Mites are arachnids too

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Introduction

Almost all arachnids are predators. The only group of arachnids that has managed to break out of the predatory habit on a large scale is the mites, which have diversified into an extraordinary range of niches. Many are still predatory, but there are also thousands of species of plant feeders, fungivores, saprophytes, pollen and nectar feeders, microbial filter feeders, and internal and external parasites on a wide range of vertebrates and invertebrates. Others have a complex life cycle, in which parasitism and predation occur at different life stages within a species, and others are omnivorous. Mites occur in soil and decomposing organic matter, in fresh water and sea water, high in the air, deep in the oceans, on and in the bodies of other animals, and on plants of all kinds. This ecological diversity has been accompanied by a bewildering degree of morphological diversity. Their diversification has in turn been reinforced by their small body size, which allows them to occupy minute spaces, and makes it necessary to use specialised techniques for their observation and taxonomic study. All of these factors conspire to create an artificial division between acarologists and other arachnologists, to the extent that mites have their own literature, their own anatomical terminology, and their own national and international conferences. One of the outcomes of this division is that research papers on mites are more likely to be found in entomology journals than those devoted to arachnology. This is a reflection of the fact that mites have much in common with insects, especially as pests of cultivated plants and crops. The purpose of this general article is to make mites more accessible to arachnologists who do not have specialist knowledge of acarology.

Classification of the Acari

Mites are the smallest arachnids in terms of body size (although the biggest mites are bigger than the smallest spiders). Adults of most species of mites are in the range 300–800 micrometres in body length. Mites are also distinguished from other arachnids by the complete absence of body segmentation, and by the fundamental organisation of the body. There is no division of the body into cephalothorax and abdomen. Instead, the mouthparts and associated sensory structures form a discrete anterior structure known as the gnathosoma. All the rest of the animal's anatomical structures, including leg bases, central nervous system, ocelli when present, and reproductive and digestive systems, are all fused into a single unsegmented body called the opisthosoma.

Many systems of higher classification have been used for the mites, and many different names have been used for the higher taxa of mites at all levels. In the most modern classification, the mites are placed in the class Acari, within which there are two superorders. The superorder Parasitiformes includes order Opilioacarida, order Holothyrida, order Ixodida, and order Mesostigmata. The superorder Acariformes includes order Trombidiiformes and order Sarcoptiformes (Walter 2006; Krantz and Walter 2007).
The order Opilioacarida includes a single family of large mites (≥ 1 mm) that have many character states that are considered to be ancestral (Krantz 1978). They are widespread but rare in semi-arid climates, where they are found under stones. An unidentified species has been collected in Kakadu National Park, where it feeds on mites and insects, as well as fungal hyphae and pollen (Walter and Proctor 1998).

![Image of a mite](image)

**Fig. 1:** Species of Asca (Mesostigmata: Ascidae) are recognised by the pair of prominent horns or protuberances on the posterior margin of the body. About 80 species occur in leaf litter and moss world-wide, where they prey on mites, insect eggs and larvae, and nematodes.

Photograph: D.E. Walter

The order Holothyrida includes large mites (≥ 2 mm) with a heavily sclerotised and highly-arched body, which feed readily on dead arthropods (Walter and Proctor 1998). The order includes about 25 species in three families, and has a Gondwanan distribution. Only three species have been described from Australia, all in the family Allothyridae (van der Hammen 1983), but many other undescribed species have been collected and await study.

There are about 80 known species of ticks, order Ixodida, in Australia (Roberts 1970; Keirans et al. 1994, 1996). They are all blood-feeding parasites of mammals, reptiles and birds, and are characterised by mouthparts with a large number of backward-directed hooks that are inserted into the host for feeding. The best known Australian species is the paralysis tick *Ixodes holocyclus*, which can be dangerous to the health of humans and dogs (Anonymous 2003).

The order Mesostigmata (e.g. Fig. 1) includes about 80 families of relatively large mites with adult body lengths in the range 300–3000 μm. They are characterised by a series of leathery sclerotised plates that cover the body, and by a pair of laterally-placed stigmata, which are the external openings of the tracheal system. Most are predatory, while a few also feed on pollen and nectar. They occur in a wide range of habitats, including soil and litter, but are also abundant in dung, carrion, compost, and in the nests of vertebrates. Many are beneficial, contributing to the control of insect and mite pests. Notable among these is the arboreal family Phytoseiidae, which are widely used in the control of spider mites that damage crop plants (Gerson et al. 2003). Many families are parasites of vertebrates, including families such as the Dermanyssididae and Macronyssididae, which parasitise domesticated animals and can attack humans (Southcott 1976). Many families have associations with insects. These relationships vary from simple phoresy for the purpose of dispersal, to much closer relationships in which the mite has specialised morphological and be-
havioural adaptations at different stages of the life cycle that are involved in its interaction with its insect carrier. Sexual dimorphism is common, in the general arrangement of body sclerites, in modification of the legs of the male which are used in fighting, and in structures on the male chelicerae that are used in sperm transfer.

Fig. 2: Stereotydeus (Prostigmata: Penthalodidae) is a genus of brightly coloured and ornamented mites found in moss and leaf litter in the Southern Hemisphere, including Antarctica. Little is known of their biology, but they are believed to be predatory.

Photograph: D.E. Walter

The order Trombidiformes, also known as Prostigmata (e.g. Fig. 2), is the most diverse of the major mite groups, in terms of the number of species it contains, and in the range of morphological and behavioural variation they display. They are called Prostigmata because the stigmata are usually located at the base of the mouthparts, or on the anterior margin of the opisthosoma. The cohort Eupodina includes the family Penthalaeidae, in which the redlegged earth mite Halotydeus destructor and blue oat mite Pentheleus major are serious pests of crops and pastures in southern Australia. The same cohort also includes the predatory families Bdellidae and Cunaxidae, whose members have been used as biological control agents of mite pests in pastures and horticulture (Gerson et al. 2003). The superfamily Eriophyoidea includes thousands of species of plant parasites, many of which are important crop pests, either through the damage they cause directly, or through their role as vectors of plant viruses. The cohort Anystina includes beneficial predatory species among its 6 families. The cohort Parasitengona includes hundreds of species, most of which have a complex life cycle in which the larval stage is a parasite and later stages are free-living predators. Larval Trombiculidae are parasites of vertebrates, commonly known as chiggers, the Australian fauna of which has been catalogued by Domrow and Lester (1985). Several families including Erythraeidae and Trombidiidae have larvae that are parasitic on insects, and terrestrial adults that are often called red velvet mites. Only a handful of species have been reared in captivity to allow the adults and larvae to be correlated. A further group of families is collectively known as “water mites” or Hydracarina. The larvae of these groups are mostly parasites of aquatic insects, and the adults are often large brightly coloured mites that can be found swimming in fresh water. Harvey (1998) reviewed the Australian fauna, which includes over 400 known species spread over 24 families. A further important group of Prostigmata includes the spider mites of the family Tetranychidae. These are damaging pests of crop plants, especially in horticulture, but the Australian fauna has never been systematically studied. The cohort Heterostigmata includes about 12 families of small to minute mites, many of which have close associations with insects. The existence of intra-species polymorphism
and often bizarre morphologies has meant that the taxonomy of these groups is very unstable, even at the family level. A diverse range of families of Prostigmata that are parasites of vertebrates have been catalogued by Domrow (1991).

The order Sarcoptiformes includes over 130 families of soil mites in the suborder Oribatida, commonly known as oribatids. These are mostly slow-moving, heavily sclerotised mites that are most abundant and diverse in the upper layers of the soil and the associated organic litter. They feed on dead plant material and the associated microfungi, and most have very robust heavily sclerotised chelicerae, adapted for crushing fungal mycelium. Their role in feeding on decaying plant material means that they are very important in maintaining and enhancing soil fertility, and they have been the subject of a substantial ecological literature for that reason. A few species are beneficial in more direct ways, contributing to the control of pest mites, nematodes, and weeds. Others are themselves pests that damage crop plants (Colloff and Halliday 1998). Some act as intermediate vectors of tapeworm parasites of livestock (Denegri 1993). The Australian fauna was catalogued by Colloff and Halliday (1998), who listed 340 described species.

The order Sarcoptiformes also includes the cohort Astigmata, which until recently has been given equal rank with the Oribatida. The Astigmata includes the common flour mites and cheese mites that infest stored food and which damage stored grain on an industrial scale, the house dust mites that cause allergy and asthma in humans, and a wide range of fungivorous and saprophytic species in soil. Many of these species have a specialised immature form known as the hypopus, which attaches itself to insects for dispersal. The Astigmata also includes hundreds of species of feather mites that occur on birds, but the Australian fauna of these groups has never been studied in any depth. Domrow (1992) catalogued 204 species of Astigmata in 24 families that parasitise Australian vertebrates or occur on their bodies. These include the mites that cause such diseases as scabies (Sarcoptes scabiei), scaly leg of chickens (Knemidokoptes mutans) and several types of mange in domestic animals (e.g. the ear mite of dogs and cats, Otodectes cynotis).

The Australian mite fauna

A recent review estimated that there are 48,000 named and described species of mites world-wide (Halliday et al. 2000), and extrapolated that number to speculate that over half a million species of mites exist in total. In Australia, 2,871 described species in 304 families had been documented to April 2000 (Halliday 2001a), and the total number of species that exist is likely to exceed 20,000 (Halliday 2001b). Significant habitats such as the rainforest canopy remain largely unexplored, and diverse faunas await discovery there (Walter et al. 1998). Major groups have never been studied in a systematic way, and are likely to contain large numbers of undescribed species. Conspicuous among these are the feather mites, with possibly 2,000 unknown Australian species, the plant parasites of the family Eriophyidae, with possibly 5,000 unknown species, and the Halacaridae (Prostigmata) and Uropodina (Mesostigmata), each of which is likely to yield hundreds of species (Halliday 2001b). A single expedition by a single acarologist revealed 200 new species of aquatic mites (Cook 1986), and similar results are likely when serious attention is
paid to other groups that have previously been neglected.

There are no general estimates of the level of endemism in the Australian mite fauna. Colloff and Halliday (1998) documented 340 species of Australian Oribatida, including 256 that were described from Australian type localities and had not been recorded elsewhere. Many distinctive elements of the Australian mite fauna are found in those mite groups that have intimate associations with other components of our flora and fauna. The mites parasitic on vertebrates have been catalogued in detail (Domrow 1988, 1991, 1992; Domrow and Lester 1985), and all these parasitic groups include species and genera that are found only on Australian native vertebrate hosts. The ticks were the subject of a monograph by Roberts (1970), but new species are still being found on native vertebrates (e.g. Keirans et al. 1994, 1996). The same is likely to apply to the Australian feather mites, which are almost completely unstudied. Plant-parasitic groups that have some degree of host specificity are also likely to include many endemic species and genera, especially the Eriophyidae and Tetranychidae. Among the free-living groups in forest litter, Australia has a rich and distinctive fauna of Holothyridina and predatory Mesostigmata that have not been adequately studied. The Uropodina are now being examined closely for the first time, and are yielding many surprises (e.g. Błoszyk et al. 2005; Dylewska et al. 2006).

The rapid rate of change in the classification of Australian mites is clearly demonstrated by the fact that new families are still being described. Recent examples are Eriolynchidae (Qin and Halliday 1997), Heatherellidae (Walter 1997), Dasythyreidae (Walter and Gerson 1998), Nothogynidae (Walter and Krantz 1999), Saltiseiidae (Walter 2000), and Uronyssidae and Teranyssidae (Halliday 2006).

**Acarology in Australia**

The history of the science of acarology in Australia has been reviewed in some depth (Southcott 1982; Halliday 2001b). The main trends have been research on agricultural pest mites and their natural enemies, on mite parasites of vertebrates, including humans and domesticated animals, on mites that have various types of association with Australian insects, and on the native mite fauna in agricultural and forest soils.

There is no single comprehensive mite collection in Australia. Instead, there are collections in a number of institutions where the research effort has historically been concentrated. The South Australian Museum in Adelaide has had the longest history of research in truly Australian mite taxonomy. Research there began with the work of Stanley Hirst, who was publishing from about 1912 to 1930, on a very wide range of mite groups. Herbert Womersley worked in the South Australian Museum from 1933 to 1962 (Southcott 1984). His work includes important publications on chiggers (Trombiculidae), including the vector of scrub typhus; on other parasites of vertebrates; on beneficial predatory groups; on pasture pest mites and their natural enemies; and on the families of Mesostigmata that dominate the fauna of soil and forest litter in this country. No modern study of Australian taxonomic acarology is complete without constant reference to Womersley's publications and collections. Acarology at the South Australian Museum continued with Ron Southcott, who published hundreds of papers from about 1945 to 1999 on a
wide range of subjects. He is best known for his major works on trombidiform mites, especially the Erythraeidae (Southcott 1961), Trombidiidae (Southcott 1986) and Microtrombidiidae (Southcott 1994). The Adelaide tradition was continued by David Lee, who published important revisionary work on Mesostigmata (e.g. Lee 1970) and Oribatida (e.g. Lee 1992, 1993).

The Agricultural Scientific Collections Unit at the New South Wales Department of Primary Industries, Orange Agricultural Institute, Orange NSW, has an important collection of predatory Phytoseiidae created by Eberhard Schicha (Schicha 1987; Schicha and Corpuz-Raros 1992), which includes many type specimens. There are also collections of other groups of plant mites including Tenuipalpidae, Tetranychidae and Pygmeophoridae. These are now being supplemented by a growing collection of plant parasites of the family Eriophyidae (Knihińicki and Boczek 2002, 2003).

The mite collection in the Australian National Insect Collection in Canberra, has grown as a result of a series of research projects on mite and insect pests and their natural enemies. A long term program of research on red-legged earth mites has included taxonomic studies of the pest and its relatives (Qin and Halliday 1996a, 1996b, 1997), and families of predatory mites that occur in the same habitats, especially Anystidae and Bdeilidae (Wallace and Mahon 1973, 1976; Otto 1999a, 1999b, 1999c; Halliday 2005). The result was the formation of large collections of plant-feeding and predatory mites from pastures, both from Australia and overseas. The ANIC also includes large collections of mites associated with dung and dung beetles (e.g. Wallace 1986; Halliday 2000) and with many other groups of insects, but only a minority of these have been documented. There is a representative collection of marine mites of the family Halacaridae (e.g. Otto 1994, 1999d), and some families of oribatids are represented (Niedbala 1987; Niedbala and Colloff 1997). There is a large collection of ticks, most importantly those documented by Roberts (1970). The mite fauna of forest litter is huge and diverse, and a few preliminary studies of ANIC collections of these groups have appeared (Halliday 1997; Halliday et al. 1998). The collection also houses hundreds of unsorted samples of fauna from forest litter and other habitats, and these contain very rich collections of mites that await study.

The Queensland Museum in Brisbane houses a collection of approximately 16,000 slides and 2,500 vials of mites. By far the most significant portion of this collection is Bob Domrow's collection of about 13,000 slides and 1,000 tubes of mites from mammals, birds and reptiles, which was originally housed at the Queensland Institute of Medical Research. Only a small portion of these slides have been registered, and even fewer databased. The remainder of the collection comprises about 1,000 vials of mixed mites (mostly from pitfall trap samples), 500 vials of ticks, and another 3,000 slides that have a strong focus on the Trigonaspida, Podapolipidae and Tetranychidae (e.g. Seeman and Nahrung 2005). The Entomology section also holds a collection of 1,270 Berleseates, mostly from the wet forests of coastal Queensland, which are a rich source of unstudied mites.

The University of Queensland Insect Collection houses a very substantial collection of mites, which was largely built up through the efforts of Dave Walter. Most of the major families are
represented, with strength in soil and litter Mesostigmata, predatory Phytoseiidae (Beard 2001), plant-feeding spider mites (Tetranychidae) and false spider mites (Tenuipalpidae), and some of the lesser known families of Prostigmata, including aquatic families. There is also a good range of Oribatid families, and both free-living and parasitic Astigmata. About 25% of the collection has been catalogued in the UQIC database. An outline of this catalogue is available at http://www.sib.uq.edu.au/acarina-catalogue, and contains links to a number of spectacular mite images.

The Museum of Victoria mite collection in Melbourne includes a substantial collection of water mites from Victoria. It includes types and identified material (Harvey 1990a; Harvey and Cook 1988), as well as unidentified water mites from multidisciplinary surveys of river faunas. There are also significant holdings of unidentified and sorted and unsorted mites from soils in a range of Victorian forests and woodlands, collected in pitfall traps during biodiversity and environmental management surveys.

Acarology at the Australian Museum (Sydney) began with Rainbow (1906), the first attempt to produce an overview of the Australian mite fauna, and some of Rainbow's types are still in the collection. The tick collection there includes types of some species described by Roberts, among others (e.g. Roberts 1960). There is also a collection of water mites, including some described by Harvey (1987, 1990a, b), but the collection is dominated by oribatids described by Glenn Hunt (Hunt 1996a, b; Hunt and Lee 1995). The slide collection is supported by substantial holdings of non-type and unidentified mite accessional material, including bulk samples from pitfall and litter collecting.

The Western Australian Museum in Perth has strong collections of mites in a range of families. There is an important collection of types of mites parasitic on vertebrates, mostly described in a series of papers that appeared in Records of the Western Australian Museum in 1978–1981, under the general title Parasites of Western Australia (e.g. Fain and Lukoschus 1979, 1981). There is also a large collection of marine mites of the family Halacaridae, especially the species from Rottnest Island (e.g. Bartsch 1993, 1994), a collection of water mites from Western Australia (Harvey 1988, 1996), a good collection of ticks, and a large quantity of unsorted mite material.

Further reading
There are several excellent modern textbooks of acarology. Evans (1992) is a comprehensive review of mite anatomy, morphology, and behaviour, with detailed coverage of the structure and function of the integument, musculature, circulatory, respiratory and sensory systems, feeding, digestion, physiology, reproduction and mating, and development and dispersal. There is also a summary of classification, with keys to higher taxa down to the superfamily level. Walter and Proctor (1999) thoroughly explores the evolutionary origin of mites, the morphology and systematics of the major mite groups, and the life cycles, development, behaviour, reproduction, habitat and ecological relationships of mites, and uses mites as models to demonstrate a wide range of phenomena in evolutionary biology. The most detailed textbook of mite taxonomy is Krantz (1978), which provides keys down to the family level for all groups. Each family study includes information on biology and behaviour, evolutionary relationships and economic importance, and a taxonomic
overview of the family. The current 1978 edition will soon be replaced by Krantz and Walter (2007), which presents the latest concepts in mite classification.

Many research publications in acarology appear in *Acarologia*, *International Journal of Acarology*, *Systematic and Applied Acarology*, *Experimental and Applied Acarology*, and a range of other acarology and entomology journals. Much important information also appears in the *Proceedings of the International Congress of Acarology*. The latest of these to be published was from the 1998 Canberra Congress (Halliday et al. 2001). The *Proceedings* of the 2002 Mexico Congress is in press, and that of the 2006 Amsterdam Congress is in preparation. Other important recent compilations of papers presented at acarological conferences include Schuster and Murphy (1991), Wrensch and Ebbert (1993), Kropczyńska et al. (1995), and Bernini et al. (2002).

A variety of valuable information about acarology is available on the internet through the Acarology Home Page at http://www.nhm.ac.uk/hosted_sites/acarology/. This site provides contact details for acarologists and their institutions, details of acarological societies and publications, and an e-mail discussion list.

**Conclusions**

One of the subjects that is discussed among acarologists on the e-mail discussion list and elsewhere is the steady decline in the level of basic skills in our science. In 1998 the acarologists of Australia felt confident enough in the strength of their science to host the 10th International Congress of Acarology. In 2007, despite the enormous economic importance of mites, the demonstrated presence of many very distinctive components of our fauna, and the existence of thousands of undescribed species and higher taxa, there is not one full-time professional mite taxonomist in Australia. The research effort is being sustained by people working opportunistically part-time, or voluntarily in retirement, or by overseas acarologists who are working on the Australian fauna. There is no regular training in acarology at undergraduate or postgraduate level in Australian universities. Many challenges lie ahead in Australian acarology, and many important questions in mite systematics remain unanswered. An increase in the level of basic skills in mite taxonomy will be needed if Australia is to avoid mistakes in biosecurity and pest management, to realise the potential of mites as a source of information in biodiversity conservation, and to make an adequate contribution to international efforts to document this fascinating group of animals.

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**References**


Western Australia. (Western Australian Museum, Perth). pp. 19–43.


Halliday R.B. 1997. Revision of the Australian Ameroseiidae (Acari:
Mesostigmata. Invertebrate Taxonomy 10, 179-201.


Niedbala W. & Colloff M.J. 1997. Euprytyme oribatid mites from


