whereas in mattresses the protein content is higher and skin scales are the main components (Bronswijk, 1981). The main constituent of the diet of house dust mites is generally considered to be human skin scales. It is not surprising, therefore, that within the home, pyroglyphid dust mites are usually most abundant in mattresses, and also sofas and other upholstered furniture, since these are the areas where man spends prolonged resting periods and are therefore the niches where skin scales accumulate.

Distribution and abundance of mites in dust

Although pyroglyphid house dust mites are found mainly in mattresses, studies on their distribution within the mattress have yielded varying results. Maunsell *et al.*(1968), Sesay and Dobson (1972) and Bronswijk (1973) found that the superficial layers of the mattress were richest in mites, wheras Mulla *et al.*(1975), Dusbabek (1979) and Colloff (1988) found most mites at the sides of the mattress. The distribution of dust over the mattress surface is greatly influenced by the pattern of seams, tags or buttons and accumulations of mites have been found in these areas (Blythe, 1976).

In addition to mattresses and upholstered furniture, pyroglyphid dust mites are found, although in lower numbers, in floor dust, particularly when the flooring is covered with carpet. These mites are also sometimes found in high numbers in soft toys (Hart & Young, personal observations), which may be of importance in childhood asthma, and they are more rarely found in pillows, bedding, clothing and curtains. A recent study by Eaton *et al.* (1985b) found pyroglyphid house dust mites in significant numbers in pets' beds.

In contrast, mites of the families Acaridae and Glycyphagidae are more abundant in floor dust than in mattresses, upholstered furniture etc. The latter mites are probably not truly associated with man since they do not feed on skin scales, but on grains and other small food particles likely to be present in floor dust. The primary niches of these mites are grains and other stored food products and they are probably only transient occupants of houses, nevertheless, in certain circumstances these mites may proliferate in the home (Cooreman, 1944).

Microclimate of house dust

The influence of the climate of houses on dust mites, particularly *D. pteronyssinus*, has been studied in some detail and the major limiting factor is thought to be indoor air humidity of the house (Bronswijk, 1973; Cunnington, 1980). Temperature appears to be of less importance. Dust mites osmoregulate through their cuticle and therefore require a high ambient humidity to prevent excessive water loss. They will therefore proliferate at an absolute indoor air humidity of 7 gm/kg (equivalent to a relative humidity of 75% at 15°C) (Korsgaard, 1979), however indoor humidity rarely reaches such high values, except in areas with excessively high outdoor humidities. This apparent contradiction can be explained by examining the microclimate of the main niche of these mites, i.e. mattresses.

During the approximately 8 hours when a mattress is occupied, the heat and transpiration of the occupant cause the temperature to rise to between 25 and 30°C, regardless of ambient temperature, and the relative humidity increases by 5 to 8% (Haarløv & Alani, 1970; Koekkoek & Bronswijk, 1972; Hughes & Maunsell, 1973). Thus for up to 8 hours a day, mites in mattresses experience favourable conditions. Furthermore, if the bed is made immediately upon rising, it can take up to 16 hours for the temperature and humidity to drop to ambient levels (Taylor, 1971). Nevertheless, whatever the level of humidity during occupation, the minimum humidity of the bedroom while the mattress is unoccupied will be the limiting factor on the mite population. Each house has its own level of indoor humidity (influenced by number of occupants, heating, construction of house etc.) which will thus create between house differences in numbers of mites present.

Unlike mattresses that are occupied daily, carpets do not have a regular increase in temperature or humidity. They are therefore more influenced by the indoor air humidity of the house and are less able to support large mite populations if the indoor humidity is low. In support of this, Bronswijk (1973) in a study of mite population dynamics in mattresses and living room carpets, reported a constant but fluctuating population in mattresses, but found live mites in living room carpets only during the summer months when indoor humidity is at its highest.

Several factors may in turn influence the microclimate of mattresses. The effects of using an electric blanket were recently investigated by Mosbech *et al.* (1988). They found that within a month of using an electric blanket every day for 8 hours, the number of mites in mattresses were reduced by one half in comparison with control mattresses. The authors attribute this to the finding that within 3 hours of the blanket being turned on, the mattress temperature rose by 26°C and the relative humidity fell by 24%. In normal circumstances electric blankets are not left on for the prolonged periods used in this study and investigations into the influence of normal use of electric blankets would be of interest. One of the most important factors influencing the temperature and humidity of the mattress microclimate is the use of central heating. This is in turn related to the seasonality of house dust mite numbers and will therefore be dealt with in that section.

Other non climatic factors have been proposed as being important in influencing mite populations in mattresses. For example (Walshaw & Evans, 1987) in a study of dust mites in England found large numbers of mites in mattresses of working class people, and suggested that this may be due to heavier perspiration by people involved in more physical work. Increased products of perspiration, e.g. ionic sodium present upon skin scales were thought to positively influence survial of *E. maynei*. A positive relationship has also been suggested to exist between the age of the house furnishings and mite numbers (Bronswijk, 1981).

Seasonal influences on house dust mites

In temperate climates seasonal fluctuations in the numbers of mites found in house dust are evident, being low at the beginning of the summer and reaching a peak in late summer before dropping again in late autumn to low winter levels. This fluctuation results from a combination of outdoor temperature and humidity along with the use of central heating. In the summer months, windows and doors are open for prolonged periods and no heating is used, thus indoor humidity equilibrates with the high outdoor humidity at this time. During the winter however, doors and windows are less frequently opened and this together with the use of central heating creates a very warm, but very dry atmosphere in the home. Since mites require a high relative humidity to thrive, these conditions are unfavourable and result in a decline in mite numbers. Thus in winter, populations of house dust mite decrease, but the temporary increase in humidity of mattresses when occupied, enables mites in mattresses to survive these detrimental conditions better than mites in carpets. Despite the drop in mite numbers in early winter, the allergenic faeces produced by these mites remain in the environment and decrease more gradually (Figure 1). Thus although mite numbers show seasonal trends, the allergic symptoms to the allergens produced by these mites are non seasonal, as seen in perennial rhinitis.

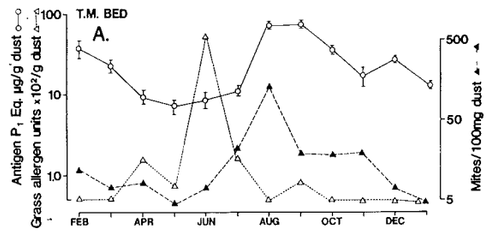

Fig. 1 : Amounts of mite allergen (P_1 Eq), mite bodies, and grass-pollen allergen in mattress dust sample (Virginia, U.S.A.), showing differences in seasonal fluctuations of mite bodies and faecal allergens. From Platts-Mills *et al* (1987).

It is possible that central heating along with modern measures to save energy, such as double glazing and other methods of insulation, result in conditions which are too dry and warm for efficient mite survival. Such conditions are found in new houses which often contain fewer mites than older, cooler, less well insulated houses (Haarløv & Alani, 1970; Koekkoek & Bronswijk, 1972). Korsgaard (1982), however, proposed that the lack of air circulation in well insulated houses actually raises indoor humidity. In a subsequent study (Korsgaard, 1983), preventive measures against house dust mites involved attempts to reduce the indoor air humidity by airing the house (opening the windows). The reduction in indoor humidity was limited and the number of mites increased over 24 weeks; however, the critical information on the time of year when this study was carried out was not described.

2. METHODS IN DUST MITE ECOLOGY

Collection of dust samples

Many methods of dust collection have been used, however the following method was recently described (Platts-Mills & de Weck, 1988) in an attempt to standardize the quantification of mites and their allergens in house dust samples:

"- Vacuum cleaners used for collecting dust samples can be equipped with a special attachment to collect dust on to a filter (e.g. linen or tissue paper) or the dust can be collected directly into a paper bag.

- Sampling time should be standardized and 2 min/m² has been commonly used.

- Sampling sites should be consistent and preferably the following sites should be sampled separately:

* The upper mattress surface (roughly 2m²) should be vacuum-cleaned for 2 min unless a shorter time provides a sample of > 200 mg. The sampling should be spaced out rather than concentrated in a single area. If the mattress is covered with plastic, the bedding should be sampled but results are not directly comparable with mattresses.

* Floor samples should be collected from an area of 1 m² in the bedroom immediately underneath and beside the bed.

* In the living room, i.e. the most occupied room away from the bedroom (not the kitchen), the carpet should be sampled in a sufficiently large exposed area (e.g. 1 m² for 2 min). Living room carpet samples can also be obtained from upholstered furniture, but results may be different from those in carpets.

- Alternative techniques of obtaining dust samples include shaking blankets in a plastic bag, using a hand-held brush to sweep surfaces and scraping flat surfaces higher than floor level with a piece of firm card, but these are less effective than vacuuming."

Comparisons of mite numbers and allergens in samples collected by various workers would be greatly facilitated if sampling was standardized as outlined above. The only paramater which has not been taken into consideration here and which may affect mite numbers, thus making comparisons difficult , is the date of sampling. Since house dust mite numbers fluctuate according to season, dust samples collected at different times of the year will vary greatly in mite abundance. We recommend therefore that dust samples be taken, whenever possible, in late summer or early autumn and that the date of sampling should always be specified.

Should a dust sample be required simply to collect mites for setting up cultures, rather than for a quantitative analysis, the above guidelines are helpful, but it is not absolutely necessary to follow the sampling areas and times recommended. Mattress dust will normally provide the richest source of pyroglyphid dust mites and the dust from the living room floor may be more likely to contain non-pyroglyphid dust mites, such as Glycyphagidae and Acaridae (Colloff, 1987b; Hart, personal observations).

Extraction of mites from dust for identification and quantification

As with dust sampling, many methods have been described for extracting mites from house dust. Some of these have been reviewed by Wharton (1976), Gridelet de Saint-Georges (1975) and van Bronswijk *et al.* (1978).

All have advantages and disadvantages depending on equipment and time available, or whether a quantitative or qualitative analysis is required. Estimates of the extractive efficiencies of these techniques ranges from 60-90%, however these techniques can be rather complicated and usually require multiple sieving, centrifugation, flotation or filtration steps. These techniques are also often extremely laborious, which can be a considerable problem if a large number of samples require analysis as is often the case in clinical dust surveys. Recently, however a quick and simple technique was described (Fain & Hart, 1986; Hart & Fain, 1987) with an extractive efficiency of 97-98%.

Briefly, this involves soaking 0.1g dust samples for at least 4 hours in 80% alcohol in a glass cylindrical tube (12 x 3 cm). After this time the alcohol is poured off with minimum disturbance of the sediment and 80 ml of saturated NaCl is then added. After 10 min the sample is then decanted into small petri dishes and examined for mites floating on the surface. The mites can be removed from the saturated NaCl using a fine needle or loop and washed in 80% alcohol before mounting onto slides for identification and quantification.

In most studies mite densities are expressed as the number of individuals per unit weight of dust, however, this does not take into consideration the total weight of dust collected. Table 1 shows an example of the difficulties in quantifying mites from dust with respect to these variables. This has important implications, not only in ecological studies of dust mites, but also in clinical studies where comparisons of allergen exposure

Site Sampled	Weight of dust (mg)	Mites (per 100 cm²)	Mites (per 100 mg dust)
Dunlopillo mattress*	3.5	9.7	276.0
Bedside carpet	189.4	32.0	16.9

Table 1 : 10 cm quadrat samples from a holiday chalet (South Wales, March 1975). * Represent the mean of three samples. From Blythe (1976).

between patients may be influenced by differences between homes in the amount of dust collected. This question has not been addressed by many workers (Blythe, 1976; Ishii *et al.*, 1979) and would be worthy of further investigation.

Identification of house dust mites

LIGHT MICROSCOPY

This is the most common technique used for identifying mites from dust samples or laboratory cultures. In order to identify mites accurately, a phase contrast light microscope should be used, as many of the important characters are not clearly visualized by bright field microscopes. For examination, the mites must be fixed, cleared and mounted onto a glass microscope slide with a cover slip.

To fix mites they should be soaked in 70-80% alcohol for at least an hour, although if the extraction technique involves soaking the samples in alcohol, this step is not required. The mites in the alcohol should then be transferred to a watch glass and, using a dissecting microscope, a cold light source and a fine needle or sable hair brush, the required number of mites should be transferred to a drop of mite mountant on a microscope slide and washed in this in order to remove any excess alcohol. The mites should then be immediately transferred to a fresh drop of mountant on another clean microscope slide and orientated with the anterior ends directed towards the observer (so that the anterior end will appear towards the upper part of the field of view and the slide label will be in the correct orientation when examined under a compound microscope). A round coverslip (12-16 mm diamaeter, number 0 thickness) should then be carefully applied. Mites should be placed at the bottom of the drop of mountant, as if placed on the surface they will move to the edge of the coverslip when it is applied.

Mounting large numbers of mites from dust samples (which can be as many as 500-1000 per gram of dust) is extremely laborious and would necessitate several hours for one sample. However Colloff (1989) described a simple technique whereby large numbers of mites can be transferred directly onto microscope slides. Briefly, after extraction from dust, the mites are transferred, using a Pasteur pipette, to a watch glass containing distilled water. This is then frozen at -20°C to -70°C. The block of ice is then emptied onto a siliconised slide (Sigmacote, Sigma Chemical Co., Poole, U.K.) and warmed on a hot plate until all the water has evaporated. The mites are then mounted using a suitable mounting medium. Any problems experienced in removing the block of ice from the watch glass can be resolved by adding a drop of lactic acid to the sample in the watch glass before freezing.

An extremely effective mountant for the very small, lightly sclerotized mites found in house dust is Hoyer's mountant, the recipe for which is given below. The advantages of this mountant are that it clears the mites effectively, thus eliminating the necessity for a clearing procedure before mounting the mites ; it is water-soluble, thus enabling mites to be remounted if necessary (simply scrape off the ringing medium and soak the coverslip in water to remove) ; and it can be used for permanant mounts. Various other mountants are commonly used, e.g. gum chloral and Heinze-PVA, however their clearing abilities are rather limited. For temporary mounts lactic acid can be used.

Once the mites are mounted onto slides, they should be labelled and placed into an oven or onto a hot-plate at 45-60°C for 5 min after which time the coverslip should be pressed gently to remove any excess mountant. This procedure has the added advantage of helping to extend the legs and mouthparts of the mites, thus making them easier to examine. After this procedure the slides should be returned to the oven or hot-plate and left at 45-60°C for 7-10 days for clearing. Permanent mounts can then be ringed or sealed with a suitable substance, such as Euparal, Glyceel (both from BDH Ltd, Poole, U.K.) or clear nail varnish.

Recipe for Hoyer's Mountant (from Baker & Wharton, 1952):

- 50 ml distilled water
- 30 g clear gum arabic crystals (not powder)
- 200 g chloral hydrate
- 20 ml glycerine

Dissolve the gum arabic crystals completely in the distilled water at room temperature, shaking occasionally. Then add the chloral hydrate and the glycerine and again dissolve at room temperature. When dissolved the liquid may be filtered through a damp cotton gauze.

SCANNING ELECTRON MICROSCOPY (SEM)

Various techniques have been described for preparing mites for examination using Scanning Electron Microscopy (SEM) (Brody & Wharton, 1971; Mumcuoglu *et al.*, 1973). A simple, but effective technique involves mites firstly being cleaned of food particles by washing for 15 min in 0.05% HCl. They should then be dehydrated by washing for 10 min in a graded series of alcohols (40%, 50%, 60%, 70%, 80%, 90%) and finally by 3 x 15 min washes in absolute alcohol. The mites should then be critical point dried and positioned on platforms with adhesive tape before being coated with gold and examined under the SEM (Hart & Fain, 1988).

In practice the principal problems in preparation of mites for SEM are to completely free the mites of food particles adhering to the body, and also due to the weakly sclerotised cuticle of dust mites, collapse of the mite cuticle is a common occurrence. The latter problem may be overcome using cryo-SEM, although the availability of equipment to do this is very limited.

SEM is a rather specialized and elaborate technique and is therefore rather impractical for the identification of large numbers of house dust mites, nevertheless, it is an extremely useful tool when a detailed morphological study is required (Griffiths 1964, 1970).

ISOENZYME ELECTROPHORESIS

When live mites are available, species can be identified according to their carboxylesterase banding pattern obtained using various types of electrophoresis. Various methods have been described for use with house dust mites (Silberstein *et al.*, 1979; Dujardin *et al.*, 1981; Hart *et al.*, 1989) and differences in the banding patterns of different species are clearly seen. Electrophoresis does need some sophisticated equipment not required by light microscopy, however, once a reliable technique has been established, mites can in fact be identified relatively quickly. For example, the cellulose acetate system described by Hart *et al.* (1989), takes less than 2 hours to obtain results. Since electrophoresis requires live mites with active esterases, however, it is unlikely to be suitable for analysis of dust samples. Nevertheless, it is an invaluable tool in distinguishing between species which are almost impossible to distinguish morphologically, for example *D. farinae* and *D. microceras* or *T. putrescentiae* and *T. longior*. It can also be used to provide an insight into inter- and intraspecific differences and phylogenetic relationships between populations of house dust and other mites (Cicolani *et al.*, 1981; Hart *et al.*, 1989).

IMMUNOCHEMICAL ASSAYS

Immunochemical assays using ELISA (enzyme-linked immunosorbent assay), RAST (radioallergosorbent test) inhibition or inhibition RIA (radioimmunoassay) have recently been developed for the identification and quantification of mite allergens in house dust samples (Lind, 1986; Platts-Mills *et al.*, 1986; Woods *et al.*, 1986). Because these assays provide an accurate estimate of allergen levels in dust samples they are invaluable in clinical assessments of mite allergens in houses. Good correlations have been found between allergen levels determined using these assays and mite numbers and, in addition, since the relevant allergens have species specific epitopes, different species of Pyroglyphidae in dust samples can be inferred from the presence of their allergens. These in vitro assays require trained laboratory technicians and sophisticated laboratory equipment, but once set up they can be automated for large scale clinical dust surveys, for which they are much less laborious than mite counts. To date, only three species of dust mites, *D. pteronyssinus*, *D. farinae* and *D. microceras* can be distinguished and quantified using these immunochemical methods and it is hoped that other important mite species, for example *E. maynei*, can be incorporated into this labour saving and effective means of assessing dust samples.

Another method recently developed to quantify dust mites and allergens in house dust is that based on measuring the dose of guanine in dust samples (Bischoff & Schirmacher, 1984 ; Le Mao *et al.*, 1988). Guanine represents the major final product of nitrogenous waste excretion of mites and the quantity of guanine in dust samples appears to give a good indication of the presence of mites. The guanine in dust samples is visualised in this method using a chemical colouration reaction and the method is simple enough to be carried out by patients themselves. Nevertheless, no indication of the species of mites present in dust is given and because allergens are not directly measured, this method is of limited use in clinical investigations.

II. BIOLOGY

1. ANATOMY AND PHYSIOLOGY OF DUST MITES

General anatomy

The general anatomy of mites is similar to that of insects (Evans & Murphy, 1987), the main differences being:

* a two part body consisting of the anterior prosoma and the posterior opisthosoma

* six pairs of prosomal appendages of which four pairs usually form walking limbs, all pairs being biramous

* the first pair of appendages are modified as pincer- or fang-like chelicerae which are pre-oral in position and involved in feeding

* the antennae are absent.

The majority of detailed studies specifically on the anatomy of house dust mites were carried out in the early 1970s (Brody & Wharton, 1970; Brody *et al.*, 1972; Wharton & Brody, 1972; Brody *et al.*, 1976). This work involved studies of *D. farinae*, but the information provided is also relevant to other species of Pyroglyphidae. Readers are advised to consult these publications for details of the anatomy, since the scope of this book permits details of only those features relevant to dust mite ecology and allergen production.

The mite cuticle, with its various secretions and hairs has been suggested as a source of mite allergens. As in insects it is divided into the endo- exo- and epicuticle with an outer wax layer. The wax layer is involved in oxygen, carbon dioxide and water vapour exchange. A number of glands open onto the surface of the cuticle. These include the lateral opisthosomal or oil glands (Figure 2) which may be important in secretion of pheromones such as citral (Brody & Wharton, 1970; Kuwahara *et al.*, 1980). The genital papillae or genital suckers are involved in secretion of adhesive substances for copulation. The supracoxal glands and the associated podocephalic canal (Figure 2) are involved in exchange of water vapour. The hairs or setae on the cuticle are in general reduced, indicating a progression towards parasitism and, although pyroglyphid dust mites are strictly speaking free-living, they have many anatomical features in common with the parasitic Psoroptidae and Epidermoptidae mites which are truly parasitic on birds and mammals (Fain, 1967b).

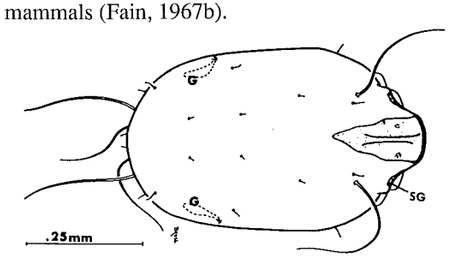

Fig. 2 : The dorsum of *Dermatophagoides pteronyssinus* protonymph showing the position of the lateral opisthosomal glands (G) and the supracoxal glands (SG). Modified from Brody & Wharton (1970).

Internally the body cavity consists of a haemocole, again similar to that of insects. This is filled with haemolymph which bathes the internal organs for exchange of gases and nutrients. The primary internal organs are the gut, the excretory tubules and the reproductive organs. The reproductive organs lie ventral to the gut in the posterior region, but no detailed study of this system has been done. More information is available as to the functional anatomy of the gut and excretory tubules and this will be dealt with in the following sections of this chapter.

Feeding and Digestion

The mouthparts of house dust mites are termed the gnathosoma and consist primarily of the chelicerae, pedipalps and the labrum. These components are moved by a combination of hydrostatic pressure and muscles which enables the chelicerae and pedipalps to manipulate solid food particles such as skin scales. The pedipalps are probably primarily sensory in function and the chelicerae are used for breaking up food and conveying it to the pre-oral region. When the pre-oral cavity is filled with food, it is closed off from the exterior in which the labrum plays an important part. A muscular pharyngeal pump then transports the food into the alimentary canal which consists of the pharynx, oesophagus, ventriculus (stomach), colon (intestine), post-colon (rectum and hind gut) and anal atrium. During passage of the food through the alimentary canal (by peristalsis), digestion and absorption into the haemolymph occurs by means of secretory and digestive cells lining the canal. Waste products are engulfed in a peritrophic membrane which is thought to be formed in the colon or posterior midgut and which surrounds the faeces when excreted. The formation of the peritrophic membrane is described in detail by Wharton & Brody (1972) who suggested that this membrane may be important in the allergenicity of house dust mites. Preliminary investigations (Thompson & Carswell, 1988) have indicated that the peritrophic membrane may be a source of allergens associated with mite faeces.

Excretion and osmoregulation

EXCRETION

Guanine is the chief nitrogenous waste product of dust mites. The process of excretion of this product is, however, unclear. Examination of dust mites and other mites in the same order has revealed very reduced or no excretory malphigian tubules associated with the gut, the most active site of excretion apparently being the

colon (Hughes, 1950; Wharton, 1976). Guanine spherules have been found in cells in the middorsal region and in the haemolymph, but the source of these is unknown. Since the group I major allergens are found in pyroglyphid mite faeces, further studies on excretion in these mites could contribute to our understanding of allergen production.

OSMOREGULATION

Humidity is the major limiting factor in the survival of dust mites and therfore an understanding of the process of osmoregulation may facilitate control measures involving humidity management (Korsgaard, 1983). Consequently osmoregulation has been studied in some detail in house dust mites, particularly *D. farinae* (Arlian & Wharton, 1974; Arlian & Veselica, 1981).

Pyroglyphid dust mites are 50-80% water by weight, but significant amounts of water are obtained neither from feeding nor metabolic production. To maintain their water balance, mites therefore rely on absorbing water from the atmosphere across the cuticle. In this context, the critical equilibrium activity (CEA) can be defined as representing the lowest ambient relative humidity (RH) at which mites can extract sufficient water to compensate for that which is transpired and thus maintain water balance and survive (Arlian & Veselica , 1981).

The CEA is 70% RH for *D. farinae* and 73% for *D. pteronyssinus* (Arlian, 1975). At relative humidities above the CEA, the balance between water loss and gain is maintained, but below the CEA mites lose water and eventually dehydrate and die. Nevertheless, mite populations are routinely found in homes where the RH is almost permanently below the CEA and indeed have been found to increase if the mean monthly RH exceeds 40-50% (Bronswijk, 1973; Dusbabek, 1975). This can be explained by the finding that in *D. farinae* the CEA for the temperature range 15-35°C ranges from 55 to 75% RH (Arlian & Veselica, 1981), thus enabling it to survive at a wide range of humidities. A similar range probably occurs for other pyroglyphid dust mites although each species seems to be adapted to slightly differing humidities.

Mites of the families Acaridae and Glycyphagidae are much more sensitive to dessication (Bronswijk, 1981), however populations of these mites can survive periods of dry conditions by the production of non-feeding hypopi which are resistant to harsh conditions. The Pyroglyphidae which do not have hypopi have therefore evolved to withstand water stress by having a wide humidity tolerance. Furthermore, the Pyroglyphidae have a quiescent protonymphal stage which is relatively impermeable to water, has a low oxygen consumption and which exchanges water much more slowly than active stages (Arlian & Wharton, 1974; Ellingsen, 1975, 1978). This stage is therefore well adapted to survival during extended dry periods and Arlian *et al* (1983) have suggested that this stage is crucial in winter survival of pyroglyphid mite populations in dry homes.

In addition to cuticular diffusion of water vapour, the paired supracoxal glands, located posterior to the supracoxal sclerite, are thought to play a crucial role in osmoregulation. Each gland has an external opening dorsal to the coxa of leg I and contains a secretion which runs from the opening into the pre-oral region of the gnathosoma. This secretion is hygroscopic and is rich in salts, thus enabling absorption of water from the atmosphere. When the humidity is low, solutes precipitate out of the secretion and block the opening of the gland rendering it impermeable to further water loss. This mechanism is reversible when mites are re-exposed to high humidities and has been observed in *D. farinae*, *A. siro* and *T. putrescentiae* (Wharton *et al.*, 1979).

Gaseous exchange

In allergenic dust and storage mites of the Order Astigmata, unlike other mite orders, no definable tracheal respiratory system is present. These mites exchange oxygen and carbon dioxide across the cuticle at a rate of 0.008 µl oxygen per hour at 75% RH in *D. farinae* females, whereas active and quiescent protonymphs of this species consume 0.11 µl and 0.003 µl oxygen per hour respectively (Arlian, 1972; Ellingsen, 1978). Little is known of the rates of gaseous exchange in other allergenic mites.

2. REPRODUCTION AND DEVELOPMENT OF DUST MITES

Various authors have investigated the reproduction and development of the Pyroglyphidae, principally *D. pteronyssinus* and *D. farinae*. More recently *E. maynei* and *E. longior* have been studied, but other species of Pyroglyphidae and also the acarid and glycyphagid storage mites await investigation. The results obtained by various authors to date have been collated and presented in Table 2.

Reproduction

Only sexual reproduction occurs in the Pyroglyphidae, Acaridae and Glycyphagidae and therefore both male and female sexes are found in these families. The adult males often mate with female tritonymphs, but males and adult females can also be observed mating in cultures.

The mating behaviour of *D. pteronyssinus* and *D. farinae* has been described in detail by Spieksma (1967) and Bronswijk and Sinha (1971). After mating the oviparous adult females lay eggs singly on the bottom of the culture dish or on firm substrate particles. Certain authors (Fain, 1969b, 1977; Bronswijk & Sinha, 1971) reported finding larvae in the body of females in various Pyroglyphidae and suggested that this family may therefore exhibit facultative viviparity. However, Fain and Hérin (1978) found that in *L. destructor*, eggs could continue to develop to larvae inside adult females which had died before laying their eggs. This phenomenon may also explain the 'viviparity' in *D. pteronyssinus* and *D. farinae*.

A few days after mating the female begins to lay eggs. The pre-reproductive period varies between species of Pyroglyphidae and may range from 9-13 days (Hart & Fain, 1988), although it has been reported to be as short as 3 days in *D. pteronyssinus* (Spieksma, 1967). *G. domesticus* and *T. putrescentiae* have pre-reproductive periods of 11 and 5 days respectively (Hart, personal observations).

The reproductive period or oviposition period again varies between species of dust mites and, as seen in Table 2, can range from 20-60 days (Spieksma, 1967; Hart & Fain, 1988). In *D. pteronyssinus* the female may have a second period of egg laying after the first (Spieksma, 1967). During the oviposition period, female dust mites may lay 40-80 eggs (Spieksma, 1967; Hart & Fain, 1988), except in *T. putrescentiae* which has been observed to lay as many as 207 eggs (Hart, personal observations). However, a very high fecundity of 200-300 eggs has also been reported for *D. farinae* and *D. microceras* (Griffiths & Cunnington, 1971; Furumizo, 1973). This variation in results can probably be explained by variation between different cultures of mites and rearing conditions (e.g. dietary components).

The rate of egg production is normally approximately one egg per day in Pyroglyphid dust mites (Spieksma, 1967; Furumizo, 1973; Hart & Fain, 1988), however *G. domesticus* and *T. putrescentiae* may produce as many as 3 and 7 eggs per day of the reproductive period (Hart, personal observations). In *D. pteronyssinus* the male has a life span of 60 to 80 days and the female of 100 to 150 days. The production of eggs by the female, however, has only been observed during the first half of her life (Spieksma, 1967).

In conclusion, the reproductive parameters may vary widely between different species of pyroglyphid dust mites reared in the same laboratory conditions. There is no trend for any one pyroglyphid species towards better reproduction than other species (Hart & Fain, 1988), although the extremely high fecundities reported for *D. farinae* and *D. microceras* should be confirmed. In contrast, the glycyphagid and acarid storage mites studied to date appear to differ significantly from the Pyroglyphidae, particularly with respect to their rate of reproduction which may be 3-7 fold higher than in the Pyroglyphidae and also in the high fecundity of *T. putrescentiae* (Table 2).

Nevertheless, exactly how these reproductive parameters, which have been recorded in laboratory conditions, relate to the natural situation in the house dust environment is not yet known. Recently, Colloff (1987c) reported differences in the development and mortality of eggs from laboratory and 'wild' populations of *D. pteronyssinus*, and suggested that in studies relating to passive physical control, caution should be taken in applying the conclusions to wild populations in the natural house dust environment.

Development

Pyroglyphid mites have six postembryonic developmental stages, each stage being separated by a moult; the egg, prelarva, larva, protonymph, tritonymph and adult (male or female). The deutonymph stage is not present in this family. The egg contains the prelarval stage which is represented by a transparent membrane bearing two sclerotized bosses which are ecdysing organs, serving to break the shell of the egg during emergence of the larva (Fain, 1977). The larva, protonymph and tritonymph have both active and quiescent phases and the development of the stages has been examined in detail for only *D. pteronyssinus* , *D. farinae* and *E. maynei*.

In *D. pteronyssinus* the egg stage lasts 6 days and the larval and two nymphal stages last 5-6 days, 4-7 days and 4-8 days respectively (Spieksma, 1967). In *D. farinae* the mean durations for each stage are: egg 8 days; larva 8.2 days; protonymph 8.3 days; tritonymph 7.6 days (Furumizo, 1973). The egg stage lasts 5-14 days in *E. maynei* and larva, protonymph and tritonymph last 10-17, 5-17 and 6-12 days respectively (Nannelli *et al.*, 1983).

Under optimal contiditons (± 25°C, 75% RH) the development from egg to adult for these three species has been reported to take approximately one month (Bronswijk & Sinha, 1971; Blythe, 1976), however the developmental time from egg to adult for *D. pteronyssinus* can be as short as 14 days (Hart & Fain, 1988). The times reported for development from egg to adult of various species of Pyroglyphid dust mites are summarised in Table 2.

TABLE 2 : REPRODUCTION AND DEVELOPMENT AT 25°C AND 75% RH IN THE PRINCIPAL SPECIES OF MITES RESPONSIBLE FOR RESPIRATORY AND CONTACT ALLERGIES

Species	Pre-reproductive period (a)	Reproductive period (a)	Fecundity (b)	Rate of reproduction (c)	Development egg to adult (a)	
D. pteronyssinus	9	34	58	1.79	14	Hart & Fain (1988)
	-	-	-	-	31-36;36	Blythe (1976) ; Gamal-Eddin & al. (1983)
	3	20	40-80	1.2-2.5	24 ; 23	Spieksma (1967) ; Ottoboni & al. (1984)
D. farinae	10	47	84	1.8	34	Hart & Fain (1988)
	-	-	200-300	-	32	Furumizo (1973)
	-	-	-	-	23	Gamal-Eddin & al. (1983)
	-	-	383	-	31-37	Griffiths & Cunnington (1971)
	-	-	-	0.8-1.4	30	Larson & al. (1969)
	-	30	-	0.8-1.4	24	Oshima & Sugita (1966) ; Ottoboni & al. (1984)
D. microceras	-	-	372	-	46-54	Griffiths & Cunnington (1971)
E. maynei	13	60	84	1.47	33	Hart & Fain (1988) ;
	-	-	-	0.4-0.8	30-35	Ottoboni & al. (1984)
	-	-	-	-	50-53	Nannelli & al. (1983)
E. longior	12	39	48	1.33	30	Hart & Fain (1988)
G. domesticus	11	26	81	3.29	17	Hart (Personal observations)
T. putrescentiae	5	30	207	7.39	10	Hart (Personal observations)
	-	-	500	-	14-21	Ottoboni & al. (1984)

Legend : (a) = Duration in days
(b) = Figures in eggs per female
(c) = Figures in eggs per female per day of reproductive period

The development of the Acaridae and Glycyphagidae are less well known than those of the pyroglyphid house dust mites. Again the Acaridae and Glycyphagidae have the egg, prelarva, larva, protonymph, tritonymph and adult stages, but in addition a third nymphal stage occurs between the proto- and tritonymph. This additional nymphal stage, called the deutonymph, is a facultative heteromorphic stage in which, under conditions of stress, an immobile hypopus is formed instead of a deutonymph. These immobile hypopi generally remain within the protonymphal skin and have evolved as a resistant stage for survival in extreme conditions, for example low humidity, but which may also have a role in dissemination, due to their small size which facilitates air-borne transport.

Data on the development times of these stages of the Acaridae and Glycyphagidae is extremely limited. In conditions of 25°C and 75% RH, *G. domesticus* takes 17 days to develop from egg to adult and *T. putrescentiae* takes only 10 days (Hart, personal observations). Their life cycle thus appears to be much shorter than that of the pyroglyphid house dust mites and this in additon to the high rate of reproduction of adult storage mites, would lead one to expect to find higher numbers of Acaridae and Glycyphagidae in house dust. That this is not the case supports our previous suggestion that house dust is not the true habitat of these mites.

3. FACTORS INFLUENCING THE REPRODUCTION AND DEVELOPMENT OF DUST MITES

Influence of temperature

The influence of temperatures above and below the optimum for reproduction and development of dust mites has, to date, been studied by very few authors. At temperatures higher than the optimum (26.6-32.2°C), Furumizo (1973) reported a shortening of the development time of *D. farinae* and survival of fewer individuals to adulthood. In addition to shortening of development, Bronswijk & Sinha (1971) observed higher fecundity in *D. farinae* at 30°C compared to 20°C, and suggested that this species prefers higher temperatures. Other studies on population growth of *D. pteronyssinus* , *D. farinae* and *E. maynei* over two months at 30°C and 25°C, however, revealed smaller popoulations of all three species at the higher temperature (Hart, personal observations).

Furuzimo (1973) also reported that temperatures lower than the optimum (15°C) reduce the survival of *D. farinae* and greatly extend development time (388 days). During most of this excessively long developmental period the immature stages were observed to be inactive. Slow development at 20°C, of 100 days and 37 days for *D. farinae* and *D. pteronyssinus* respectively, has also been reported (Oshima & Sugita, 1966; Spieksma, 1967).

Colloff (1987c) found that 35°C and 80-85% RH were optimum conditions for development of *D. pteronyssinus* eggs. In sub-optimal conditions (between 10-20°C and 30-35°C and below 65% RH), mortality and development time of eggs increased.

Temperature fluctuations in mattresses or upholstered furniture are probably buffered from external temperature variations and, particularly during occupation, the mattress or sofa temperature will be warmer than the external minimum temperature. It is conceivable, therefore, that optimal temperature conditions for dust mites regularly occur in the microclimate of the mattress or sofa. In contrast, house floors are less well buffered from temperature fluctuations and do not experience the increase in temperature, caused in upholstered furniture by close human contact. Thus acarid and glycyphagid mites, which are more common on floors than in upholstered furniture, may be more temperature tolerant than the Pyroglyphidae, perhaps due to their quiescent hypopi.

Further information on the influence of non-optimal temperatures on reproduction and development of pyroglyphid, acarid and glycyphagid mites is required, particularly since this has potential in the development of control measures against these mites. The lower thermal death point of *D. farinae* is -18°C for 48 hours (Pauli & Sinha, 1972). Bronswijk and Koekkoek (1972) found that exposure to -28°C for 6 hours was lethal to *D. pteronyssinus*, *D. farinae*, *D. microceras*, *E. maynei* and *Hirstia chelidonis*. In this context, liquid nitrogen has been used successfully to kill mites in mattresses by rapid freezing (Colloff, 1986).

In *D. pteronyssinus* the highest tolerable temperature (higher thermal death point) is 45.5°C for 24 hours (Kinnaird, 1974). Mosbech *et al.* (1988) recently reported that the heat from electric blankets and the resultant decrease in RH reduces the concentration of *Dermatophagoides* mites on the surface of mattresses.

Influence of relative humidity

There is now a general consensus in the literature that RH is the critical factor influencing the development and survival of pyroglyphid mites in the house dust environment (e.g. Hart. & Whitehead, 1990). Correspondingly, the geographical distribution and seasonal abundance can be related to RH. Pyroglyphid dust mites are most abundant in areas of low altitude with a damp, temperate climate, for example The Netherlands. However, it has been suggested that *E. maynei* is more abundant at higher altitudes and in warmer climates (Abed-Benamara *et al.*, 1983; Charpin *et al.*, 1986). The seasonal abundance of pyroglyphid dust mites also corresponds with the RH of the indoor air, being greatest in late summer and autumn when the indoor humidity is highest and decreasing thereafter when central heating has a drying effect on the indoor air (Spieksma, 1967). Epidemiological studies on the Acaridae and Glycyphagidae are lacking, but Gridelet and Lebrun (1973) report similar seasonal flutuations in *G. domesticus*.

Laboratory studies on *D. pteronyssinus* at relative humidities of 50-90% and 25°C revealed optimum population growth between 70 and 80% (Spieksma, 1967; Bronswijk, 1968; Saint Georges-Gridelet, 1984). Optimal conditions for development of *D. farinae* are from 50 to 60% RH at a temperature of 25 to 30°C. Below 2% and above 75% RH the development of *D. farinae* is inhibited (Waki & Matsumoto, 1973; Dusbabek, 1975). *D. farinae* therefore can develop at lower relative humidities than *D. pteronyssinus*. This corresponds with the critical equilibrium activity (CEA) of these two species which is 73 and 70% RH at 25°C for *D. pteronyssinus* and *D. farinae* respectively

(Larson, 1969; Wharton, 1976). This difference in humidity preference probably explains the difference in geographical distribution of these two species.

Nevertheless, both *D. pteronyssinus* and *D. farinae* have a wide range of humidity tolerance. For example, in *D. farinae* the CEA ranges, proportional to temperature, between 55 and 75% RH in the temperature range of 15-35°C (Arlian & Veselica, 1981) and this enables these mites to survive in the home environment where humidites are rarely as high as the optimum. Dust mites, however, have developed a number of other mechanisms to enable them to withstand adverse humidity conditions. They can decrease evaporation and thereby avoid dessication by aggregating under extreme conditions. In addition, during times when the mattress is occupied and therefore the humidity is higher, dust mites can actively absorb moisture through their hygroscopic cuticle. Furthermore, the Pyroglyphidae have a quiescent protonymphal stage which is adapted to survival during extended dry periods. Finally, although in limited amounts, dust mites can obtain some moisture from their food or from metabolic processes (Bronswijk & Sinha, 1971). These features may help to explain how small populations of Pyroglyphidae can exist at humidities as low as 33% (Bronswijk, 1968).

Colloff (1987d) found that in cool, dry conditions, eggs from 'wild' populations of *D. pteronyssinus* had a significantly lower mortality and faster development than eggs from laboratory populations. This also suggests that 'wild' dust mites can survive at lower humidites than realised from studies using populations reared for prolonged periods under optimal laboratory conditions.

Mites of the families Acaridae and Glycyphagidae are much more sensitive to dessication (Bronswijk, 1981), however populations of these mites can survive periods of dry conditions by the production of hypopi which are resistant to harsh conditions.

The possibility of eliminating populations of dust and mites by reducing the humidity of the habitat does not, therefore, seem very promising. Nevertheless, although populations are unlikely to be eliminated, if mites numbers can be reduced to levels below 100 mites / g dust , improvements in clinical symptoms may be seen. Humidity management in the homes of atopic patients, by for example heating the bedroom and airing the bed, is therefore under further investigation (Adan *et al.*, 1988).

Influence of fungi

Xerophilic fungi of the genus *Aspergillus* have been found in association with Pyroglyphid house dust mites, both in the house dust environment and in laboratory cultures (Sinha *et al.*, 1970; Lustgraaf, 1978a). These studies also demonstrated the location of these fungi in the guts of dust mites (Figure 3), indicating that they are ingested by the mites during feeding. Indeed, these fungi are commonn inhabitants of house dust (Bronswijk, 1981) and are also found in laboratory cultures (Hart & Douglas, 1990). Despite few studies on dust mite - fungal associations, there is a general concensus in the literature that these fungi may be of nutritional significance to the mites and that the high humidity requirement of fungi may be related to the high humidity requirement of pyroglyphid dust mites.

Bronswijk and Sinha (1973) reported greatly enhanced population growth of *D. pteronyssinus* when the diet was preincubated with *A. amstelodami* in comparison to diet which had not been preincubated. As a result of this they suggested that these fungi predigest the lipid component of the diet, thus reducing the lipid content of the diet, rendering it more suitable to the mites. Subsequent studies by Lustgraaf (1978b) and Saint Georges-Gridelet (1984) support these conclusions. In particular, Saint Georges-Gridelet (1981a and b) found that by eliminating fungi from the diet of *D. pteronyssinus*, nymphal development was severely retarded. More recently it has been suggested that fungi of the genus *Aspergillus*, particularly *A. penicilloides*, may also contribute to the sterol and vitamin requirements of *D. pteronyssinus* (Saint Georges-Gridelet, 1987a). Douglas and Hart (1989) suggest that *A. penicilloides* is of nutritional value to the mites but do not support the hypothesis that the principal function of the fungus is modification of the diet to a form more nutritious to the mites.

The same fungi, however, may exert a detrimental effect when, at RH above 80%, proliferation of the fungi occurs. This is the case not only for *D. pteronyssinus* in culture (Spieksma, 1967) but also for stored products mites (Solomon *et al.*, 1964).

Xerophilic fungi have also been found in the guts of *D. farinae*, *D. microceras*, *E. maynei* and *E. longior* (Hart & Douglas, 1990), however the importance of them to these species of pyroglyphid dust mites has yet to be elucidated. Their presence and importance to the Acaridae and Glycyphagidae also requires further attention. Nevertheless, due to their apparent importance in the development of *D. pteronyssinus* populations, the use of fungicides, for example Natamycin, to eliminate

fungi in mattresses has already been investigated by various authors. Bronswijk *et al.* (1987) and Saint Georges-Gridelet *et al.* (1987b) have reported successful reduction in mite populations following elimination of fungi using fungicides. Nevertheless, limited success using fungicides has also been reported (Reiser *et al.*, 1988) and the value of this as a long term control measure has therefore yet to be established. Fungicides are also toxic which is a major disadvantage in the home situation (Saint Georges-Gridelet *et al.*, 1988).

Influence of nutrition

In the house dust environment pyroglyphid mites appear to feed on the skin scales shed by man. This diet has a high protein and fat content, but is probably low in sterol and vitamin content (Saint Georges-Gridelet, 1987a). Colloff (1985) studied laboratory and wild populations of *D. pteronyssinus* and found that size and percentage mortality of eggs was influenced by diet, as was the oviposition rate of adult females. Nevertheless, nutritional studies on house dust mites have mostly been limited to searches for diets suitable for their culture

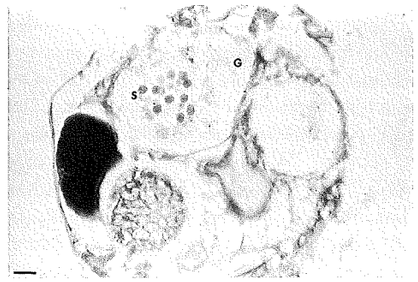

Fig. 3 : Section of *Dermatophagoides pteronyssinus* showing fungal spores (S) in gut (G). Scale bar = 10 µm.

(Bronswijk, 1972b; Hart & Le Merdy, 1988) and indeed, the diets found to be suitable all have a high protein content and also contain yeast (*Saccaromyces cerevisiae*). The high protein requirement of dust mites may be of particular significance in the allergenicity of these mites, since it has been suggested that the major allergen in *D. pteronyssinus* is a cysteine protease (Chua *et al.*, 1988).

Acaridae and Glycyphagidae storage mites do not appear to feed on skin scales in house dust. In contrast to the Pyroglyphidae they are not predominant in mattresses and upholstered furniture where skin scales accumulate, but instead they are more common on house floors where they are thought to feed on various organic food particles. Information on the nutritional requirements of these mites is severely lacking, but again diets containing a high protein content and yeast are successfully used to rear these mites in the laboratory.

Rodriguez and Blake (1979) described a chemically defined meredic diet on which they have successfully cultured *D. farinae*. A similar diet has been used to culture *T. putrescentiae* (Rodriguez & Lasheen, 1971). This diet contains sodium caseinate, alphacel, sucrose, wheatgerm, agar, vitamins and minerals. Such a standardized, defined diet could be an invaluable tool in investigations into the nutrition and metabolism of house dust mites. These authors also found that the physical characteristis of the diet, particularly particle size, are important in rendering it suitable for mites. Subsequent studies (Saint Georges-Gridelet, 1987a; Hart & Le Merdy, 1988) support these conclusions.

More recently, Walshaw and Evans (1987) found large populations of *E. maynei* in the homes of people with physically demanding occupations, e.g. builders, gardeners etc. They suggested that increased sodium content in the skin scales of these people (due to perspiration) may have a beneficial effect on populations of *E. maynei*, however subsequent laboratory studies have indicated that addition of sodium to the diet of *E. maynei*, *D. pteonyssinus* and *D. farinae* may in fact be detrimental to population growth (Hart, personal observations).

4. LABORATORY CULTURE OF DUST MITES

The ability to cultivate house dust mites in the laboratory has facilitated research into the biology of these mites and their precise role in allergen production. A laboratory culture of dust mites can be initiated by extracting live mites from house dust samples, which can be a delicate process.

Extraction of mites from dust

When live mites found in dust samples are required to start laboratory cultures, the dust sample should be placed into a large Petri dish and examined under a dissecting microscope. Any live mites found should be removed with a fine needle and placed into culture as described below. However, unless the sample is extremely rich in mites, live mites are seldom seen in fresh dust samples and therefore it is often advantageous to place the dust sample into a container of appropriate size for a period of 1-2 months in order to allow the mite populations to build up. A dish containing saturated NaCl should be placed in the dish beside the dust

sample in order to provide the mites with an optimum RH (75%) and the sample should be kept at 25°C for maximum population increase.

After this period of time the sample should again be examined under a dissecting microscope for live mites and any mites found can be removed using a fine needle or a sable hair brush. Mites which appear to be different species should be placed into separate dishes, and care should be taken to keep predatory mites (*Cheyletus* species) separate from the other mite species. As many mites as possible should be placed into small , uncovered glass Petri dishes (up to 5 cm in diameter) coated with tanglefoot or another sticky substance around the rim in order to prevent escape of the mites. A small amount of heterogeneous mixture of food should be added to the dishes - a mixture of (1:1:1 w/w) fishmeal : insect meal : dried yeast powder should support any species of dust mite. Again leave these cultures for 1-2 months with 75% RH (provided by saturated NaCl) and 25°C to build up numbers, after which time slides should be made (as previously described) and the different species identified and maintained separately. At this point a more defined food mixture, suitable for each species can be introduced if required and if larger populations of mites are desired, larger Petri dishes can be employed.

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containing saturated NaCl to provide 75% RH. If the lid is not airtight, evaporation of NaCl will be problematic. House dust mites can be reared in light or darkness at room temperature, but for optimal population growth, a temperature of 25°C should be used.

The food requirements vary for different species of dust mites. In general, the Pyroglyphidae can be reared successfully on a 1:1 (w/w) mixture of acetone-washed human skin scales or beard shavings and dried yeast powder (Bronswijk, 1972b; Wharton, 1976). Other allergenic mites, such as the Glycyphagidae and Acaridae can be reared successfully on a 1:1 (w/w) mixture of wheatgerm and dried yeast powder (Hart, personal observations). Other diets can also be successfully used for dust mites, however these two diets have a low allergen content and are therefore recommended for use with mites reared for use in immunology experiments.

Nevertheless, the Allergenic Products Advisory Committee recently recommended that house dust allergen extracts for use in clinical studies should not contain human dander. This recommendation may also extend to house dust mite extracts reared for clinical use and therefore, an alternative diet to the dried yeast and beard shavings may be required for such cultures. In this context, Hart and Le Merdy (1988) have reported that pyroglyphid dust mites can be reared successfully on a human dander-free diet of wheatgerm, dried liver and dried yeast powder (1:1:1 w/w) which also has a low allergen content.

Mite cultures should be examined weekly using a dissecting microscope. For examination the culture medium should be gently shaken to one side of the dish to facilitate observation of the mites which often accumulate on the bottom of the dishes. This also serves to aerate the culture, without which, fungi which are lethal to the culture may proliferate. During the weekly examination, if required, fresh food may be added or the cultures thinned and checked for contamination with fungi or other species of mites which may be in cultivation in the laboratory. When thinning, a small quantity of the old culture should be added to a clean dish containing fresh food. Alternatively, the old culture can be emptied out of the dish and replaced with fresh food, the mites remaining on the bottom of the dish constituting the new culture. However, if the culture is contaminated with fungi or another mite species, a minimum of 40 individual mites, including adult males and females, should be isolated from the old contaminated culture and added to a clean dish containing a small amount of fresh culture medium to generate a new, uncontaminated culture.

Extraction of mites from laboratory cultures

If low numbers or individual mites are required, they can simply be removed from the culture using a fine needle or sable hair brush. However when using house dust mites for immunological experiments, very large amounts of protein are required. There are three types of house dust mite extract which are commonly used in immunological studies :

1 -Whole mite culture extract : This is simply an extract of the whole mite culture, containing mites, dead mites, food, faecal particles, cast skins and eggs. Before a culture is ready to be used as a whole mite culture extract it should be saturated, that is, overcrowded to the point where mites start to try to escape from the culture dish. This is characterized by many mites sticking to the sticky barrier around the rims of the dishes.

2 -Clean mite extracts : This is an extract of clean mites without the presence of dead mites, food, faecal particles, cast skins or eggs. Such extracts can again be prepared by an overcrowding technique. As mentioned above, once a mite culture is saturated the mites will try to escape from the culture dish. If this culture is emptied into a dish without any sticky barrier around the rim and then placed inside a larger dish with a barrier around the rim, the mites will escape from the smaller dish into the larger dish. These mites tend to aggregate together and therefore the aggregations of mites can be easily collected again using a fine needle, brush or aspirator (Arlian *et al.*, 1984).

This method of collection can be carried out at room temperature, but it can be enhanced by using heat to accelerate the movement of the mites. However, in such a case, rather than collecting the mites in a larger dish, a lid, ventilated with 100µm nylon mesh should be placed over the dish. Dishes containing mite culture should be placed onto a hot plate at 45°C, and after approximately 30 minutes, mites can be collected from the sides of the dish and the inside of the lid where they aggregate to escape the heat (Hart, personal observations).

Other techniques have been described for collection of clean mites from laboratory cultures. These include flotation (Arlian *et al.*, 1979) and filtrations (Eaton *et al.*, 1985a), however, these methods allow collection of dead mites only. In addition, any water soluble allergens associated with these mites will be lost using these techniques.

3 -Mite faecal extracts : Extracts of mite faeces, free of live or dead mites, cast skins or eggs and with minimum contamination with food can be obtained by sieving mite cultures through a nylon mesh of 35 - 100 µm. In doing so the faecal particles and only extremely small particles of food pass through the sieve, providing a concentrated extract of mite faeces. Eaton *et al.* (1985a) describe a suspension and filtration procedure for preparation of faecal extracts for immunological studies, but again soluble allergens may be lost during this process.

CHAPTER III

Pathogenicity and Control of mites in Allergic Disease

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I. MITES IN THE AETIOLOGY OF PERENNIAL ALLERGIES

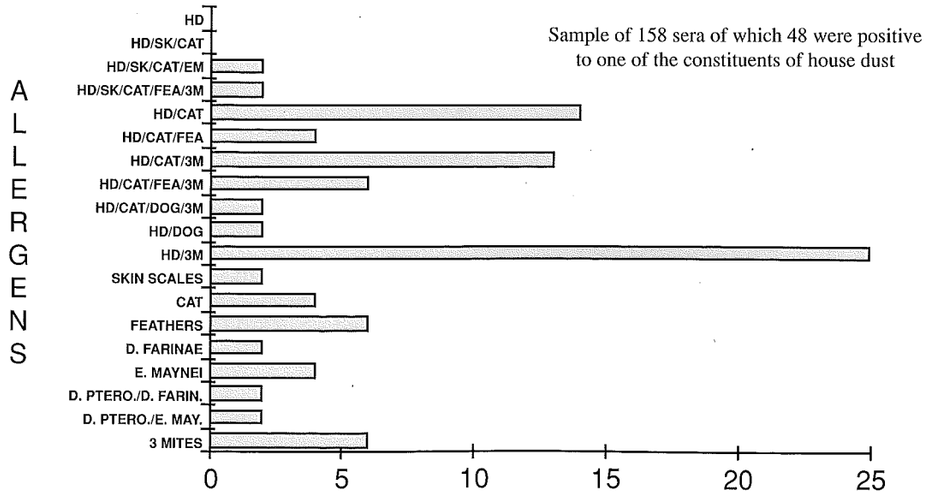
1. HOUSE DUST AND MITES

House dust has long been considered as the principal aetiology of perennial allergies which are characterized by their presence throughout the year and temporary variation in intensity ; they are also called extrinsic allergies since they are associated with a specific sensitization to environmental allergens. The first immunochemists who studied these allergies, explained their ubiquity by the existence of a common allergenic determinant which Berrens (1971) suggested originated from a recombination of products of degradation of proteins and carbohydrates by the Maillard reaction. This simplified explanation, to which we must however return, was abandoned after the discovery of the dominant role of pyroglyphid mites which proliferate in the bedding and more generally in all textile products and upholstery created for the comfort of man. The absence of a single dust allergen was definitively demonstrated by the work of Pauli *et al.* (1977, 1979) which specified the various components of dust ; these authors measured the relative importance of each component and confirmed the predominance of mites which are alone responsible for almost 70% of allergies, called house dust allergy, followed by the skin products of various domestic animals, primarily the dog and cat, which are important for 11% of subjects in the population studied. Other constituents of dust, which vary according to the environment, can also be incriminated ; they may originate from insects such as cockroaches, fungi, pollen and algae, and the possibility of human skin scales should also be included, against which specific IgE has been identified (Spieksma *et al.*, 1969 ; Guérin *et al.*, 1981). The separation of these antibodies from the serum of a group of subjects, presumed allergic, has confirmed the existence, in 4% of them, of a monosensitization to skin scales and in 12% of an apparent monosensitization to feathers from bedding ; in contrast there were no sera positive only to house dust.

FEATHERS AND MITES

The occurrence of allergy to feathers derived from domestic exposure remains controversial since the origin of the primary material used to prepare extracts is open to question. It is indeed well established that fresh feathers boiled in water or washed regularly, such as those of feather beds routinely used in the germanic countries, constitute an unusable primary material since they are very poor in extractable proteins and even poorer in allergens. The only feathers of bedding which provide allergens originate from old, preferably unwashed eiderdowns or pillows. This experimental verification, already suggested by Berrens (1971, 1974),

DETAIL OF RELATIVE ALLERGENIC ACTIVITY OF VARIOUS CONSTITUENTS OF HOUSE DUST



HD : House dust
SK : Skin scales
EM : *E.maynei*
FEA : Feathers
3M : *D. pteronyssinus, D. farinae, E. maynei*

gives rise to the question of the nature and origin of extractable allergenic molecules ; are they products of degradation of keratin and the fungi which invades it, or of mites which find their preferred food in the feathers ? The identification of a specific sensitization to extracts of old feathers, independent of a sensitization to house dust mites, does not provide a definitive answer, but appears to suggest the existence, as a minor allergen perhaps, of sensitization to degradation products of various fibres or skin products present in our furniture, as described by Berrens (1971). This sensitization to "a common metabolite", does not exclude the presence, in animal workers, of a professional sensitization to feather mites, thus named because these mites inhabit the plumage of living animals. It is moreover possible, if not very likely, that allergies to domestic birds, such as the canary or the parrot, correspond more to the feather mite fauna than to a specific sensitization to the keratin of these birds.

DOMESTIC ANIMALS AND MITES

Specific allergy to allergens originating from skin products and metabolites of domestic animals is now well established ; this does not exclude a possible concomitant sensitization to the mites which inhabit their kennels and baskets. Moreover, the study of allergies to the dog, including atopic eczema and also asthma, has confirmed that domestic mites constitute the principal aetiology, followed by human skin scales and pollen (Willemse, 1984).

PLANT MITES AND ALLERGY

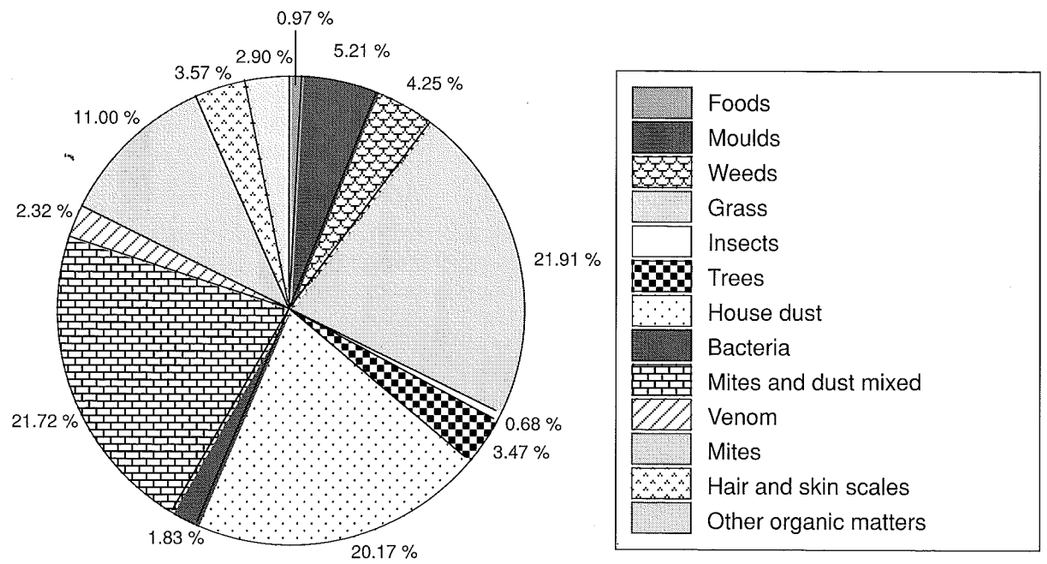
Some clinical observations also suggest a possible sensitization to phytophagous mites, such as the fruit tree red spider mite *Panonychus ulmi* (Michel *et al.*, 1977), yellow spider mite *Tetranychus urticae*, responsible for professional allergies in the pesticide industry, and also *Tetranychus macdanieli*, implicated in false pollination of vines (Carbonelle *et al.*, 1986). The concomitant sensitization of these patients to dust mites suggests, according to these authors, the existence of a cross antigenicity between these mites ; demonstration of this remains to be established but it seems unlikely or at least a very feeble cross antigenicity, as the mites are clearly different in terms of their systematics and biology. It is true, however, that Lind (1984) established the existence of a partial immunological community amongst the insects, such as the Hymenoptera for example, and mites.

2. STATISTICS AND EPIDEMIOLOGY

USE OF ALLERGENIC EXTRACTS

The classification by order of prevalence of various primary allergenic materials is very difficult to accomplish since methods of analysis do not always correspond to the same population of subjects.

It is clear that people allergic to pollen who suffer regularly during a limited period of time, with the exception of rare patients polysensitized to trees, grasses and herbaceous plants, do not usually consult specialised clinicians ; they are therefore treated by symptomatic or avoidance therapy, and thus can only be included in methods of statistical evaluation by analysis of the use of medicines. As for those who consult an allergy specialist and for whom a specific immunotherapy is prescribed, it is possible to evaluate the relative importance of various sensitizations by measuring the use of allergenic extracts ; this approach has given the following values for France in 1986 (Guérin, 1987) :



These proportions of the sale of allergens, accounted for as far as possible, confirms the predominance of perennial allergies and of the group dust-mites which represents approximately 55% of prescriptions and almost 59% if the 3.5% skin products of domestic animals is included, or 63.9% including fungi. It should however be noted that the relative importance of dust mite extracts, a mixture of dust and mites or pure mites, is very variable from one region to another, which probably reflects the influence of local traditions and practices. The grasses come in second position with 22.7% of prescriptions whereas the other specific allergen extracts together represent the remaining 13.4%, of which 3.6% represents tree pollen, 2.4% venoms, 4.4% herbaceous plants and 1.8% bacterial extracts. The analysis of the use of medicines to alleviate symptoms emphasises important regional variations which suggest a climatic influence, notably in coastal regions, which has merited a specific analysis, the results of which are not yet available.

EPIDEMIOLOGY STUDIES

The predominance of sensitization to house dust mites is confirmed by epidemiology studies and more precisely by studies of specific skin reactions to the principal environmental allergens, but this varies according to latitude and climate. This approach is particularly interesting when the population studied is not pre-selected using biased stimulatory tests and contains a considerable percentage of the eligible population ; as is the case in various studies carried out in Arizona by Barbee *et al.* (1981, 1987) on whole communities, in Baltimore by Friedhoff *et al.* (1981) on a sample selected from the personnel of a large electrical industry, and in Finland by Haahtela *et al.* (1980, 1981) on a group of school age children of a small village. Their results are not directly comparable as they differ in many aspects, age of subjects under investigation, species of mites, regional flora and therefore species of pollen, but all these variables can be regrouped

systematically and they are summarised in the following table in conjunction with those of an epidemiological study conducted in Lyon in 1986 on almost 5,000 subjects who volunteered for a health survey (Guérin *et al.*, 1986):

PREVALENCE OF THE CUTANEOUS REACTIVITY OF VARIOUS POPULATION SAMPLES

Authors Country and date populations	% of total sample	DETAIL OF CUTANEOUS REACTIVITY TO DIFFERENT ALLERGENS					
		Dust and mites	Domestic animals	Fungi	Pollens and grains	Tree pollens	Grass pollens
Barbee *et al.* Arizona 1976/81/87 Pop.: 9 - 65 yrs*	24	30/10	25/15	ND	50/19	50/22	50/18
Friedhoff *et al.* Baltimore, Maryland, 1981 Workers : 18 - 55 yrs**	24/57	10/29	8/34	6/21	13/42	ND	13/37
Haahtela *et al.* Imatra, Finland, 1979/80/81 Students : 15-17 yrs***	49	40	32	ND	29	15	18
Lynch *et al.* Amazon 1983/1987	6.7	3.1	0.5	3			
Caracas****	?						
HSEL Non aller/allerg.		17.5/60.3	9.5/22.2	7.9/27	7.9/23.8	7.9/23.8	7.9/23.8
MSEL Non aller/allerg.		60.4/71.5	12.5/7.3	22.9/20.8	22.9/22.9	22.9/22.9	22.9/22.9
LSEL Non aller/allerg.		9.8/22	4.9/4.9	7.3/7.3	4.9/7.3	4.9/7.3	4.9/7.3
Guérin *et al.* Lyon, France, 1986 Executives and Families 18 - 65 yrs	9	8	3.5	ND	26		4.9

* 9 to 19 yrs / 20 to 50 yrs
** All participants / subjects reporting allergic symptoms
*** Subjects without any allergic symptoms who showed positive skin tests in 17% and a RAST in 14% of cases.
**** HSEL (upper class)
MSEL (middle class)
LSEL (lower class)

The prevalence of sensitization to stored products mites is even more difficult to establish since extracts of these mites are not included in the batteries of tests used on subjects included in epidemiological studies. Published studies on these mites are relatively few in number and involve limited populations living in humid, rural regions such as certain areas of Australia and New Guinea (Green *et al.*, 1978), Swiss farms (Mumcuoglu, 1976), islands in the North Sea (Cuthbert *et al.*, 1979), the south-east Asiatic (Woodcock *et al.*, 1980), farms in east Finland (Terho *et al.*, 1985) and the Baltic islands (Van Hage-Hamsten *et al.*, 1985). They however do confirm the much more ubiquitous nature of stored products mites than was initially realised by Spieksma and Voorhorst in 1969 in their analysis of house dust. It appears, notably in the work of Wraith *et al.* (1979), conducted in the suburbs of London on 210 subjects suffering from asthma or perennial rhinitis and with positive skin tests to mites, that the frequency of sensitization to storage mites is identical to that of mites of bedding with an incidence of approximately 50%. In the more complete study of a rural population of Gotland, this type of allergy was diagnosed, using anamnesis and RAST, in 52 of 440 farmers tested which corresponds to a prevalence of 6.2% of the total population, and which is approaching an overall level of 15.6% of all atopic allergies. The sample populations used in recent French studies are more representative of the general population since they correspond to allergic patients from the east of France, equally divided between rural and urban areas (Hardel *et al.*, 1986), or to allergic, and primarily asthmatic children from the north of France, living mainly in an urban area (Lelong *et al.*, 1986).

In these two cases the authors confirmed the ubiquitous nature of storage mites to which more than 40% of the subjects examined were sensitized and of which 43.10% were allergic to *Tyrophagus putrescentiae* and 44.95% to *Lepidoglyphus destructor* , whereas 21% of the children presented positive skin tests to *Acarus siro*, but in addition 43 of 44 were positive to *Dermatophagoides pteronyssinus*, which poses a problem in the cases where these sensitivities may be independent of any immunological cross reactivity and associated with an environment of straw, grain of contaminated food. This controversial subject will be discussed in the paragraph dealing with various allergenic molecules and their epitopes.

A MODERN AETIOLOGY

The level of abundance of allergic disease in general, and that of sensitization to various mites of house dust or stored products, usually increases in countries which are in the course of development, but also in more civilised, urbanised countries. The example of New Guinea clearly demonstrates this growth in allergic disease which is increasing in parallel with the number of mites in blankets which have been recently introduced and generally used in the populations in the high plateaux. There has been a consequent increase in the incidence of asthma from 0.3% (Anderson *et al.*, 1974) to more than 7% in ten years (Turner *et al.*, 1988) in certain regions such as "South Fore", but the incidence has remained low elsewhere, notably in the Asaro valley where the climate is identical. The explanation of this progression is difficult to establish because the modes of life are apparently identical, but the authors found lower levels of mites in the Asaro valley (283 per gram of blanket dust compared to 1371 in South Fore), elevated total IgE counts and above all a much greater infestation of intestinal parasites.

The hypothesis of a negative relationship between parasitism and atopic sensitization has already been seriously considered to justify the explosion of allergic patients in developed countries in which the populations are now totally deparasitised, with the idea of a change in the functioning of the IgE system, having been liberated of its principal role. Nevertheless, comparisons made in Venezuela in equally parasitized rural and urban areas (Lynch *et al.*, 1983, 1987) did not unequivocally confirm this, but instead they accentuated the importance of urbanisation as a risk factor and also demonstrated that differences in quality of life and medication are important.

In developed countries, in which large qualitative differences in medical care no longer exist, it should be noted that the frequency of allergic disease, and more particularly perennial rhinitis and house dust mite asthma, increases in parallel with urbanisation, with development of tertiary areas and with work in confined or air conditioned circumstances. Since the beginning of the industrial revolution, pollution has continued to grow, and is only now beginning to slowly decrease, a phenomenon primarily demonstrated in the homes of non-smokers. Pollution has resulted in a weakening of the respiratory mucous membrane which could explain the increase in sensitization in genetically predisposed subjects, as the stress of modern life can explain a decrease in the threshold of activation of the effector cells and of the response to mediators of the immune system against the aggressions of the environment. In this context, the recent change in conditions of domestic life, created by women now working and the consequent reduction to a minimum of daily housework, in addition to a decrease in washing outside and exposure of bedding and carpeting to the sun, and also the now widespread use of electric heating and thermal insulation of houses which reduces ventilation in winter, have all created conditions which have become progressively more favourable for the development of house dust mites.

At the same time, an increase in the number of pets inside the home has introduced allergens related to cutaneous mites and to storage mites which multiply in the kennels and other beds of these animals, in addition to increasing the risks of a specific allergy to products of the animals themselves.

II - ALLERGIC DISEASE CAUSED BY SENSITIZATION TO MITES

The clinical manifestations of sensitization to house dust or storage mites classically include, in order of appearance and severity : perennial rhinitis of variable intensity according to season, a rhinitis associated with bronchial crises called asthmatiform, pure asthma which is well characterized, more rarely atopic dermatitis, and exceptionally urticaria. The medical literature also mentions the possible role of mites in the aetiology of Kawasaki disease and the existence of an acariasis of the pulmonary tracts of man in intertropical or hot regions.

ALLERGIC RHINITIS CAUSED BY MITES

Perennial allergic rhinitis constitutes one of the most frequent clinical manifestations of allergic patients, but their diagnosis is very difficult in the absence of associated asthma, because the aetiology is rarely unequivocal. In the first instance it has to be established, even in atopic subjects, that the nasal symptoms are of an allergic nature which indicates a complete Ear-Nose-Throat assessment which is rarely necessary in the case of pollen rhinitis. Rhinitis includes sneezing, running eyes and nose, nasal obstruction and sometimes sinus complications. As in pollen allergy, the purely allergic symptoms are complicated by a non-specific nasal hyperreactivity, but the circumstances which lead to crises are characteristic ; they appear most often upon awakening in the morning, when the patient is still in bed, whereas non allergic vasomotor rhinitis is triggered most readily in the bathroom. Other factors, such as housework, using vacuum cleaners, shaking sheets, beating or turning over mattresses, occasional change of housing conditions, especially in city dwellers who move to a house in the country which is humid, all can evoke an allergy to dust which is in effect an allergy to mites. Otherwise the symptoms, if they are a result of house dust mites, disappear during the day. Diagnosis is also sometimes complicated by the use of local therapies which often perpetuate the rhinitis. The importance of non specific triggering factors should also be remembered, such as tobacco smoke, sudden changes in temperature, strong emotions, etc..., which interfere more in cases of non allergic rhinitis. Diagnosis is almost always confirmed by positive skin tests using allergen extracts standardised in units of biological activity to eliminate non specific responses (see below in diagnostic methods).

ASTHMA AND HOUSE DUST MITES

This is largely asthma in children which is principally of allergic origin ; the other allergens incriminated in this are fungi, and more rarely pollens and foods.

The allergic origin of asthma is evaluated using a series of criteria:

* age at the onset of illness which is sometimes very early in childhood;

* family history of rhino-conjunctivitis, eczema and asthma;

* personal history of atopic eczema to food, of tracheitis and of rhino-conjuctivitis, which together constitutes an atopic profile.

The responsibility of dust mites is suggested by the essentially nocturnal nature of the dispneic crises, their increased severity in autumn and spring, their frequent disappearance when the subject leaves the home and by the collective criteria already described regarding rhinitis. The frequent late reactions should also be emphasised, the most serious of which appear many hours after provocation and provide one of the most characteristic features of asthma to dust or to mites. Usually preceeded by an immediate reaction, they are seen in one case out of every two involving house dust mites according to Booj-Noord *et al.* (1971-72), in 43% of cases according to Gaultier *et al.* (1979), in one of every three cases according to Orie (1973) , and in 23% of cases according to Warner (1976).

ASTHMA RELATED TO STORAGE AND PLANT MITES

These mites which are more abundant in the dust of living rooms, or in the place of work, rather than in bedrooms and bedding, unless these rooms are habitually occupied by domestic animals and birds, more commonly provoke the respiratory mucous membranes during the day. This statement is however rather theoretical since the majority of work on allergies to straw and to storage mites, indicate a polysensitization of subjects in which skin tests are also positive to house dust mites (Green *et al.*, 1978 ; Cuthbert *et al.*, 1979 ; Woodcock *et al.*, 1980). Certain professions or clinical peculiarities are however indicative of specific allergy to plant or storage mites. Respiratory problems and dermatitis of uncovered areas of the body, occurring in the summer in areas of horticulture or apple production and in subjects in more or less direct contact with plantations, are characteristic of a possible sensitization to red spider mites. A cough and asthmatic wheeze which appear principally on winter mornings in bakery workers are characteristic of asthma to flour which can disguise a sensitization to storage mites. The appearance of alveolite with flu symptoms, a cough and dyspnosis, in dairy employees, corresponds to the illness described by de Weck *et al.* (1969) who implicated fungi associated with cheese as the causal agent. The aetiology of this illness was resolved by Molina *et al.* (1977) who showed that the cause was contamination of the surface of cheese by mites (*Acarus siro*, *Tyrophagus casei*).

PROFESSIONAL DERMATITIS

Repeated contact with various foodstuffs contaminated by detrivorous mites (i.e. mites feeding on detritus), primarily Astigmata, can provoke dermatitis. The most common are dermatitis of bakers caused by *A. siro* (the cheese mite), dermatitis of grocers, the usual cause of which is *Glycyphagus domesticus*, "copra itch" which is caused by *T. putrescentiae*, and dermatitis of dried fruits, produced by *Carpoglyphus lactis*, amongst others (Baker *et al.*, 1956).

ATOPIC DERMATITIS

In the 1930s, 40s and 50s, a number of studies indicated the possible intervention of respiratory allergies in the aetiology of atopic eczema, however interest in this idea soon waned. Sampson (1983) updated this hypothesis by showing, in a double blind trial, the role of food allergens in the production of atopic eczema in children. At the same time, two studies (Mitchell *et al.*, 1982 ; Reitamo *et al.*, 1986) showed positive skin prick tests and patch tests to bronchial allergens in patients suffering from this illness, while Chapman *et al.* (1983), using another series of patients, measured an increase in specific antibodies of the IgE and IgG classes, to the P1 antigen of *D.pteronyssinus* and to the Rye 1 antigen of grasses.

More recently Adinoff *et al.* (1988) identified a group of 10 patients suffering from atopic eczema for whom he was able to establish a series of significant indications of a direct relationship with the respiratory allergens to which they were sensitive: positive skin tests for type I and IV hypersensitivity, elevated levels of IgE, and the influence of respiratory allergens, particularly those of *Dermatophagoides farinae*, on the fluctuations of the illness. Four of these patients moved out of warm humid regions (Hawaii, Haïfa, Porto Rico, Boston) to the dry region of Denver, and their eczema rapidly disappeared, except in the nape of the neck of one patient who had kept his pillow, elimination of which resulted in complete recovery. These observations do not, however, completely answer the question of the influence of respiratory allergens on atopic eczema, but they do at least suggest that each case should be considered individually.

URTICARIA

Hypersensitivity to mites is less frequent in subjects suffering from chronic urticaria than in the general population, but the application of this allergen, in the form of a patch test, occasionally produces a papule which appears within an hour after application. An association between these mites and urticaria cannot therefore be completely rejected, even if it is rare.

KAWASAKI'S DISEASE

This lymphonodular cutaneomucous syndrome is a disease of young children for which the aetiology remains unclear, although it is similar in incidence to a rickettsia and more recently to a retrovirus. Studies in Japan (Furosho *et al.*, 1981 ; Ishii *et al.*, 1983) have suggested a direct relationship between this disease and exposure to mites found in large numbers in the homes of subjects suffering from this disease, but other studies in America have not confirmed this hypothesis (Jordan *et al.*, 1983). During the same period Patriarca *et al.* (1982) suggested that house dust mites act as a reservoir or transferring agent of rickettsias, however, subsequent studies have not confirmed this hypothesis.

ACARIASIS OF THE RESPIRATORY SYSTEM

Occurrence of mites in the respiratory system of mammals, particularly in seals, was described by Allman as early as 1847, and later in monkeys by Grijns and de Haan in 1901. Since then many other species have been described in the respiratory tracts of these animals. This type of acariasis is also very frequent in birds in which 600 species have been described. All these species are strictly specific for this habitat and for their host.

In 1944 Carter *et al.* described in man, under the name of pulmonary acariasis, a clinical syndrom which they ascribed to the presence in the lungs of non parasitic dust mites which had been inhaled by the patients. The proof of the presence of these mites in the respiratory tract has, however, never been presented. According to Fain (1966b) the syndrom of pulmonary acariasis in man has never been clearly defined and it probably corresponds to bronchial asthma to dust, caused by pyroglyphid mites, and was not recognised at the time because the role of mites in respiratory allergies was unknown.

DERMATITIS CAUSED BY PARASITIC MITES

Certain parasitic mites can provoke dermatitis in man where an allergic component is more or less directly implicated. *Cheyletiella yasguri* is a parasite of dogs capable of causing a contact dermatitis in man. This mite is never found on the skin of man, but contact with the skin of infected dogs triggers the allergy (Fain *et al.*, 1982).

Dermatitis provoked by the bites of mesostigmatid mites, which are normally parasitic on birds (*Dermanyssus galinae* or *Ornithonyssinus* spp.) or on rodents (*Ornithonyssinus bacoti*), is perhaps partly allergic in nature. The same may be true for autumn erythema caused by the larvae of *Trobiculidae* (*Trombicula autumnalis*) or for the more serious dermatitis caused by the bite of *Pyemotes ventricosus*.

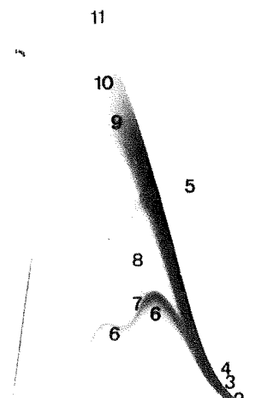
SARCOPTIC MANGE

The existence of an allergic component in human sarcoptic mange caused by *Sarcoptes scabiei* is now well established (Mellanby, 1944 ; Arlian *et al.*, 1988).

III - MITE ALLERGENS

ALLERGENS ASSOCIATED WITH HOUSE DUST MITES

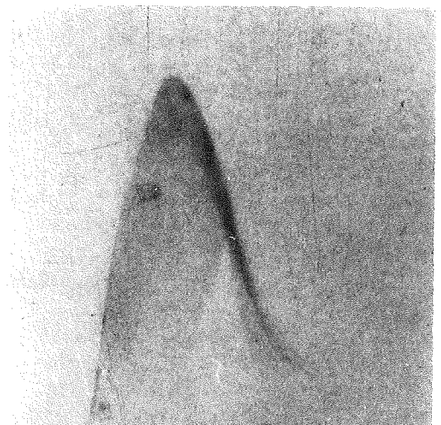
The first immunochemical analyses done on extracts of *D. farinae* in Japan by the group of Miyamoto (Nakagawa *et al.*, 1977), in France by the group of David (Le Mao *et al.*, 1981) and in Scandinavia by the group of Løwenstein (Lind, 1982) enabled the identification of two allergens of molecular mass between 8,000 and 25,000 daltons, which were termed major allergens because they are recognised by the serum of the majority of sensitized subjects. These same authors specified the protein and glycoprotein nature of various mite allergens. By combining the techniques of immunoelectrophoresis and autoradiography, Le Mao et al showed that a purified extract of whole *D. farinae* culture (Df 80) contained 11 antigens, as shown on the figure below, and that the serum of allergic subjects recognised 6 of these antigens as allergens (Df 3, Df 4, Df 5, Df 6, Df 8 and Df 11) of which two (Df 6 and Df 11) were considered as major allergens because they were recognised by more than 50% of subjects, reaching up to 100% for Df 11.



Two-dimensional immunoelectrophoresis using an extract of the mite *D.farinae* (Df80d) against an anti-*D.farinae* rabbit serum.

Similar studies, conducted primarily in Europe by Lind *et al.* (1979), Chapman and Platts-Mills (1980), Le Mao *et al.* (1983) and in Australia by Stewart *et al.* (1980) resulted in the identification of the major allergens of *D. pteronyssinus*. More recently, Lind (1986) showed the striking physicochemical similarity, but at the same time the only partial identity at the immunochemical level, of antigens produced by *D. farinae* and *D. microceras*, which is of interest since these two species differ morphologically by only a single character (c.f. Chapter I page 37). It is not possible to dismiss the possibility of immunological variability between strains of mites depending on their environment.

As a result of the international program of standardization, initiated by the International Union of Immunological Societies (I.U.I.S.), in collaboration with governmental agencies for control of serum, vaccines and allergens, numerous allergenic molecules separated and identified by various groups, have been compared and then standardized against each other ; they have been characterized by Marsh *et al.* (1986) and given a new standard code, adopted by the World Health Organisation (W.H.O.). Each allergen is identified by the first three letters of the genus and the first letter of the species to which it belongs, followed by a roman numeral which indicates the chronological order of purification; thus the first allergen purified from *D. pteronyssinus*, formerly called, according to author, P1, Dp 42 or Dp 12, is now coded by the symbol *Der p* I. Numerous antigens or compounds capable of binding IgE on plates of crossed immunoelectrophoresis have been described for different mites, however, the new nomenclature only includes those for which purification is considered to be sufficient to permit an unequivocal identification. Various allergens have been classified using the similarity of their physicochemical characters and the homogeneity of their



Radioimmunoelectrophoresis, showing the allergenicity of *D.farinae* in the extract Df80d.

amino acid sequence into three groups of homologous molecules, named I, II and III. The allergens of group I, *Der p* I, *Der f* I and *Der m* I, are glycoproteins of similar molecular mass around 24,000 daltons, but their isoelectric points are apparently different, ranging from 4.7 to 7.4. They are thermolabile and are found primarily in the faeces of these mites. The group II allergens *Der p* II, *Der f* II and *Der m* II are proteins with a molecular mass of approximately 15,000 daltons. The gene encoding *Der p* I, has been cloned and expressed in Lamda gt 11 and the complete amino acid sequence has

been determined from cDNA (Chua *et al.*, 1988). This allergen has a high homology with the cysteine proteases papain and actinidin. The possibility therefore exists that proteolytic activity of *Derp I* has some function in the elicitation of allergic reactions in asthma or atopic dermatitis. The majority of subjects allergic to house dust mites produce specific IgE to group I and II allergens. The production of monoclonal antibodies, principally by Lind (1985), Chapman *et al.* (1987), Horn *et al.* (1987) has allowed the purification of allergens by affinity chromatography, the elucidation of an epitope map and the establishment of specific methods for quantification.

The characteristics of the three principal groups of allergens are presented in the following table, adapted from Platts-Mills and Chapman (1987) and Heymann *et al.* (1989).

Four groups of monoclonal antibodies have recently been defined by immobilization on a solid phase and which recognise an identical region of the antigen. 5 cases of cross reactivity between *Der p* I and *Der m* I and one case of cross reactivity between *Der p* I and *Der f* I have been found. The N-terminal amino acid sequence of amino acids show a 93% identity between *Der f* I and *Der m* I and 70 to 77% homology between *Der p* I, *Der m* I and *Der f* I which the present authors consider as consistent with their morphological taxonomy.

The group I allergens are thought to be the major mites allergens, however, recent analysis by protein blotting of sera from 96 different house dust mite-allergic subjects revealed a previously unrecognized complexity of low molecular mass (<20 kD) IgE-binding proteins in extracts of whole bodies of *D. pteronyssinus*. Of 11 different IgE-binding components of molecular mass <20 kD identified, two (MW ~ 16 kD and ~ 15 kD), showed both a high frequency (88% and 49% respectively) and a high intensity of IgE-binding.

PRINCIPAL ALLERGENS OF PYROGLYPHID MITES

Allergens	M. M. (daltons)	p I	Observations
Group I			
Der p I (P1, Dp42, Dpt 12)	24,000	4.6 - 7.4	The molecular mass of Group I allergens varies between 24 and 30,000 in SDS PAGE and between 15 and 20,000 in gel filtration.
Der f I (F1, Ag. 11, Df 6)	24,000	4.6 - 7.2	
Der m I (Dm 6)	24,000	4.9 - 6.5	
Group II			
Der p II (Dp X)	15,000	5.0 - 6.4	The molecular mass shown for Group II correspond to analysis on SDS PAGE.
Der f II (Ag. 19/20, DF 2)	15,000	7.8 - 8.3	
Group III			
Der f III	29,000		

mutual inhibition of radiolabelled antisera (Lind *et al.*, 1988); they can be interpreted as each representing a defined region on the surface of the antigen, carrying epitopes sufficiently spaced to exclude the simultaneous fixation of two antibodies of the same group. Five of the 19 antibodies studied belong to groups II and III, which demonstrates a considerable recovery of epitopes between the corresponding zones of fixation. The degree of species specificity, which is studied by levels of inhibition by antigens *Der p* I, *Der f* I and *Der m* I, appear to be extremely variable, even for antibodies

The ~ 16 kD component, identified as allergen *Der p* II, showed the highest frequency of IgE antibody reactivity of any of the major *D.pteronyssinus* allergens including *Der p* I and *Der p* III (Ford, 1989).

No such detailed information is presently available for the allergens of *Euroglyphus maynei*, but preliminary immunochemical studies (Le Merdy *et al.*, 1988) and notably comparison of antigens in tandem crossed immunoelectrophoresis with ALK anti-*D. pteronyssinus* and ALLERBIO anti-*E. maynei* antibodies, suggest the existence of common determinants with extracts of *D.*

Figure 1

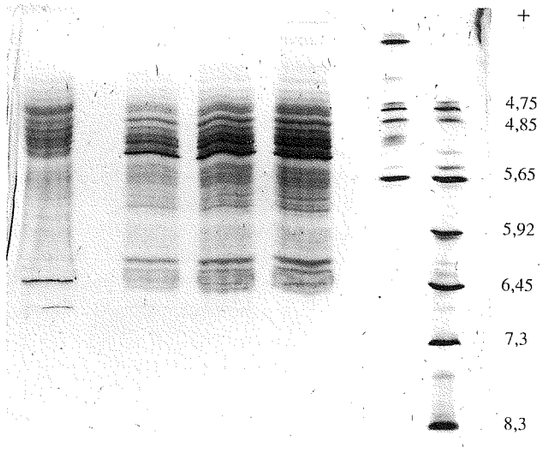
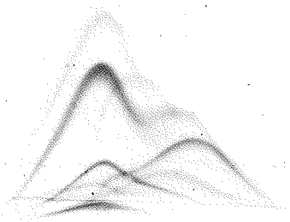


Figure 2



Applications

Left
10µl
DPT 70605

Right
10µl
EM 70942
Migration 1h / 150 V

Anode
36µl anti-serum ALK
anti DPT - rabbit
Migration 18h / 100 V

Cathode
No anti-serum

pteronyssinus and *D. farinae*, with similar profiles being found with isoelectrofocussing (Figure 1) and crossed immunoelectrophoresis (Figure 2).

STORAGE MITES AND CROSS ALLERGENICITY

Storage a mites have not yet been the object of detailed immunological studies and their allergens have not yet been isolated. In contrast to house dust mites, the major storage mite allergens may originate primarily from the body, which may explain the absence of cross allergenicity between these two groups of mites, although cross allergenicity is very important within each group. This difference has been shown by Van Hage-Hamsten *et al.* (1987) using the technique of RAST inhibition, however, Arlian *et al.* (1984) characterized common allergens, both in whole body and faecal extracts of *T. putrescentiae* and *D. farinae* using the techniques of crossed immuno and radioimmuno electrophoresis, and thus it is impossible to draw conclusions at this stage. The two groups of mites are effectively distantly related at the level of classification and in their nutritional requirements, however contrasting results may also be explained by biases related to methods of analysis and to the selection of serum used

IV - ALLERGENIC EXTRACTS AND STANDARDIZATION

SELECTION OF PRIMARY MATERIAL

The ad hoc committee, directed by the I.U.I.S. to propose an outline of recommendations for an international primary standard extract of *D. pteronyssinus*, considered that it should be prepared from a primary material representative of that to which man is exposed in his natural surroundings ; it was thus decided to select cultures of mites, reared on a material natural for man, but almost totally digested by mites at the time of collection, containing not only somatic antigens but also metabolic antigens, for which the essential component is the faecal pellets for *Der p* I (Lind *et al.*, 1984).

On the other hand, the Australian workers, since followed by the North Americans and the Food & Drugs Administration of the United States, preferred to retain a source of purely somatic antigens, namely mites free of culture medium and products of metabolism ; these antigens are obtained by sieving mature cultures through a 100 µm mesh, followed by purification by differential flotation in organic solvents which yields mites at the surface, but excludes the faecal pellets. This option, justified by the theoretical elimination of human skin scales, which according to Baer (1986) could potentially

carry the risk of transmission of the aids virus, does not, however, guarantee the absence of non specific allergenicity. Thus the major producers of so-called purified mites, were advised to abandon their culture medium which contained traces of allergenic hairs and skin scales of animals such as the horse, however, they continue in general to refuse to state in what conditions they rear their cultures. It would have been beneficial if the standardization committee had proposed research on undesirable antigens, primarily animal hairs and skin products in the control of primary material ; this precaution is essential for products destined for preparation of extracts for administration to man (Ford *et al.*, 1985).

REFERENCE EXTRACTS

D. pteronyssinus

The sub-committee for the standardization of allergens chose *D. pteronyssinus* as the first model for which a reference extract was to be established. In this intention it created an ad hoc group with the remit of drawing up, using the scientific knowledge to date, an outline of recommendations for preparation of this extract, to bring together valuable reagents, in particular a pool of human serum from sensitive subjects, to propose methods of control and to select a definitive aim.

The results of the comparative study conducted in 1982-83, of 10 extracts and of primary material, supplied by 8 suppliers and coded by the National Institute of Biological Standards and Control (N.I.B.S.C., Great Britain), were published by Ford *et al.* (1985). They included a comparison of the total acitvity measured by skin tests, RAST and RAST inhibition, as well as detailed analysis of the antigenic and allergenic composition using crossed immuno- and radio-immunoelectrophoresis, rocket-immunoelectrophoresis and radio-immunoassay. This work confirmed the conclusions of Lind (1980) on the differences caused by the choice of primary material on the composition and intensity of various allergens; thus whole mite extracts, separated from their culture medium and products of metabolism, clearly contained a superior relative level of Ag X (*Der p* II), compared to *Der p* I, than preparations obtained from primary material containing faecal pellets.

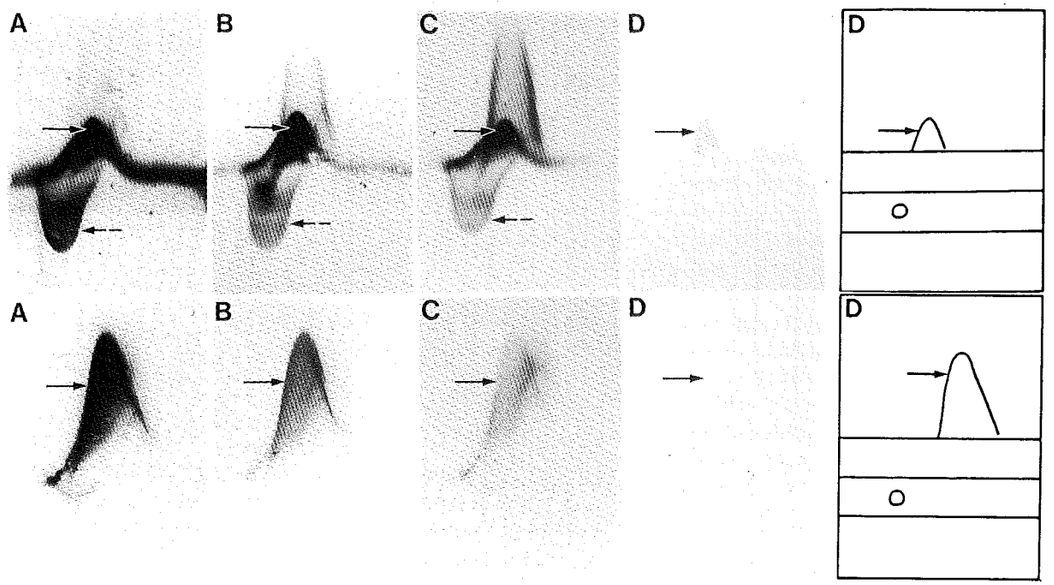
In considering the circumstances of provocation of patients, the committee followed the conclusions of the ad hoc group and chose a culture extract containing both somatic and metabolic allergens. The first international reference of mites was proposed by the I.U.I.S. (Geneva meeting) and was accepted by the W.H.O. in 1984 ; this can be obtained from N.I.B.S.C. which is charged with its keeping and delivery. The information accompanying the reference extract, explains the inclusion of products of human origin in the primary material, the negativity of Hepatitis-B antigens and anti-HIV tests, but confirms that the preparation is not destined for human administration. It is essentially for laboratories and institutions involved in the production or control of allergens, as a reference for the calibration of internal standards which will then serve to guarantee constant composition and activity of commercial products.

Each vial contains 0.31 mg (0.30 to 0.33) of total protein, measured by the method of Lowry, and a residual humidity of 0.25% ; the contents, reconstituted in 1 ml of distilled water, are called by arbitrary definition 100,000 I.U. (International Units). It can serve to measure by comparison, either the total activity, or the strength of an extract of *Der p* I or *Der p* II. The international unit assigned to this reference is in no way related to the systems of units actually used by producers or proposed by various governmental or academic agencies, such as the F.D.A. or the Northern Society of Allergy ; neither does it indicate any common level of biological activity between various reference extracts, which emphasises its use only as a reference for calibration.

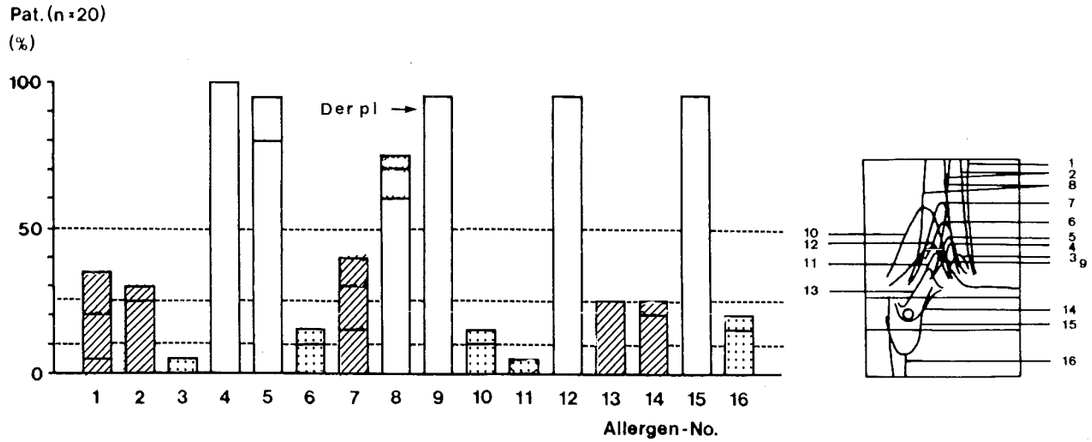
Since the adoption of this extract by the I.U.I.S., its criteria for selection have been the subject of a very lively debate by some of the scientific community, in particular in Australia, the United States and Germany ; they principally lean towards the demonstration of the great variety of allergens regularly identified, shown by the analysis of immunoblots produced using atopic patient sera (Tovy & Baldo, 1985).

In this study 20 fractions isolated by polyacrylamide gel electrophoresis were recognised by the serum of 45 atopic patients and 7 of these fractions were recognised by the half of the sera. This result called into question the definitition of allergens termed major and the relationship between them. Maasch *et al.* (1987) and then Wahl *et al.* (1988) identified, in purified extracts of *D. pteronyssinus*, proteins of pI between 4.5 and 5.7 as well as some bands between 5.7 and 7.3 with molecular weights between 180,000 and 5,000 ; they demonstrated the allergenicity of these fractions using crossed radioimmunoelectrophoresis (see figure) and their clinical importance by a series of RAST using immunosorbant discs to which the fractions were bound.

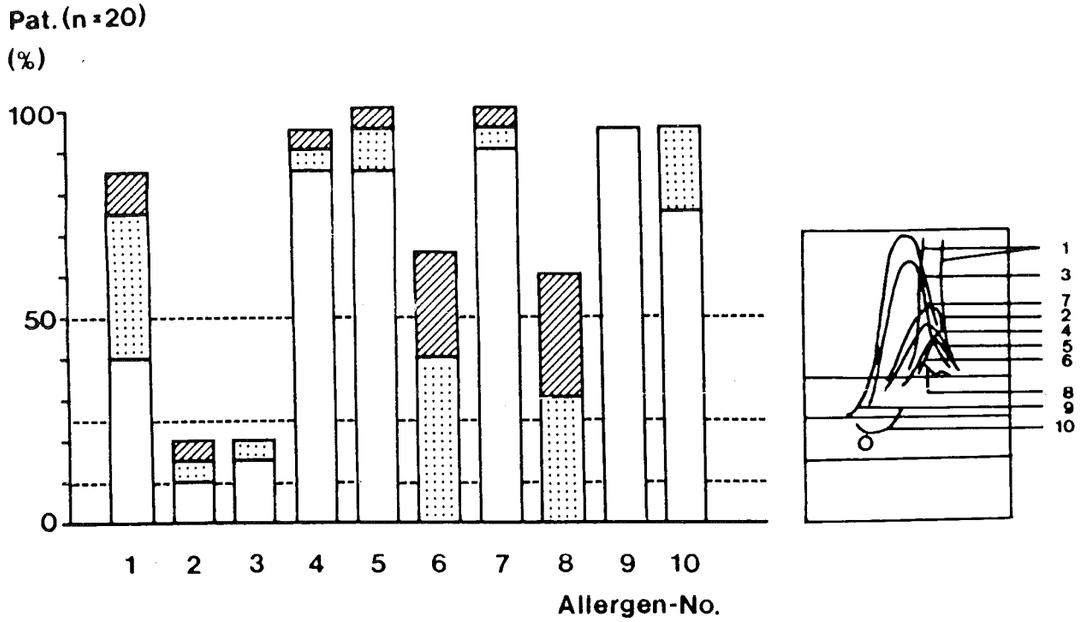
These differences are largely explained by methodological constraints, characteristic of immunochemical techniques, which limit the worker in the vicious circle of selection of patients and reference sera. This problem should not, however, be greatly exagerrated since experience shows that different extracts are perfectly compatible if they are compared to the equivalent concentration of *Der p* I, as Lind (1980)



Images produced after 14 days on CRIE by the serum of four patients (A - D) allergic to *D.pteronyssinus* on cross electrophoresis using a purified mite extract (upper row) and whole culture (lower row).



Allergogram obtained using a purified extract of whole mite body, and in addition the image produced on CRIE using the sera of twenty subjects allergic to *D.pteronyssinus*.



Allergogram obtained using whole mite culture extract, containing somatic and metabolic antigens , and in addition, the image produced on CRIE using the sera of twenty subjects allergic to *D.pteronyssinus*.

suggested in a comparison of extracts of purified whole mite bodies, faeces and whole culture. Maasch *et al.* (1987) confirmed the problems of standardization caused by the characteristics of the international reference, but they also showed in RAST and skin tests, that these differences do not occur if extracts of sufficient concentration are used. In contrast it is possible to take this difference in composition into account when choosing an extract for use in desensitization.

D. farinae

At the present time an international reference extract for this species does not exist, but in the United States a national standard has been prepared, as for *D. pteronyssinus*, using purified mites.

STABILITY OF MITE EXTRACTS

The stability of mite preparations is very variable according to the method of production, presentation and conditions of preservation.

In the dry, freeze-dried state, with a residual humidity less than 2%, extracts can be kept at 4°C for up to 5 years and at room temperature for many months without any qualitative changes or reduction in total allergenic activity.

In aqueous solution, particularly in large dilutions prepared for intradermal reactions or use in therapy, the allergenic activity decreases very rapidly at temperatures more than 20°C, that is, at temperatures easily attained in examination rooms as soon as vials are exposed to the sun; the decrease is clearly less rapid in a refrigerator but it is strongly advisable not to keep these solutions for any length of time without the addition of a stabiliser such as human serum albumin or epsilon amino-caproic acid.

Aqueous solutions prepared by dissolving a standardized freeze-dried extract in a glycero-saline diluant adapted for skin prick tests, but not otherwise useful except as a stock solution, are in contrast very stable and can be kept for several months.

The same is true, to a lesser degree, for extracts absorbed on an aluminium hydroxide gel made using the extract and then washed to eliminate non-fixed allergens. The technique devised to produce these extracts can, however, alter the nature of the allergens, if the pH of the solution is too high during production, before acidification.

This modification, which is characterized by the loss of the capacity to bind specific IgE, is not total, since certain allergens such as the cat allergen *Fel* I can still be measured by the technique of immunoprecipitation (Guérin, 1983), and also the activity of pollen extracts obtained in these conditions, is still detectable by the technique of RAST inhibition.

The denaturation, encountered in the course of preparation or during preservation, is a result of three features of house dust allergens: sensitivity of the major allergens of low isoelectric point to large variations in pH in the alkaline zone, thermolability of the metabolic molecules of the group I allergens, and hydrolysis induced by a protease which is unstable in acidic conditions.

V - DIAGNOSIS OF SENSITIZATION TO MITES

The diagnosis of hypersensitivity to mites depends, as for all allergic diseases, on the results of anamnesis, skin tests, in vitro tests and eventually provocation tests. The aetiology often seems obvious but it nevertheless requires a detailed analysis to identify the "real causes" which can be hidden behind "false friends", such as bird feathers or the hair and skin products of domestic animals, or which may merge into other types of allergenic communities, and represent a polysensitivity to, for example, storage mites.

HISTORY

Involving a detailed inquiry with questions designed to eliminate wrong claims and to identify the assumed aetiology, anamnesis can only be conducted by specialists with experience of this category of illness and of the problems of allergic disease. The type of questionnaire, presented in the following table, has only an indicative value and requires, for a good interpretation of the responses, an in depth knowledge of the typical characteristics of allergy to mites, as described in part II, various cross allergies, and possible perennial polysensitization.

SKIN TESTS

These consist of provoking the mast cells of the skin, sensitized by specific antibodies, essentially IgEs (although a possible interference of other isotypes remains to be discussed) by allergenic extracts used at a well-defined concentration which will not provoke non-specific degranulation. The use of standardized extracts in Biological Units of reactivity (I.R. in France, H.E.P. in Scandinavian countries and A.U. in the United States) is essential, since at high concentrations these cells react in a large number of subjects which clinically do not show any allergic symptoms ; thus Germouty *et al.* (1979) using the intradermal route, was able to obtain a positive response to extracts of house dust in 80% of the general population and in certain epidemiological studies already cited, levels of positive responses to mites in skin prick tests approaching 40% were found, especially in adolescents. The importance of the choice of allergenic extract is well documented by Haahtela *et al.* (1980) who recorded a level of cutaneous reactions which was always very variable according to sex, but more importantly depending on the extracts used. Cutaneous reactions for boys and girls respectively are 43/35% with the dust extract of Bencard compared to 26/16% with that of Dome-Hollister-Stier and 21/18% for the Bencard extract of *D. farinae* compared to 15/13% for that of Dome-Hollister-Stier. The response also depends on the choice of technique and on its execution by well trained personnel with experience of quantification of the cutaneous response by reference to positive and negative controls of reactivity. The description of these techniques is not within the scope of this book, but the reader can easily consult the work of Charpin (1986) or the critical review of Guérin *et al* (1988) which detail the necessary precautions.

BRONCHIAL AND NASAL PROVOCATION TESTS

If the responses of patients to the anamnesis scheme give a confused picture or do not agree with the skin test results and eventually blood tests, it is desirable to use provocation tests of the respiratory mucous membranes. These tests involve reproduction of the conditions which induce the initiation of symptoms.

Their use, which is adequately described elsewhere (Ruffin, 1986), is rarely necessary for pollens, but is used primarily to distinguish the allergens of dust (mites, fungi, feathers) and the hairs of domestic animals.

The provocation is achieved by spraying a freeze-dried allergen extract, dissolved in distilled water or physiological diluant into the nasal passages or the lungs. The diluants must not contain any irritating substances such as phenol or more general preservatives.

The effect of the allergens in bronchial tests is characterized by quickened expiratory movements and a measure of bronchial and pulmonary resistance. These techniques are difficult to carry out and must be carried out by a specialised service. They require strict control, taking into account late reactions, and for these reasons those who practise these tests prefer nasal rather than bronchial provocation.

Overall, the information given by these two types of provocation are equal, but disagreement can exist in asthmatic subjects without rhinitis.

TESTS IN VITRO

Different in vitro techniques which complement rather than compete with one another, enable the confirmation of diagnosis of allergy to mites,

Example of a scheme for taking histories

A/ FAMILY HISTORY

1. Is there in the family (parents, grandparents, brothers, sisters, children, etc...) cases of : hay fever, nasal allergies, asthma, urticaria, eczema, migrain? 1.
2. Are there cases of: tuberculosis, liver disease, bile stones, gout, goiter 2.

B/PERSONAL HISTORY

3. **Allergic** 3.
   Rhinitis (Hay fever) yes - no
   Eczema yes - no
   Urticaria yes - no
   Oedema yes - no
   Asthma yes - no
   Others yes - no
4. **Infectious** 4.
   Sinusitis yes - no
   Bronchitis yes - no
   Angina yes - no
   Pneumonia yes - no
   Others yes - no
5. **Other** 5.
   Medical :

   Surgical :

   Incidents during vaccination :

   Reactions to insect bites/stings :

C/ ASTHMA

I - First Asthma Attack

6. Do you have asthma ? 6.
   If yes, describe your first asthma attack, replying to the questions below
7. What age were you? 7.
8. At what time of year was the attack? 8.
9. Did the symptoms appear gradually or suddenly? 9.
10. Was the attack, in your opinion, provoked by a definite cause, or did it follow certain events? 10.
11. Did it happen after a respiratory infection (flu, bronchitis lung congestion, pneumonia, pleuresy, sinusitis) or after measels or whooping cough? 11.
12. Did it happen after a general operation or after an operation on the nose or tonsils ? 12.
13. Did it happen after an important moral problem (distress, financial or sentimental problems) ? 13.
14. Or following a change in residence, climate or occupation ? 14.
15. Or following a new contact (animals, furs, etc...) or at work ? 15.
16. Did it start at the time of puberty, or gaining weight or menopause ? 16.

II - Current situation

17. How is your current health ? 17.
18. Is your asthma permanent or does it come in attacks ? 18.
19. Do your attacks happen often or seldom, do they last long ? 19.
20. At what frequency do they happen : daily, weekly or seasonally ? 20.
21. If they occur daily, do they happen during the day, either after a meal or after eating a certain food - what food, or during/after one of your daily occupations, or at your work ? 21.
22. Or do they happen during the night, whenever you enter your bedroom, when you start to sleep, towards the end of the night, or when you awaken ? 22.
23. Are the attacks limited or strongly aggravated at certain periods of the year - what periods ? 23.
24. Can you give a precise date when your symptoms begin ? 24.
25. What is your condition : at the beginning of the main pollen season (May to July), at the end of August to the beginning of October, during cold, humid periods (October to March) and during frost (dry cold) ? 25.
26. Do the attacks happen when you eat seasonal foods ? 26.
27. Do they happen after seasonal activities ? 27.
28. Do you often have bronchitis ? Is this accompanied by fever or purulent sputum (yellow) ? Does it provoke asthma attacks? At what period of the year does it usually occur ? 28.

D/ HAY FEVER - NOSE - EYES

I

29. Do you suffer from sneezing attacks from May to July ? 29.
30. On what dates do your sneezing attacks start and finish ? 30.

II

31. Do you often sneeze ? At what period of the day, of the year ? In what circumstances ? 31.
32. Is you nose often blocked ? Do you have to blow your nose often ? What are the nasal secretions like (watery, shiny, white, yellow, green) ? 32.
33. Since what age have you had nasal problems ? 33.
34. Do the symptoms arise mainly after meals, after eating certain foods, after contact with certain substances, or are they permanent ? 34.
35. Do you often have head colds ? If you often have head colds, state : 35.
    a/ if they are accompanied by fever, sore throats;
    b/ if they are followed by a chest cold;
    c/ if sneezing occurs only at the beginning of the cold or is persistent;
    d/ during how many days do you find when you blow your nose, a liquid resembling water and for how many days do you find a thicker mucus ?
36. Have you already had sinusitis ? 36.
    Do you often have recurrences ?
37. Have you had your tonsils and adenoids removed ? 37.
38. Have you had any nose operations? 38.
    (extraction of polyps, excision of a crest of the septum or of a turbinate tail, etc...)

III

39. Do you often have eye problems ? 39.
    (smarting, irritation) ?

E/ ECZEMA, URTICARIA, MIGRAINES GASTRO-INTESTINAL PROBLEMS

40. Do you have eczema ? 40.
    On what part of the body ?
41. Do you have urticaria ? 41.
    How frequently does it occur and what provokes it ?
42. Do you have migraines ? 42.
    Are they accompanied by problems in seeing ?
    Are they uni or bilateral?
    What provokes them?
43. Do you often have indigestion ? 43.
    What provokes it ?
44. Are there certain foods which make you ill ? 44.
    What is their effect (cramp, diarrhoea, eczema, asthma, etc...) ?

F/ TRIGGERING FACTORS

45. Have you noticed factors which provoke asthma attacks, sneezing or running of the nose, the appearance of eczema or urticaria ? What are they ? 45.

I - Atmosphere

46. Are your attacks provoked or aggravated by cold, humidity, wind, draughts ? 46.
47. Are your problems more obvious on sunny days, with or without wind, or cloudy, cold days ? 47.
48. How is your health at the seaside, in the mountains : Amelioration, aggravation, or the same ? 48.

49. Are there certain places or localities where you have asthma or on the contrary are in perfect health ? 49.

II - Your state

50. Are your problems provoked by tiredness, nerves, laughter, worry ? 50.
51. Are you emotional ? Do you have many worries : financial, sentimental, professional ? 51.
52. Food excesses, alcohol or constipation ; do these aggravate your problems ? 52.
53. Does your monthly period aggravate the problem ? What has been, in the evaluation of your illness, the role of puberty, increased weight, the menopause ? 53.

III -Your normal life

54. How do you do your cleaning (with water, a broom, or a vacuum cleaner) ? 54.
55. Are you disturbed by a dusty atmosphere during cleaning, during a major cleaning, during sweeping, or at the cinema or theatre ? 55.
56. Are you disturbed in a dusty street ? 56.
57. Does the cleaning of your cellar or attic provoke your problems ? 57.
58. Since what age have you smoked ? How many cigarettes a day ? Does tobacco smoke disturb you ? 58.
59. Do other types of smoke or smells provoke your problems (smells of the kitchen, frying, petrol etc...) ? 59.
60. Does the smell of paint, wax, varnish, insecticides disturb you ? 60.
61. Does the use of rice powder, soap powder, toilet soap perfumed shampoo aggravate you ? 61.

IV - Animals

62. Do you have any domestic animals ? 62.
    Dogs, cats, canaries, budgerigars, parrots ?
63. Do the animals enter your bedroom ? 63.
64. Are there mice in your house, are there mites or other insects in abundance ? 64.
65. Are there in you home, or in your neighbourhood hen houses, stables, cow sheds, rabbits, pigeons, guinea pigs, etc...? 65.
66. During work are you in contact with animals ? What sort ? 66.
67. From occasional contact with animals, have you had problems (asthma, urticaria, sneezing) either at the circus, a menagerie, at friends' homes ? 67.
68. Do furs (coats, collars, etc...) provoke your trouble ? 68.

V - Plants and trees

69. Are you sensitive to contact with certain plants : certain flowers (rose, primrose, chrysanthemum) ? 69.
70. Do you have flowers or plants in your home, in your bedroom ? 70.
71. What plants do you have in your garden ? 71.
72. Do you live in the country, near a park ? 72.
    Are there many trees ? What kind ?
73. Is there any particular vegetation in your garden or near your home ? 73.

VI - Your house

74. Does your trouble occur exclusively or is it more marked in the house or in certain rooms of your home ? 74.
75. Was your house constructed recently or is it old ? 75.
    For how long have you lived there ?
76. In your house are there areas where dust accumulates : old wardrobes, old carpets, old armchairs, books ? 76.
77. Is your house humid ? 77.
78. Is your cellar humid ? What do your store there ? 78.
79. Does fungus grow in certain places (cellars, old materials, wallpaper, humidity plates) ? 79.

VII - Your bedroom

80. Do you sleep alone ? 80.
81. What are your pillow, mattress, bedspread and bed covers made of ? 81.
82. Do you have a carpet or rug ? Do you have curtains or open shelving ? 82.
83. Are you bothered by or sneeze when you turn your mattress, or when shaking your curtains or bed covers ? 83.

VIII - Your area

84. How long have you lived in the same area, the same town, or the same region ? 84.
85. Describe the area in which you live. 85.
86. Is the area humid (lake, park, canal, river, etc...) ? 86.
87. Is there in the area : a mill, a barn, a warehouse, a factory, an industrial complex ? 87.
88. Are there any special smells or smoke ? 88.

IX -Your work

89. What is your occupation ? 89.
    Describe in detail what you do and the contacts that you have during your work : various products, animals, places frequented. 89.
90. Does your trouble occur mainly at your work or is it aggravated by this ? 90.
91. Do you suspect any particularly harmful contacts ? 91.
92. Is there much dust where you work ? 92.
93. Is it warm or cold or humid ? 93.
94. Do you still have problems at weekends or during holidays ? 94.

X - Your diet

95. Does eating certain foods provoke your problems ? 95.
    Which foods ? Which problems ?
96. Do you dislike certain foods ? 96.
    Why ?
97. Have you ever followed any special diets ? Which? 97.
    Why ? With what result ?

XI - Medicines and treatments

98. Do certain medicines (antibiotics, sulfamides, aspirin, etc...) provoke your trouble ? Which problems ? Which medicines ? 98.
99. Have you had X-rays of your lungs, sinuses ? 99.
    What did they show ?
100. What treatment have you had ? With what result ? 100.
101. What means do you use to relieve your illness ? 101.
     With what results ?

XII - Your family

102. What is the occupation of your partner ? 102.
103. What is the occupation of your children or other people living in your house ? 103.

DATE :

particularly the identification of the mite species involved, and even visualization of the allergenic molecule to which the individual is sentitized, which is practically impossible in vivo.

In fact, the very large antigenic community of allergens of the same group, more generally the existence of important cross senstizations between skin-eating mites, and the frequence of polysensitizations to storage mites, cannot be distinguished by tests in vivo which are very sensitive but do not discrimate at the quantitative level. To reduce this uncertainty it is possible to measure, either the absolute or relative quantity of specific IgE present in the serum of the subject, or the response in mediators, particularly histamine, that trigger the basophils in the blood by various extracts. It is also, exceptionally, possible to identify sensitization at the molecular level using the techniques of immunoblotting.

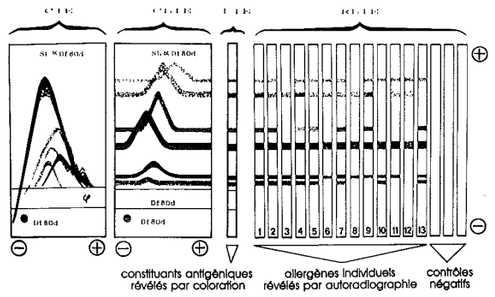
QUANTITY OF SPECIFIC IgE

Positive skin tests must be verified by a measurement of the dose of specific IgE expressed in a system of units comparable from one allergen to another. This must also be cumulative to permit distinction of results which may depend on cross antigenicity to which the major sensitization is displayed. In practice this objective is only possible by the use of methods using the same antibodies for the evaluation of total IgE and specific IgE, which allows the expression of results in international units and not in arbitrary classes or units which vary from one producer to another (Guérin, 1987). The interpretation of biological results must take into account the probability of general infestations in the area, specifically in the home, cross allergenicity, the profession of the subject, and other factors of contamination associated with the environment such as the presence of domestic animals or a strong disposition to the development of fungi or moulds. In France ideally the specific IgE titres of the three principal house dust mites and of three storage mites are measured, but it is also possible to limit this to, in the first instance, the mites representing the most ubiquitous species of the two types, such as *D. pteronyssinus*, except in dry areas, and *T. putrescentiae*.

T.D.B.H. AND LIBERATION OF HISTAMINE

These two methods tend to measure sensitization by its effect on the degranulation of polynuclear basophils, circulating target cells with specific receptors for antibodies of the IgE class. They consist of incubating a sample of the subject's blood with increasing concentrations of the allergenic extract under consideration followed by measurement of either the resultant degranulation, or the histamine liberated by this degranulation. Both measurements tend to represent the

C I E : Crossed Immuno Electrophoresis
C L I E : Crossed Line Immuno Electrophoresis
L I E : Line Immuno Electrophoresis
R L I E : Radio Line Immuno Electrophoresis



In the example above, patients n°1 to 9 had a RAST class 4 to the allergen studied. Patients n°10 to 12 had a RAST class 3, and patient n°13 a RAST class 2.

first physio-pathological mechanism of the allergic reaction as a whole rather than measuring only the amount of free antibodies which can be reduced by interference with immune complexes or antibodies with different affinities (Stadler, 1988).

The measure of the level of degranulation requires: availability of fresh blood samples, a preliminary concentration of samples and a cellular count, which is always difficult ; it gives reproducible results, but does not allow easy distinction of a true cross sensitization response.

The dose of histamine, which is more quantitative, can be obtained using total blood or a washed cellular suspension with liquid allergenic extracts or extracts fixed covalently on a solid support (Morel, 1988).

IMMUNOBLOTTING

To precisely identify, not overall but individually, the allergen molecules to which a subject is sensitized, Peltre *et al.* (1982) for the first time proposed the use of the classical technique of immunoblotting. This consists, after having separated the allergens by SDS electrophoresis on polyacrylamide gels and having transferred them to a nitrocellulose membrane, of incubating a strip of this membrane with a sample of serum and then visualisation of the areas of binding using radio or enzyme labelled anti-IgE ; the activation of the nitrocellulose by bromide or cyanogen permits a good transfer of glycoproteins which constitute the principal mite allergens (Demeulemester *et al.*, 1987). The same authors simplified the experimental protocol by combining the four techniques in the above figure to

produce results for which each band is exactly identified by the profile of initial cross immunoelectrophoresis. The analysis which can be described under the name of IDALI, in conjunction with RAST is currently carried out by the ALLERGOTEST Laboratory of the Pasteur Institute in Paris.

This technique cannot be systematically applied for all diagnosis, but it is valuable in research, in the case of failure of desensitization or to refine identification of the causal agent.

VI - PREVENTION - EVICTION

Due to the perennial character of allergy to mites, the possibility of a continuous symptomatic treatment does not seem feasible, and consequently preventative methods to prevent hyposensitization are very important. This approach consists of firstly identifying the locality and importance of ecological niches of the mites and then to embark upon an active programme of reduction of mite numbers.

1. DUST ANALYSIS

COLLECTION OF SAMPLES

The reader will find a detailed description of the general technique for taking dust samples in Chapter II, but it is also possible in the case of the carpet, clothes and thin cushions, to evaluate directly the importance of mite populations using the method of Bischoff (1988).

This consists of slowly heating from underneath a defined surface of the chosen object, in principal a carpet, which modifies the temperature and relative humidity in the area inhabited by mites ; gradually with the increase in temperature, the mites try to escape from the heat and progressively come to the surface of the carpet. It is thus easy to trap them on a large sticky surface, such as the sellotape currently sold in book shops to protect books, which is covered with a plate of glass or a heavy opaque tray to prevent the mites being irritated by the light. The source of heat can consist of a heated cushion or cover but in such a case it is desirable to attach a sheet of aluminium foil to the lower surface to concentrate the radiation and to provide the maximum heat. Bischoff advises that the trap should be kept in place for an hour and, for a very precise measurement, to then place a second control trap in position to ensure that few mites remain in the material. After having been carefully removed from the textile surface the trap is fixed to a sheet of thin plastic, to facilitate manipulation and the mites are then counted under the microscope. The same protocol, but without heating and instead leaving the trap in contact with the sample for 24 hours, enables measurement of the mobility and thus the health of the mite population.

These two techniques have the advantage of measuring living mites which will influence prescription or embarkation on acaricidal treatment.

CHEMICAL DETECTION

In the absence of an acarologist capable of analysing the mites collected on the trap or to extract mites from dust, the patient can proceed himself to evaluate the level of mite contamination using the Acarex-Test® ; this test uses the preferential excretion by mites of their metabolic products in the form of guanine. This substance has been described in mites by Vitzthum (1943). The quantitative colorimetric determination of guanine in dust constitutes a good indicator of the level of contamination by mites or perhaps occasionally by insects such as cockroaches ; a good correlation between this technique and clinical (Pauli *et al.*, 1988) or immunological (Le Mao *et al.*, 1988) studies has been found.

IMMUNOCHEMICAL METHODS

The research and the quantification of allergens can be achieved by various immunochemical techniques, particularly by the combination, proposed under the name of CARLIE by Dandeu *et al.* (1987), of simple cross immunoelectrophoresis, intermediate gel and "rocket line" immunoelectrophoresis. This consists of constructing a reference plate with an internal standard extract, then to slowly pour a new gel in which wells have been cut for the introduction of dust extracts for analysis, and in the upper part a gel containing antibodies which recognise the reference allergens. The lines of precipitation which form, after displacement of the allergens in an electric field, are visualised by colouration of the proteins ; they follow the lines produced by the internal standard and thus enable the identification and quantification of the different peaks.

The large scale production of monoclonal antibodies has allowed the development of simple techniques of quantification of mites allergens ; they consist of incubating the mite extract or dust extract with an antibody bound covalently or by absorption on a solid phase, such as a cellulose disc, a microplate or a tube, and then measurement of the bound products with the aid of a radio or enzyme labelled second antibody (Luczynska *et al.*, 1989).

DOMESTIC HYGIENE

It is in textile products with which man surrounds himself that house dust mites find the optimal conditions of their normal biotope, whereas storage mites are mainly found in proximity to stored food. To reduce the build up of mite populations, various factors which optimise their development and their dietary requirements should be examined. In this respect, a high standard of domestic hygiene plays a crucial role and is relatively easy to achieve by reorganization of the furnishings, regulation of the interior microclimate and a regular, systematic plan of cleaning.

REORGANIZATION OF FURNISHINGS

The principal effort should be concentrated on the bedroom which must be rid of all useless, difficult to clean textiles such as heavy curtains, wall hangings in fabric, woolen carpets or cushions, and books. Mattress, pillows and duvets filled with wool or feathers should be replaced with similar objects filled with synthetic aerated materials based on rubber or polyester foam. Care should be taken to avoid substitution with feathers or other substances of animal origin, such as silk which was shown in Switzerland for example, to cause serious allergic reactions due to sensitization to the metabolites of silk worms (Wutrich, 1985). The surface of pillows and mattresses, which are in direct contact with the subject during sleep, can be covered by a washable sheet specially made of a lined material to prevent the passage of mites through the sheet, but at the same time letting the skin and mattress "breathe". The choice of armchairs and sofas is also important because mites multiply easily in the stuffing as is the case with soft toys. The furnishings in other rooms plays a less direct role in the provocation of the patient, but it is desirable to eliminate everything which could constitute a preferential niche for mites or which could reduce the efficiency of cleaning measures. In addition, particular attention should be paid to the seals of wardrobes and also food stores. Finally, domestic animals such as dogs, cats, guinea pigs and also birds should be excluded from living areas and if possible prevented from regular contact with the patient since they are not only allergenic but they may constitute a permanent source of skin and storage mites which are difficult to eliminate.

AIR CONDITIONING

Since the reproduction and development of mites is directly related to temperature and relative humidity within the limits detailed in Chapter II, maintenance of these parameters at a level unfavourable to mites is an essential measure. An attempt should be made to reduce the temperature of the bedroom to below 20°C and the relative humidity to between 40 and 50%, a result which can be obtained in winter by limiting the use of humidifiers and in summer by the installation of an air conditioner. The attention of the patient should also be drawn to the risks of development of fungi in the condensation filter of the apparatus and of cleaning procedures to prevent this.

It is also possible to purify the ambient air with the aid of a portable filter apparatus such as ENVIRACAIRE®, which retains 99.97% of particles greater than 0.3µm diameter and within a few minutes recycles, without noise, the air of an average sized room.

The ad hoc committee of the F.D.A. however feel unable to issue advice on the usefulness of this practice, due to lack of clinical trials (Nelson *et al.*, 1988).

PLANNING FAMILY LIFE

As far as possible it should be attempted to avoid holidays, especially those limited to a few days, in an old family house, normally unoccupied and badly heated, unless it is a chalet in the mountains ; in any case it is necessary to apply the same rules of hygiene as those described for the principal home to the holiday bedrooms of atopic subjects.

CLEANING THE HOUSE

To complete the reorganisation of the furnishings and climatic control, a stringent programme of house cleaning should be established, including:

- Daily vacuuming of dust on the floor and aeration of the bed by a non-allergic person or protected by a mask, however, the use of a vacuum cleaner on carpets only eliminates a very small quantity of mites ; the ideal procedure is to varnish wooden flooring and to wash it with a damp cloth.
- Wiping all surfaces of furniture with a damp cloth.
- Hanging up all clothes in wardrobes and removing other objects likely to retain dust or provide temporary niches for mites.
- Washing blankets in hot water every two weeks to prevent the reproduction of mites and to eliminate residual allergens.
- Daily aeration of the bed which results in the temperature of the mattress falling by several degrees.
- Washing bed sheets several times per year.
- Elimination in the living room and kitchen of all food particles, without which storage mites cannot survive.
- Regular control, with the aid of a hygrometer, of the humidity of different rooms.

- If necessary, washing humid areas with antifungal substances. Areas such as underneath sinks, baths or wash hand baisins are particulary favourable for fungi which can favour the multiplication of mites.
- Should the parents think it necessary, sterilization of soft toys can be achieved by frequently placing them in the freezer ; this procedure does not guarantee total destruction of mites as they can resist lengthy periods at temperatures produced by domestic apparatus, but it at least inhibits growth of the population.

2. TREATMENT BY ACARICIDES AND ANTIGENIC DENATURANTS

Indispensable as they are, active domestic hygiene measures cannot pretend to completely eradicate house dust mites and it is almost always necessary to resort to an offensive action which will modify the furnishings to suppress the traditional niches of the mites without completely depersonalizing the home. The use of acaricides involves a practical balance in terms of the relation between efficiency/cost and efficiency/risk, since some of these products are only active at doses close to atmospheric concentrations which are irritable for asthmatics. In fact, the majority of acaricides consist of molecules known for their antiseptic, insecticidal or fungicidal properties, usually used out of doors on vegetation during a period of time limited by atmospheric conditions.

A descriptive list of acaricidal substances should therefore include their chemical formula and conditions of use, in addition to a critical analysis of their efficiency, toxicity and their acceptability for domestic use. Such a list has been described by Saint Georges-Gridelet *et al.* (1988), but is updated here to take into account the new formulas now available.

COMPOSITION AND CHARACTERISTICS OF PRINCIPAL ACARICIDES

(see table on page 174)

SAFETY OF ACARICIDES

Concerning the question of security, these various products must be analysed under three aspects ; toxicity, risk of fire, and acceptability for domestic use which takes into account their effect on treated furnishings.

In practice toxicological information is obtained from evaluations conducted in relation to the major usage of the principal acaricides of various origins. The most recent belong to a group of synthetic pyrethroids which are of low toxicity to mammals, and also to the group of organophosphates, such as pirimiphos methyl, which are inhibitors of cholinesterases and thus more or less suspect of a certain toxicity. Normally acaricides are products developed as agricultural and veterinary insecticides, which have been examined according to the directives of the Commission of the Study of Toxicity of the Service of Protection of Vegetation at the Ministry of Agriculture. They consider the risks associated with their application (accidential ingestion or exposure) and the risks of these products circulating in the environment, but do not normally consider the consequences of a prolonged domestic exposure to them. Other recently developed molecules, such as Natamycine or Pimaricine (antibiotic-antifungicide), the imadozole derivatives (also antifungicides) are used primarily in various skin preparations and have thus been evaluated at these strengths by the Commission of Authorisation for Putting Medicines onto the Market who are answerable to the Minister of Health. Finally, certain acaricides contain much more established molecules, either used in scabies such as benzyl benzoate, antibacterials, or "disinfectants" such as benzalkonium chloride, benzoic acid and essential oils (terpinol, thymol etc.). This diversity of origin explains the disparity in results assembled by Saint Georges-Gridelet *et al.* (1988). In fact in this particular study, after the evaluation of the strength of vapour, an eventual examination of the irritant and sensitization properties would have been valuable.

Physical agents themselves, such as dry ice or liquid nitrogen, are not without toxic risks since they can cause, if released into the atmosphere, a drop in oxygen levels which is so severe that liquid nitrogen is unavailable to non-specialised users.

As for other risks, the domestic consequences of using treatments which can occasionally stain or alter furniture should be emphasised ; for this reason the misuse of physical agents such as gas, which is harmless at first sight, can crack varnish in cold conditions or weaken solids such as wood or foams. It is possible that steam cleaning which is relatively harmless, could provide a good compromise between the requirements of efficiency, non-toxicity and of respect for furniture, since humid heat has not only acaricidal properties but also the ability to denature mite allergens.

EFFICIENCY OF ACARICIDAL PRODUCTS

The following table summarises the suggested activity of various acaricidal preparations studied in the laboratory, with respect to the speed of action in killing mites and to percentage reduction in their populations.

The clinical efficiency of these products is much more difficult to establish, at least in double blind trials, as Mitchell *et al.* (1987) demonstrated with respect to one product which was found to be more active in the laboratory. It seems that many months are necessary to allow the return to normal of the bronchial mucous

CHARACTERISTICS OF PRINCIPAL ACARICIDES

(in alphabetic order)

Brand Name	Formulae	Weight/Vol.	% without propel.	% with propel.	General Characteristics
ACARDUST (1) **Applipharm (France)** *Spray*	Esbiol (Esdepallethrine) Piperonyl Butoxyde Excipient Propellant TOTAL	1.89 g 15.12 g 192.99 g 325.00 g 535.00 g	0.90 7.20	0.35 2.83	Aerosol solution for spray or atmospheric release Synthetic pyrethrinoid. 4 to 6 sprayings per year on carpets and upholstery.
ACAROSAN (2) **Werner-Mertz (FRD)** *Spray (foam)*	Benzyl benzoate (solid) Excipients & gas (butane) q.s.p.	7.20 g 276.00 g		2.60	Flask for generation of acaricide foam + detergent. 50-100 g/sq m. Lemon scented. 1 or 2 treatment per year on mattress and upholstery.
Powder	Benzyl benzoate (solid) Excipients q.s.p.	37.50 g 750.00 g	5.00		3 sachets of 250 g for treatment of carpets and curtains with 50 - 100 g/sq m. 1-2 /years.
ACTELIC (3) **ICI (U.K.)** *Solution*	Pirimiphos-methyl	50.00 g/l	5.00		10 different formulations, depend on application. Wide-range organo-phosphorous of low toxicity.
Aerosol	Pirimiphos-methyl + syn. pyrethroids	20.00 g/l	2.00		Used for carpets and bedding. Pyrethroids for quick knock-down. 8-10 applications/year.
ALLERBIOCID (4) **Allerbio (France)** *Solution*	Benzyl benzoate Tannic acid Tween 20 Isopropyl-alcohol 70% Dist. water 30% q.s.p.	33.50 g 10.00 g 11.00 g 1000.00 ml	3.35 1.00 1.10 70.00	3.35 1.00 1.10 70.00	Bottle of 1/2/5 soln acaricide for use with manual-pressure spray. 125 ml/sq m for the first treatment then reduced for the residue. 4 treatments per year of mattress and carpets.
ARTILIN 3A (5) **Artilin S.A. (France)** *Paint*	Alkyd resins Benzyl benzoate White spirit or water	? ?			5 kg pot of paint. 4 presentations. Acaricide / fungicidal action claimed. 3-4 years on walls and woodwork.
LIQUID NITROGEN (6) **Air Liquide (France)** *Bottled gas*	Liquid N2	100.00	100.00	100.00	Dewar flask, odourless, 5 l for a single bed, 7 l for a double ; cryogenic effect (-195°C). Stability depends on container. Treatment annually by specialist. Beds and carpets.
DSM (7) **Allersearch (Australia)** *Solution*	Benzyl alcohol Tannic acid Ethyl alcohol Dist. water	10.00 ml 1.00 g. 30.00 ml 60.00 ml	10.00 1.00 30.00		Alcohol soln of a complex, presented in cans of 1 and 2.5 l. Acaricide and allergen denaturing properties, for use 2 times per year on beds and carpets.
PARAGERM AK (8) **Paragerm SA (France)**	Benzoic acid Terpinol/Salol Thymol Chlorophenols TOTAL	? ? ? ? 325.00 ml	? ? ? ?	? ? ? ?	Aerosol-generating bottle of 325 ml solution fo vapourisation. 2 applications per month on mattress and bedding.
TYMASYL (9) **Gist-Brocades (The Netherlands)**	Natamycine Benzalkonium chloride Butane/Propane TOTAL	 192.00 g.	2.17 0.02		Aerosol-generating bottle, antifungal, indirect acaricide. 0.5 g/sq m for mattress and pillows. 6 sprays in 2-3 weeks then monthly.

membrane and that during the period following eradication of mites, irritation can be provoked by very small quantities of allergens originating from old niches. This remark justifies the use of substances which denature the allergens, such as solutions of tannic acid in alcohol which work by the action of the alcohol on the survival of the mites and also by the polyphenol on the allergenic determinants (Green *et al.*, 1989). It should nevertheless be noted that Kersten *et al.* (1988) in a recent study using Acarosan obtained astonishly rapid results with respect to clinical scores and without denaturation of the allergens.

REGULATIONS APPLICABLE TO ACARICIDES

The appearance on the French market of insecticides and acaricides for use on man was the object of an authorisation given by the Minister of Health applying article L.658-11 of the public health code. The document, defined by articles R.5266-1 to 15, must be accompanied by, as for a medicine, a report of analytical toxicological and clinical trials which prove the efficiency and safety of the preparation.

These rules does not seem to concern acaricides for domestic use which are not applied directly to man, such as products used to treat upholstery fibres, incorporated into paints, or sprayed onto carpets and beds.

In other countries of the European Community , the situation is often similar or more restricting, even if direct application to man is not involved. In Belgium, the Superior Advisor of Public Hygiene demands the demonstration of the absence of respiratory risks, a complete toxicological survey including chronic and carcinogenic studies, and the proof that there is clinical improvement in subjects whose home has been treated ; a similar situation exists in Great Britain.

VII - TREATMENT

The treatment of allergic disease induced by hypersensitivity to the allergens of house dust mites or storage mites, does not differ overall from that used for other specific allergens. It always includes, in the first instance, a combination of rigorous avoidance methods, involving the use of the various techniques previously described, and of a symptomatic treatment.

Many months are necessary to judge the efficiency of hygiene methods or of a prolonged stay in a mountainous region which has a low mite contamination ; an improvement is judged by a reduction in the consumption of symptomatic medicines (for which the instructions for use, now well coded, will not be treated in the book). It suffices to recall that the range of therapeutic treatment for rhinitis includes, a combination of modern antihistamines, which are very effective for rhinitis, less effective for obstruction, and without effect on an associated polypous, along with Cromoglycate or Ketotifene and also local corticoids. In the case of asthma, symptomatic treatment is associated with brochodilator beta-2 stimulants, such as Salbutamol, corticoids with a local action, such as Beclometasone, and mast cell stabilisers, such as Cromoglycate which blocks the degranulation of the target effector cells associated with hypersensitivity.

In the case of failure after avoidance measures for a long period associated with a well conducted symptomatic treatment (difficult to maintain permanently for a perennial illness), it becomes totally legitimate and even necessary to plan an aetiological treatment such as desensitization, also called specific immunotherapy. Recent studies (Bousquet, 1989) separate the treatment of rhinitis and asthma ; it is true that the relation between efficiency/risk and side effects of new antihistamines count against immunotherapy for which the prescription must often be accompanied by another for symptomatic medicines, but the permanent character of the illness advocates, in contrast to asthma to pollen or a classic hayfever, an attempt to intervene in the pathological mechanism. In fact, extrinsic asthma to mites constitutes the major use of specific desensitization ; it is entirely legitimate, taking into account the gravity of the debilitation of the illness and the efficiency of therapy confirmed by a series of controlled clinical trials (Bousquet *et al.*, 1985). Its execution does not however constitute a therapy without risks; it must be strictly supervised as incorrect instructions side effects can result in serious accidents which can exceptionally be fatal. Practically, immunotherapy prescription should only be under the control of specialist clinicians. It should be kept for monosensitive subjects to perennial dust allergens who have previously regained a respiratory function corresponding to 70% of the normal value following appropriate pharmacological treatment. The posology of maintenance, after the initial accelerated phase ("rush") or grouped and in stages ("clustered"), must endeavour to establish an effective dose less than the maximum well tolerated dose but enough to protect against a sudden change in the level of sensitization caused by various factors such as physiological shock, a viral infection or an abnormal provocation. The recommendation of the European Academy of Allergy and Clinical Immunology, as that currently being established by the W.H.O., has indicated that the treatment should be followed by between three and five years of periodic reevaluation by a specialist.

VIII - CONCLUSION

At the end of this review on allergic disease caused by hypersensitivy to mite allergens, it should be remembered that this aetiology constitutes the principal cause of perennial rhinitis and asthma both of which are particularly debilitating. Their diagnosis appears at first sight to be simple, but anamnesis is difficult and must always be confirmed by a specialist to identify with certainty the mite or mites responsible. Analysis of dust can certainly provide a first confirmation of the importance of the provocation, but the chemical dust test does not permit details of the species of mite involved and thus must be supplemented by microscopical examination or immunological analysis, both rather complicated procedures for standard use. In contrast, skin tests and serial dosage of specific IgE to various perennial allergens, and confirmed exceptionally by a nasal or bronchial provocation test, enable confirmation of the diagnosis and establishment of a therapeutic programme. Priority will normally be given to measures of domestic hygiene to reduce to a minimum the source of allergens and thus the level of provocation of the respiratory mucous membranes, inflammation of which prolongs the illness. This will usually be completed by pharmacological treatment which aims to reduce non specific reactivity by blocking the degranulation of effector cells and by reducing mucousal inflammation, followed by treatment of the symptoms by anti-histamines or bronchodilators. Only in the case of failure of these various measures, will the decision to institute immunotherapy be taken, for which a protocol must be established and the administration controlled by a qualified allergy specialist.

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