

MANGE

SUMMARY

*Mange is a contagious skin disease, characterised by crusty, pruritic dermatitis, and hair/feather loss, and caused by a variety of parasitic mites burrowing in or living on the skin. Some alternative historical names for mange are 'la gale' (in French), 'itch', 'scab', and 'scabies' (a term that should be reserved only for mange caused by *Sarcoptes scabiei*). Specifically, on domestic hosts (i.e. livestock, poultry, companion, and laboratory animals), about 50 mite species in 16 families and 26 genera may cause mange. A number of other skin conditions (e.g. dermatitis, wheals, blisters, nodules) may be confused with mange and must be considered in differential diagnoses, including those resulting from allergic reactions to other kinds of mites, various arthropod bites, fungal diseases, or reactions to physical or chemical aspects of plants. Mange diagnosis in domestic animals is based on clinical manifestations and the demonstration of mites or their developmental stages in host skin scrapings.*

Identification of the agent: *Mange mites are mostly weakly sclerotised, slow-moving, very small (100–900 µm), and live permanently on their hosts. Although the Acari is an extremely diverse and ubiquitous group of arachnid arthropods, all of the major mange mite species fall within only two acariform lineages, the Astigmata: Psoroptidia and the Prostigmata: Rhabdignathina. Some economically important mange mite genera are Cheyletiella, Chorioptes, Demodex, Knemidokoptes, Notoedres, Otodectes, Psorobia, Psoroptes, and Sarcoptes. Specialised illustrated diagnostic keys, taxonomic descriptions, and reference specimens should be consulted to properly identify the causative agents of mange. Special collecting techniques and compound microscopy usually are necessary for diagnosis. Certain identifying characteristics of each of the mange mite groups are highlighted in the following discussion. Although availability is limited, serodiagnostic tests have been developed for certain mange mites and are useful in some circumstances.*

Requirements for vaccines: *Currently, no commercial vaccines against mange are available.*

A. INTRODUCTION

Mange is a contagious skin disease, characterised by crusty, pruritic dermatitis and hair/feather loss, and caused by a variety of parasitic mites burrowing in or living on the skin. The French term for mange is 'la gale' (Pangui, 1994), and in English, it has been called 'itch', 'scab', or 'scabies' (a term that should be reserved specifically for mange caused by *Sarcoptes scabiei*).

Numerous species of mites cause mange in literally hundreds of species of wild and domestic birds and mammals. In fact, approximately 60 mite families have members that live in or on the skin, hair, or feathers of homeothermic vertebrates and are potential mange mites. Specifically, on domestic hosts (i.e. livestock, poultry, companion and laboratory animals), about 50 mite species in 16 families and 26 genera may cause mange. Humans are host to the readily transmitted *S. scabiei*, and human scabies occurs most frequently in elderly nursing homes and children's day-care centres. Some other mange mites may cause transient disease in humans, but infestations seldom persist.

Mites (Acari) are an extremely diverse, abundant, and ubiquitous group of arachnid arthropods with about 55,000 described species. Higher-level acarine classification is still an unsettled construct, but the following is a consensus system (Bochkov & Mironov, 2011; Krantz & Walter, 2009) encompassing the mange mites. Acari comprises two major evolutionary lineages, Parasitiformes and Acariformes, but only certain acariform mites cause mange in domestic animals. Moreover, both lineages – Trombidiformes and Sarcoptiformes – within the Acariformes contain mange mites. Trombidiformes includes the major suborder Prostigmata, with multiple superfamilies and many families, five of which contain mange mites. Sarcoptiformes contains the major suborder

Oribatida, with many cohorts, superfamilies, and families included, but only 11 constituent families in Astigmata: Psoroptidia contain mange mites.

Some other mites may cause less serious dermatitis in animals or humans (Yunker, 1964). Certain Parasitiformes (order Mesostigmata: e.g. *Ornithonyssus*, *Dermanyssus*) and other Prostigmata (e.g. *Trombicula* [and other chiggers], *Pymotes*) transiently bite a host while feeding, leaving itchy welts and wheals behind. Stored-products, animal-nest, and house-dust mites (e.g. *Acarus*, *Glycyphagus*, *Dermatophagoides*) may cause contact dermatitis (e.g. baker's itch, grocer's itch) but no persistent infestation. Certain free-living bird-nest mites (Hypoderatidae) have a parasitic nymphal stage (hypopus) that characteristically lives subcutaneously in the bird host (e.g. *Hypodectes propus* in domestic pigeons), causing skin irregularities. Pediculosis or certain fungal diseases, such as ringworm, can cause alopecia and crusty dermatitis, and even the physical (e.g. awns, urticarial hairs) or chemical (e.g. urushiol) aspects of some plants may cause host skin reactions that could be confused with mange.

B. DIAGNOSTIC TECHNIQUES

Table 1. Test methods available and their purpose

Method	Purpose					
	Population freedom from infection	Individual animal freedom from infection prior to movement	Contribute to eradication policies	Confirmation of clinical cases	Prevalence of infection – surveillance	Immune status in individual animals or populations post-vaccination
Agent identification¹						
Direct visualisation/ microscopy	+++	+++	+++	+++	+++	n/a
PCR	+	+	+	+	+	n/a
Genome sequencing	+	+	+	+	+	n/a
Detection of immune response						
ELISA	+	+	+	+	+	n/a

Key: +++ = recommended method, validated for the purpose shown; ++ = suitable method but may need further validation; + = may be used in some situations, but cost, reliability, or other factors severely limits its application; – = not appropriate for this purpose; n/a = purpose not applicable.
PCR = polymerase chain reaction; ELISA = enzyme-linked immunosorbent assay.

Mange diagnosis in domestic animals is based on clinical manifestations and the demonstration of mites or their developmental stages in host skin scrapings (Kettle, 1995). The condition is typified by hair/feather loss, crusty or scaly skin lesions, dermatitis, thickened skin, scurf, and pruritus.

1. Identification of the agent

1.1. Detecting the agent

Hair/feather loss and crusty or scaly skin are the most apparent clinical signs of mange. A number of other diseases must be considered when one is confronted with a possible case of mange, including fungi, bacteria, insect bites, irritating plants, mechanical abrasion, etc. In most cases, scrapings should be taken from the edge of the lesion, from obviously pruritic locations, and from where there are thick, crusty flakes. Take a skin scraping by holding a scalpel blade or other sharp instrument at a right angle to the skin and scraping off the outer surface of the skin. For those mite species that burrow into the skin, the scraping must be deep enough to cause a small amount of blood to ooze from the scraping site. A drop of mineral oil or glycerol may be placed on the blade to help hold the skin scrapings during the procedure. Skin scrapings should be placed in sealed containers (e.g. clean, empty salve tins; stoppered

¹ A combination of agent identification methods applied on the same clinical sample is recommended.

glass/plastic test tubes; small, sealable plastic bags) and promptly taken or sent to a laboratory for more thorough examination. An even more effective method of collecting mites from the skin surface and hair is by using a vacuum cleaner fitted with an in-line filter (Klayman & Schillhorn van Veen, 1981). The material collected, along with the filter, is then examined as a skin scraping would be. An otoscope can be valuable in revealing the presence of ear mites. A cotton-tipped applicator can be used to swab the ear canal if ear mites are observed or suspected; examine it in the same way as a skin scraping.

Perform an initial examination of the skin scraping under a dissecting microscope. Obviously visible mites, especially those that are alive and moving, may be picked up with a dissecting needle dipped in glycerine or a mounting medium and transferred to a drop of mounting medium on a glass slide. When the desired number of mites has been collected, gently place a cover-slip on the drop of mounting medium, taking care to avoid air bubbles. Hoyer's medium, Berlese's fluid, Vitzhum's fluid, and Heinze's modified PVA medium are all acceptable mounting media. If permanent mounts are desired, allow the slides to dry for at least 1 week at room temperature, then ring the cover-slips with nail polish or other sealant to keep them from drying out.

Mites that are embedded in oil and exudate, *Demodex* for example, may be demonstrated by placing a small amount of skin scraping directly on the slide with some glycerine or immersion oil and pressing a cover-slip on top of it. The slide then can be examined directly with a compound microscope.

Skin scrapings that contain dead mites, large amounts of skin flakes or scabs, or large amounts of hair should be processed further. Place the skin scraping (up to several grams of skin and hair) in a suitably sized beaker, then add sufficient 10% potassium hydroxide to immerse the sample. Cautiously bring the solution to a gentle boil, stirring frequently (a laboratory hot-plate with a magnetic stirrer works well for this), for 5–10 minutes or long enough to digest most of the hair and skin. This step should be performed under a chemical fume hood to limit exposure to caustic fumes. Do not boil for an extended period of time, or the mites may disintegrate. Transfer the digested material to suitable test tubes, and centrifuge at 600 **g** for 10 minutes. Decant the supernatant. Resuspend the pellet in a small amount of flotation medium (e.g. Sheather's solution or a mixture of 50% corn syrup and 50% water); then, fill the tube completely with flotation medium, and place a cover-slip on top of the tube, assuring that it makes contact with the flotation medium. Let stand for 1 hour, or centrifuge for 10 minutes. Carefully remove the cover-slip by lifting straight up, so that a drop of fluid remains on the underside of the cover-slip, and place on a glass slide. Any mites in the sample will have floated to the top and will be found in the drop of fluid attached to the cover-slip. Another simpler but satisfactory technique, that is used in many laboratories, is to re-suspend the pellet in a small amount of distilled water, drop onto a large (76 × 51 × 1 mm) glass slide and cover with a 40 × 50 mm cover-slip. This is examined under a dissecting microscope (×40 or ×100) with understage lighting. The slide then may be examined under a compound microscope for the presence of mites.

In cases where mites are difficult to find in skin scrapings from small domestic pet animals, they sometimes may be demonstrated by faecal flotation.

1.2. Identifying the agent

Mange mites are mostly weakly sclerotised, slow-moving, very small (100–900 µm), and live permanently on their hosts. The general life cycle of mange mites is brief (1–5 weeks) and includes four stages: egg, six-legged larva, eight-legged nymph (one or more instars), and eight-legged adult (male and female.) Specialised illustrated diagnostic keys (e.g. Baker *et al.*, 1956; Bochkov, 2010; Gaud & Atyeo, 1996; Giesen, 1990; Kettle, 1995; Klompen, 1992; Krantz & Walter, 1999; Yunker, 1973), taxonomic descriptions, and reference specimens should be consulted to properly identify the causative agents of mange. However, certain diagnostic characteristics of each of the mange mite groups are highlighted in the following discussion.

Mange in domestic animals results from the host's physiological, immunological, and behavioural responses to infestation by certain mites in any of eleven families of Astigmata or five families of Prostigmata.

1.2.1. Astigmata

Astigmatan mange mites are generally small, globose or oval in outline, and thin-skinned. The somatic cuticle often shows a pattern of fine, parallel striations (finger print patterns), with distinctively shaped and placed setae, spines, pegs, or scales, and sometimes, lightly sclerotised plates or shields. Adults usually have eight legs and anterior mouthparts that include paired palps and chelicerae used for cutting and feeding. The legs attach proximally to the body through distinct cuticular epimeres (coxal apodemes) and terminate distally in a variety of setal forms or in a pretarsal empodium that may be shaped like either a claw or a bell-like sucker (caruncle or

ambulacrum.) Astigmatan mites do not have true, paired pretarsal claws. Males sometimes bear somatic suckers or other secondary sexual characteristics used in mating, but the form and placement of setae and empodia on the legs is usually sufficient to separate the sexes as well as identify the various mange mite species. Fertilised eggs are simple, soft, and translucent ovoids that are produced by mated females through a usually midventral ovipore.

1.2.1.1. *Sarcoptidae*

Sarcoptid mites are all obligate, burrowing skin parasites of mammals, with over 100 described species (Bochkov, 2010; Klompen, 1992). Survival time under moderate conditions for mites off the host is limited to about 10 days or less. Because of their activities in the epidermal layers of the skin, mange caused by these mites is generally more severe than that caused by mites dwelling above the surface of the skin. The body outline of sarcoptids is generally rounded, dorsoventrally flattened, and the cuticle is striated. The palps are one-segmented, and the legs are usually short. Three genera contain domestic animal parasites of interest.

i) *Sarcoptes scabiei*

This mite causes sarcoptic mange (scabies) in humans and other mammals. It is among the most common, widespread, and serious types of mange extant. More than 100 known species of infested hosts occur worldwide in at least 10 mammalian orders and 26 families (Bornstein *et al.*, 2001). Domestic hosts include camels, cattle, dogs, sheep, goats, horses, swine, llamas, and alpacas. Sarcoptic mange in dromedaries is a particularly debilitating chronic condition with high morbidity, and it may predispose afflicted hosts to other infections. Fain (1968) suggests that humans were the original host of *Sarcoptes*, and all other hosts were secondarily infested. Despite some dissention, current scientific consensus generally views all *Sarcoptes* mites on all hosts as no more than host-adapted variants of a single, variable species. Transmission between individuals within a host species or genus may occur easily by close contact, but taxonomically unrelated hosts are not readily infested or infestations are self-limiting. For example, *S. scabiei* var. *canis* easily transfers among dogs and can move to foxes, coyotes, and other canids, but humans serve as no more than transient hosts for this variant. Recent molecular analyses support the conspecificity of all *Sarcoptes* variants (Zahler *et al.*, 1999), and an immune response has been demonstrated in *Sarcoptes* infested hosts (Arlian *et al.*, 1994).

Mature female *S. scabiei* are approximately 500 µm long, with fingerprint-like striations on the cuticle, short and stubby legs, various characteristic setae and pegs, and with a dorsal patch of tooth-like spines. Males are similar but smaller (about 275 µm), and the tooth-like spines are reduced in size and number. The anus is posterior in both sexes, and the first pair of epimeres is fused in a midventral Y-shape. Long-stalked, unjointed pretarsal suckers occur on legs I and II in both sexes and on legs IV in males. The remaining legs all terminate in long, hair-like setae. In addition, each tarsus bears at its tip one or two highly modified setae in the form of short spurs. Nymphs resemble females but are smaller and lack an ovipore. Larvae are similar but smaller still and have only six legs.

ii) *Trixacarus caviae*

This mite is a specific parasite of captive and laboratory guinea-pigs, *Cavia porcellus*, but it never has been found on wild-caught animals (Klompen, 1992). Although these mites are a little smaller, the morphology and life cycle are similar to *S. scabiei*. However, all dorsal setae in *T. caviae* are long and hair-like, unlike some of those in *Sarcoptes*, which are short and broad or peg-like; males of *Trixacarus* also lack pretarsal suckers on the fourth pair of legs, and the pedicels (stalks) of all suckers are a bit shorter than those typical of *Sarcoptes* mites. This mite may cause a severe mange in host animals, especially in the laboratory setting. A similar mite, *T. diversus*, rarely occurs on laboratory rats.

iii) *Notoedres* spp.

Notoedres is a large genus comprising some 45 species, most of which are associated with bats (Chiroptera) (Klompen, 1992). Four species are of some concern with respect to notoedric mange in domestic animals. The cat mange mite, *N. cati*, is a cosmopolitan parasite of domestic cats, but it also infests several wild cats (e.g. bobcat, cheetah, serval, snow leopard), palm civets, coatimundis, mongooses, and domestic rabbits. These are highly contagious mites, and they cause intense mange, especially about

the host's head and sometimes spreading to the legs, genital area, or even the tail. Laboratory rats are hosts to *N. muris*, which burrows into the stratum corneum and causes thickening and cornification of the skin on the pinnae, eyelids, nose, and tail. Additional hosts include other *Rattus* spp., several other rodents, two marsupials, and a hedgehog (Klompén, 1992). The laboratory mouse may be infested by two *Notoedres*, *N. musculli* and *N. pseudomuris*, but the latter primarily occurs in wild populations of this host. Each mite also infests a few other murid rodent species. The mange caused is similar to that caused by *N. muris* in rats. *Notoedres* mites are generally similar to *Sarcoptes* but about half the size, and they lack the mid-dorsal field of tooth-like cuticular spines and peg-like setae, which may be replaced by a slight scale-like pattern in the cuticular striations and short, stout setae. The anus is posterodorsal, the first pair of epimeres is not fused medially, and the tarsi of legs I and II each end in three or four short, spur-like setae, not just two.

1.2.1.2. *Psoroptidae*

Psoroptid mites are obligate parasites of mammals. They dwell and feed on the surface of the host's skin. Survival time for some of these mites off the host may be two weeks or more. The generally oval-shaped body is dorsoventrally flattened, has a striate cuticle with scattered setae but no spines, and bears longer legs and more prominent mouthparts than those of sarcoptid mites. The anus is posteroventral. Males usually each have a pair of terminal posterior lobes bearing diagnostic setae and a pair of ventral adanal suckers used in mating. The first pair of epimeres is not fused medially. Fifty species in about 30 genera of psoroptid mites are known from at least 11 mammalian orders, with the greatest number on primates (Bochkov, 2010). Three genera have veterinary importance for domestic animals.

i) *Psoroptes ovis*

For decades, conventional practice among acarologists has been to distinguish several species of *Psoroptes* among the mites that cause psoroptic mange worldwide in wild and domestic ungulates and rabbits, e.g. *P. cuniculi* in the ears of rabbits and various ungulates, *P. equi* on the bodies of English equids, *P. ovis* on the bodies of sheep and other ungulates (Bochkov, 2010). Distinctions between the species were based primarily on host and anatomical site infested and on morphology of the males. Recently, several workers have invalidated these criteria and used genetic analysis to show conspecificity of the traditionally different species. The earliest published description for *Psoroptes* mites is that for *P. ovis*, making this the proper designation for all such mange mites on all domestic hosts. Thus, the nomenclatural situation in *Psoroptes* becomes similar to that in *Sarcoptes*, with one morphologically and genotypically variable species occurring worldwide, albeit on a smaller spectrum of hosts and with a bit less stringent host specificity among the variants. Two other named *Psoroptes* spp. remain as tentatively valid taxa occurring only on wild mammal hosts (Bochkov, 2010). Psoroptic mange in both sheep and cattle seems to vary in its severity according to the variant of *P. ovis* present, with the most severe form being a reportable condition caused by an especially virulent genotype and known as 'sheep scab'. This form has been eradicated from the USA, New Zealand, Canada, and Australia, although it still persists in many other parts of the world. Thus, particularly for further eradication efforts against psoroptic sheep mange, genotypic analysis of the involved mites may be an especially valuable tool (Falconi *et al.*, 2002).

Mature female *Psoroptes* are 550–750 µm long, with a striate cuticle and four long and 16 short dorsal somatic setae. A noticeable anterodorsal cuticular plate is present behind the mouthparts, and the midventral ovipore is an inverted U-shape. Males are about one-fourth smaller, and they have an additional, larger posterodorsal cuticular plate, a pair of posteroventral adanal suckers, and two terminal posterior lobes, each equipped with four setae of varying lengths and structures. Nymphs and larvae are somewhat similar to adults but progressively smaller, and all *Psoroptes* are pearly white in colour. In all stages, the anterior two pairs of legs are thicker and more robust than the posterior pairs, which are thinner, and in the male, shortened in the fourth pair. Legs I and II terminate in pretarsal empodial suckers on long, segmented pedicels in both sexes, with similar structures on legs IV of the female and legs III of the males. The female's third tarsus ends in two long, whip-like setae, and the male has a single short seta on tarsus IV, plus a long, thin seta accompanying the empodial sucker on tarsus III.

ii) *Chorioptes* spp.

This genus currently comprises six putative species of obligate ectoparasitic mites that may cause chorioptic mange in domestic and wild mammals (Bochkov *et al.*, 2014). Four of the species, collected rarely from wild animals, are not well studied, but *C. bovis* and *C. texanus*, primarily from domestic animals, have withstood modern biogenetic scrutiny and are accepted species (Bochkov, 2014). A number of allegedly host-specific varieties within these species are not separable from one another (Sweatman, 1957). The two species are morphologically distinguishable primarily by differences in the terminal posterior lobes and setae of males (Sweatman, 1957). Chorioptic mange, also called ‘barn itch,’ may be the most common form of mange in cattle and horses. It is a relatively mild condition that usually is more localised and less intensely pruritic than psoroptic or sarcoptic manges. This is probably because *Chorioptes* mites are able to feed and survive on host-produced epidermal debris at the skin surface, without necessarily attacking the living parts of the host’s skin. Infestations tend to concentrate on the lower portions of the host, especially the feet and legs, but may include the udder/scrotum, tailhead, and perineum. In some cases, *C. texanus* infests the host’s ears (Sweatman, 1957). *Chorioptes bovis* has been known for more than 165 years and occurs widely on cattle, goats, sheep, camelids (mainly bactrians), and possibly domestic rabbits. *Chorioptes texanus* was not discovered until 1924, and for 50 years, it was recognised only from goats and reindeer in the USA and Canada (Sweatman, 1957). Since 1975, it has been found on European elk, *Alces alces*, fallow deer, *Dama dama*, Taiwan serow, *Capricornis swinhoei*, and multiple times on cattle from Brazil, China (People’s Rep. of), Germany, Israel, Korea (Rep. of), Malaysia and the USA. Based on unpublished observations by the USDA, *C. texanus* may now be the prevalent *Chorioptes* species on cattle in the USA.

Both *Chorioptes* species on domestic animals are nearly identical morphologically in all stages. The circular body is dorsoventrally flattened, with a striate cuticle, and about 400 µm long in the female; males are about one-fourth smaller, and the somewhat similar nymphs and larvae are progressively smaller yet. Dorsally, adults of both sexes have both anterior and posterior cuticular shields and a variety of mostly short, hair-like setae. Ventrally, the female ovipore is a transverse slit with a pair of trailing apodemes. The mouthparts are unremarkable, and the legs are moderately long and robust, except the fourth pair in the male are very short, and the third and fourth pairs in the female are more slender. All legs in both sexes terminate distally in empodial suckers with short, unjointed stalks, except for the female’s third pair, which end in two long, whip-like setae each. The male also has a long, whip-like seta on each third leg and a pair of adanal suckers. The terminal posterior lobes of males bear five setae each. The lobes of *C. bovis* each have a nearly rectangular margin, the seta at the external angle is long and whip-like, and the two spatulate setae are moderately shorter (ca. 115 µm) and broad. The lobes of *C. texanus* are each more angulate, almost bilobed, with a very short hair-like seta at the external angle and two much longer (ca. 215 µm) spatulate setae that seem narrowed basally

iii) *Otodectes cynotis*

Carnivores are the primary hosts for these highly contagious mites, which mainly infest the host’s ear canals but sometimes spread to the pinnae and even beyond. Clinical signs of otodectic mange (otacariasis, ‘ear canker’) may include rubbing and scratching the ears, vigorous head-shaking, depression, excessive drainage, and haematoma of the ear. Worldwide, *Otodectes* is probably the most frequent mange mite infesting carnivores, both wild and domestic. In addition to companion animals (e.g. dogs, cats, ferrets), these mites also affect various farm-raised furbearers (e.g. foxes, mink) and occasionally may stray to humans. As with other mange mites, past workers often have treated *Otodectes* mites from different localities or different hosts as separate varieties, or even different species, but recent molecular and phenotypic studies conclude that the genus is monobasic.

Otodectes mites have a typical psoroptid morphology and life history mirroring those of *P. ovis*. The female body is about 435 µm long and oval-shaped; the male length is about 325 µm. The female ovipore is a transverse slit with trailing genital apodemes, and bilaterally, the epimeres of the first pair of legs are joined to those of legs II. The terminal posterior somatic lobes of the male are only weakly produced, but adanal suckers are present. Each lobe bears five hair-like setae of varying lengths. All of the legs are moderately long and robust, except for the fourth pair, which is much reduced, especially in the female. Empodial suckers with very short, simple pedicels occur distally on all legs except for the

posterior two pairs in females, which each end in a pair of long setae. The third tarsus of the male also bears a pair of long, whip-like setae in addition to its ambulacrum.

1.2.1.3. Epidermoptidae

This acarine family comprises 23 genera and about 100 species of mites, particularly species in the subfamily Knemidokoptinae (six genera, 17 species), that inhabit the same microhabitats in birds that Sarcoptidae occupy in mammals (Krantz & Walter, 1999). As a result, possibly due to convergence, the morphology of the two groups is similar. The body is generally globose, with cuticular striations that are sometimes modified into patches of scale-, furrow-, or tooth-like structures. The mouthparts and legs are usually short and stubby. Pretarsal suckers may be present, incomplete, or absent on all legs, and the tarsi may terminate in one or two chitinous spurs. Somatic setae are generally few, unmodified, and quite short. Knemidokoptids have a distinctive anterior dorsal shield marked by a pair of strongly sclerotised, longitudinal, paramedial apodemes running to the base of the mouthparts. Males (but not females) also may have a median posterior dorsal shield, and their first pair of epimeres is fused into a midventral Y-shape. The first epimeres in females (and immatures) may be free or joined by a transverse apodeme into a V- or U-shape. The ovipore is a transverse slit or a three-valved, inverted Y-shape, and the anus is terminal or posterodorsal. Males may or may not have adanal suckers. Most species occur, sometimes worldwide, only on various wild birds in which they may cause clinical knemidokoptic mange; however, species in three genera are of concern for domesticated and cage birds.

Knemidokoptes mutans commonly burrows in the epidermal layers of the skin on the feet and legs of chickens, turkeys, and pheasants, causing a crusty mange known as ‘scaly leg.’ If untreated, lameness, distortion, or loss of digits may result. The first epimeres of female *Knemidokoptes* are free; legs I and II each have two terminal spurs, but no ambulacrum occurs on any leg; the ovipore is transverse; the anus is dorsal; and the body has a mid-dorsal patch of cuticular scales. Females are 350–450 µm, and males are less than 240 µm long. As in other knemidokoptids, legs of males are longer than those of females, and all of them terminate in a small, long-stalked sucker. A second, similar species, *K. pilae*, infests the face, cere, and legs of budgerigars, leading to a condition known as ‘scaly face.’ These mites are slightly smaller than *K. mutans*, and both species probably occur worldwide on their respective hosts.

Picinemidicoptes laevis infests columbid birds, including the domestic pigeon, sometimes leading to clinical mange. In females, the first epimeres are fused in a U-shape; each leg has an empodial stalk only, and legs I and II end in one spur each; the ovipore is transverse; the anus is terminal; and the dorsal cuticular striae are unbroken by scales.

Neocnemidocoptes gallinae may infest the skin of the back, head, neck, abdomen, and upper legs of chickens, geese, and pheasants, causing intense pruritus. Feathers in these areas may fall out, break, or be plucked by the host, leading to a condition known as ‘depluming itch.’ Affected skin, especially on the neck, may become scaly, thickened, and wrinkly. Although depluming itch is less common worldwide than scaly leg, it may be more damaging and even fatal. Female mites are 340–440 µm long, but males subtend about 210 µm. The first epimeres of female *Neocnemidocoptes* are free; the tarsi each end an empodial stalk only, and one spur terminates each of the anterior two pairs of legs; the ovipore is transverse; the anus is dorsal; and the dorsal somatic cuticle is transversely striate but without scales. Two other, smaller *Neocnemidocoptes*, *N. columbicola* and *N. columbigallinae*, infest columbiform birds in limited circumstances and possibly might cause pathology in domestic pigeons.

1.2.1.4. Miscellaneous families

Eight remaining astigmatan fur and feather mite families contain a variety of mange mites that are generally of minor significance due to their limited host ranges or relatively mild clinical effects on their hosts.

Three families of mammal parasites are worthy of note. Atopomelidae comprises over 400 species in nearly 50 genera of fur mites with known hosts in 14 mammalian orders, mostly marsupials in the Southern Hemisphere. The body plan is variable, but most are soft, slightly elongate, flattened or cylindrical, and the legs usually have some flattened segments for grasping the host’s hairs to the mite’s ventral surface, which often is ridged in the coxal areas of legs I and II. *Chirodiscooides caviae* probably occurs worldwide on guinea pigs, but it has been reported commonly only in Asia and Europe, where it sometimes causes severe pruritus and alopecia to laboratory animals. Listrophoridae is another family of fur mites

comprising 170 species in about 20 genera found on nine mammalian orders, mostly rodents and mostly in the Northern Hemisphere. These are somewhat soft, elongate, cylindrical mites with various cuticular striae, spines, and punctate shields, including a sclerotised tegmen dorsally covering the mouthparts. They cling to the host hair-shaft bases by means of a pair of ridged flaps projecting ventrally from the area between the first pair of legs. *Lepoacarus gibbus* is a common listrophorid that sometimes causes mange in domestic and laboratory rabbits, and *Lynxacarus radovskyi* lives on several wild felines and the domestic cat, where mild, scurfy mange sometimes results. Myocoptidae is a nearly cosmopolitan family containing six genera and 60 species of skin-feeding, hair-clasping mites that occur on rodents and marsupials. Myocoptids are generally oval-shaped and dorsoventrally flattened. The cuticle may be extensively striate, scale-covered, or denticulate in females, whereas male cuticles are generally less ornate and more heavily sclerotised. Host hairs are grasped by robust, highly modified legs III and IV in females and legs III in males. *Myocoptes musculus* is probably the most ubiquitous ectoparasite of laboratory mice. Infestations are usually benign, but stressed or compromised mice may suffer alopecia, erythema, pruritus, and traumatic dermatitis (myocoptic mange.) Another, smaller myocoptid, *Trichoecius romboutsii*, occasionally occurs on laboratory mice, along with *M. musculus* or other mites, but its role in clinical mange is unclear.

Five families of mites from the skin and feathers of birds deserve mention. These are classified among 36 astigmatan mite families in three superfamilies loosely known as feather mites (Gaud & Atyeo, 1996). Thousands of species of feather mites live on or inside the feathers or skin of nearly every kind of bird worldwide in generally commensal relationships. In rare and unexplained circumstances, the commensal status of nearly any kind of feather mite may transition to that of a parasite, leading to negative consequences for the host. Some entire families of nominal feather mites (e.g. Cytoditidae, Laminosioptidae) have become true parasites with distinct associated pathologies, even mange (e.g. Knemidokoptinae). A few species in other families are more prone than is usual to cause debilitation or injury to their hosts. In the Analgidae, *Megninia cubitalis*, *M. ortari*, *M. holoagastra*, and *M. ginglymura* occur on domestic chickens and may cause depulping behavior and economic losses (Gaud *et al.*, 1988). *Dermoglyphus elongatus* (family Dermoglyphidae) occurs on caged canaries, and *Dubininia melopsittaci* (family Xolalgidae) occurs on budgerigars, and excessive presence of each mite species may engender depulping and associated skin lesions in the respective hosts. Members of the families Dermationidae and Epidermoptidae (subfamily Epidermoptinae) generally feed on the skin or in the feather follicles of their bird hosts, placing them very close to being parasitic. Domestic poultry are hosts to *Rivoltasia bifurcata* and *Epidermoptes bilobatus* from the two respective families, and each mite has occasionally been associated with pityriasis (epidermoptic mange) in chickens (Baker *et al.*, 1956).

1.2.2. Prostigmata

With over 19,000 named species classified into approximately 130 families, prostigmatan mites as a group exhibit tremendous morphological and biological diversity, making generalisations about them difficult. However, all of the prostigmatan mange mites belong in either of two superfamilies, Cheyletoidea (comprising seven families) and Myobioidea (one family). Together, these eight families include nearly 1,100 named mite species, but there are hundreds of undescribed species, as well. The anterior mouthparts in this group may be variously modified by palpal segment elaboration or reduction and by basal cheliceral fusion and extension into elongate, needle-like stylets used to pierce the host's tissues for feeding. Some prostigmatan mange mites have paired, elongate, dorsal respiratory peritremes above the mouthparts. The body usually is elongate, sometimes very much so, and usually soft and thin-skinned, but sometimes with sclerotised plates. Adults usually have eight legs that vary in length and morphology according to the habits of the family, but they each usually terminate distally in a pair of pretarsal claws and a linear empodium that often is equipped with numerous sticky hairs. Proximally, the legs may articulate with simple coxal fields or sclerotised somatic apodemes. The ovipore is a longitudinal, usually mid- or posteroventral slit, whereas, the genital pore in males is dorsal and sometimes equipped with a long aedeagus.

1.2.2.1. Demodecidae

The demodecids comprise more than 150 species of parasitic mites in seven genera from hosts in 11 mammalian orders. *Demodex* is the only genus of importance for domestic hosts, and it contains at least 70 named species plus many more that are unnamed and undescribed. Although other genera display their own unique features, adult *Demodex* are elongate, spindle-shaped, or vermiform mites, 250–850 µm long, that live in the host hair follicles, sebaceous glands, Meibomian glands, and occasionally in epidermal pits. They

have short anterior mouthparts with two-segmented palps and retractable needle-like stylets used to puncture surrounding host tissues and feed on predigested cellular fluids. The normally four pairs of legs are usually short, stumpy, composed of three segments each, and terminate distally in paired pretarsal claws, usually with a linear empodium. Coxal fields occupy much of the anteroventral surface of the body where the legs attach. The palps or one pair of legs of some stages of some species may be greatly elongated or otherwise modified, primarily as holdfast organs. The very thin cuticle of the body and appendages is all but devoid of setae, but the opisthosoma is usually transversely striate. Befitting the confines of their narrow follicular or glandular habitats, the immature stages, including the eggs, of *Demodex* spp. are usually spindle-shaped or elongate oval, sometimes extremely so. *Demodex* species are very host specific, only rarely inhabiting more than one species of congeneric mammal host. However, it is not uncommon for a host species to harbour two to four different species of parasitic *Demodex*. Transfer between hosts occurs only by very close contact between individuals (most probably mother to neonate), making transmission between animal species or from animals to humans very unlikely. Their very thin cuticles mean that demodexids cannot survive away from their hosts for more than a few hours.

Although *Demodex* mites frequently infest the skins of 100% of the individuals of their respective host species, their presence is usually without noticeable consequence for the hosts. On occasion, because of stress or other poorly understood factors, resident mite populations explode in numbers that result in a pathological condition known as demodectic mange. Healthy feral animals almost never suffer from demodectic mange, and laboratory or domesticated hosts are the usual victims (Nutting, 1985). Clinical signs may range from presence of small skin papules, to large nodules, to extensive hair loss. Although rare, severe or generalised cases may lead to mites invading the host circulatory system, secondary bacterial skin infection, and even death. Among domestic animals, clinical disease (sometimes called 'red mange') is most often seen in dogs (*Demodex canis* and *D. injai*), but swine, (*D. phylloides*), goats (*D. caprae*), horses (*D. caballii*), sheep (*D. ovis*), cats (*D. cati* and *D. gatoi*), cattle (*D. bovis*, *D. tauri*, and *D. ghanensis*), and rabbits (*D. cuniculi*) occasionally develop demodectic mange. Humans are normal hosts for two species of *Demodex* (*D. folliculorum* and *D. brevis*).

1.2.2.2. *Psorergatidae*

Worldwide, fewer than 100 species of these small parasitic skin mites are described in three genera (Giesen, 1990) (treated as subgenera of *Psorergates* by some authors). Known hosts are in eight mammalian orders, mostly rodents and bats. Adult psorergatids are about 100–200 µm long, generally circular in outline, and dorsoventrally flattened. The cuticle is very thin, finely striate, and a large, punctate, lightly sclerotised shield covers most of the dorsum. The short anterior mouthparts have stylet-like chelicerae and two-segmented palps, each of which ends in a stout, claw-like seta. There are no dorsal peritremes. The four pairs of moderately long legs are radially attached ventrally, have five segments each, and terminate distally in paired pretarsal claws but no empodium. The femur of each leg often bears a sturdy, retrorse spur ventrally. Psorergatids have relatively few setae, including a few on the mouthparts, five or six pairs on the dorsal shield, one small ventral pair, one or two long pairs on posteroventral body lobes, and less than 10 on each leg. The eggs are almost round and large, nearly two-thirds the size of the mature female. They are deposited in hair follicles or in epidermal pits made by the female. Immature stages are much like adults but smaller, with only six legs for larvae and all legs greatly foreshortened. Transfer from host to host is accomplished directly by motile adult mites, which then move selectively to less-keratinised areas of the host skin, frequently about the head, neck, and the back. There, they invade the hair follicles or burrow body-sized pits into the epidermis, feed by puncturing cell walls with their stylets, and reproduce. Psorergatid mites rarely survive off the host for more than a day.

Psorergatid infestations on healthy wild hosts and most domestic animals are generally low and of little consequence. Sometimes, however, populations of a few species may explode, particularly on sheep and laboratory mice, producing psorergatic mange. Skin damage from activities of adult mites usually is mild and only slightly irritating, but their progeny, from egg nests cut into the dermis, may enlarge these pockets into fluid- or keratin-filled papular lesions that may rupture and cause inflammation and other host immune responses (Nutting, 1985). Psorergatid mange mites of concern occur in two genera, *Psorobia* (with four pairs of marginal setae on the dorsal shield) and *Psorergates* (with three pairs of such marginal setae). Infestations of *Psorobia ovis*, the sheep itch mite, are most troubling in older animals and cause the hosts to rub, scratch, and bite at the wool in the most irritated areas, giving the fleece a ragged, tufted appearance. Powdery scurf sometimes may be present, as well. The life cycle of *P. ovis* takes about five weeks, the condition spreads slowly and

inconsistently through a flock, and detection of infestations often is difficult. A similar mite, *P. bos*, occurs widely on cattle, but it seems to have little pathological effect on hosts. *Psorobia cercopitheci*, from Africa (and a similar undescribed Asian species), occasionally cause mange in colonies of laboratory primates. The laboratory mouse is subject to papular lesions on the head and neck and auricular mange caused by *Psorergates simplex* (Yunker, 1973). Incidence of these mites in some mouse colonies may be as high as 80 per cent. Another *Psorergates* mite, *P. muricola*, has been found on five different rodent species, including *Mus musculus*, and *Psorergates rattus* occurs on *Rattus norvegicus*; whether either of these mites infests or damages laboratory rodents is unknown.

1.2.2.3. *Cheyletidae*

This family of approximately 375 species comprises mostly free-living predator mites and about 100 species parasitic on birds and mammals. The parasites are arranged into approximately 15 genera, with about one-third of the species on mammals and the rest on birds. Although a number of the genera contain species capable of causing limited pathology in their hosts, only a few members of the genus *Cheyletiella* are of concern as mange mites on domestic animals. *Cheyletiella* mites are 300–530 µm long, elongate rhomboidal, and distinguished by a strongly striate cuticle with one (females) or two (males) large dorsal shields. A number of moderately long, simple or barbed setae occur in distinctive patterns on the body, mouthparts, and legs. The anterior mouthparts are large, with short piercing stylets and especially robust, five-segmented palps, each of which terminates in a strong, curved claw-like seta that is lined with weak, ridge-like teeth on the inner margin. Prominent M-shaped peritremes occur on the dorsal surface of the mouthparts. The four pairs of legs are long and strong, and each terminates distally in a linear empodium equipped with a double row of sticky hairs. Although almost all other cheyletiellids also have paired pretarsal claws on each leg, none occurs in *Cheyletiella*. A small sensory organ (solenidion) occurs on the middle segment (genu) of each leg I, and its shape is (statistically) distinctive for each species (Bronswijk & de Kreek, 1976). Females lay their eggs singly and attach them to host hairs near the skin using a finely woven mass of threads. Transmission between hosts is primarily by close contact, but phoresy on ectoparasitic insects is a possibility, as well.

For many years, the identities of the various pathological *Cheyletiella* spp. were confused under the single name *C. parasitivorax* (Smiley, 1970), and these mites were mistakenly thought of as predators on other parasitic mites. However, *C. yasguri* (on dogs), *C. blakei* (on cats), and *C. parasitivorax* (on domestic rabbits) are now separately known to be the cause of mange, and any of the three may sometimes afflict humans in close contact with infested hosts, leading to severe dermatitis, pruritus, and other signs of cheyletiellosis for them, as well. The mites move easily among the host hairs on the keratin layer of the skin, periodically attaching to the surface by means of the palpal claws and puncturing cells of the epidermis with their stylets to engorge on predigested host fluids. The disease is similar in all three domestic hosts and usually is most evident on the back, shoulders, and neck. However, clinical signs are generally mild and not very distinctive or definitive. They may include scruffy hair coat, inflammation, occasional pruritus, alopecia, and almost always, hyperkeratosis. The barely visible, moving mites in the fur of the host and the abundant, powdery white scurf associated with cheyletiellid mange have engendered for it the alternative name 'walking dandruff.'

1.2.2.4. *Myobiidae*

Myobiids are small (to 900 µm), soft, elongate rectangular, somewhat dorsoventrally flattened fur mites known from five orders of mammals worldwide. More than 450 species of myobiids have been identified, at least half of them from bats. The cuticle is generally transversely striate, without sclerotised shields, and dorsally usually bears 12 to 16 pairs of setae, many of which are expanded, leaf-like, and longitudinally striate. The anterior mouthparts are small, with simple two- or three-segmented palps, cheliceral stylets, and dorsal peritremes. The legs, especially the first pair, are strong and highly modified for grasping host hairs, one or two at a time. They terminate distally in large pretarsal claws but no empodium; sometimes one of the two paired claws on a leg is greatly reduced or absent. The apparatus for clasping hairs are characteristic and consist of various combinations of modified leg segments and setae in the form of spurs, hooks, bosses, ridges, and grooved surfaces. Nymphal and larval myobiids generally resemble their respective adults except for size. Myobiid eggs are usually attached by the females with an adhesive secretion to the bases of the host's hairs. Larvae may actually enter the hair follicles to feed on host fluids issuing from punctures made with the stylets. Nymphs and adults feed at the surface of the host skin in the same way, sometimes even puncturing capillaries and imbibing blood. The life cycles of myobiids are generally brief (ca. 14 days), and the mites freely move between

host individuals. Myobiid infestations on wild mammal hosts are usually low in intensity and of little consequence (Nutting, 1985), but on laboratory rodents, they frequently expand greatly and cause intense pruritus and hair loss known as myobiic mange.

Both *Myobia musculi* and *Radfordia affinis* occur on the laboratory mouse and its wild progenitor, the house mouse, and each may cause pathology in laboratory animals. The two mites are superficially similar in appearance, but differ in many minute details, the most readily observed of which is the number of pretarsal claws present on the second leg; there are two in *Radfordia* and one in *Myobia*. *Radfordia ensifera* infests the Norway rat and the laboratory rat, sometimes causing mange in the latter. Whereas, both pretarsal claws on leg II in *R. ensifera* are of equal size, the posterior claw in *R. affinis* is smaller than the anterior one.

1.2.2.5. *Syringophilidae*

Approximately 350 species of these very host-specific quill mites have been described from a wide variety of bird hosts worldwide, but probably thousands of unknown species remain extant. The body is elongate (about 500–950 µm) and cylindrical in keeping with the infestation site within the quills of the host. The cuticle is thin, striate, and without sclerotised plates, but a variety of usually long setae arise from its surface, particularly at the posterior end. M-shaped peritremes arise above the mouthparts, which are equipped with stylets and simple, linear palps. The legs are short, stubby, and terminate distally in paired claws and haired empodia. Sclerotised epimeres occur in coxal fields I and II. While residing in the quill shafts, syringophilids puncture the quill walls with their stylets to feed on fluids from the surrounding feather follicle tissues.

Two species of quill mites from domesticated hosts sometimes occur in large numbers and cause serious irritation and severe feather loss that might be confused with knemidokoptic mange; *Syringophilus columbae* parasitises domestic pigeons and *S. bipectinatus* occurs in the quills of chickens. Modern poultry production methods that physically separate chick broods from laying hens have been very successful in breaking the chain of passage for *S. bipectinatus* from one host generation to the next, all but eliminating the depulming problem except in more traditional production settings. Two other described quill mites, *Picobia polonica* from chickens and *P. khulkhshani* from pigeons, have not yet been associated with host feather loss.

1.3. Molecular methods

1.3.1. Polymerase chain reaction

DNA of *Sarcoptes scabiei* has been successfully amplified and detected by polymerase chain reaction (PCR) from human cutaneous scales (Bezold *et al.*, 2001). This technique holds promise as an additional procedure for detecting specific, hard-to-find mange mites in skin scrapings.

1.3.2. Genome sequencing

Identification of mite specimens based on their DNA sequence, typically mitochondrial DNA, is being done, mainly in research settings, but the method is also suitable for clinical settings. So far, the number of species with genetic sequences from authoritatively identified specimens is limited, but will undoubtedly continue to grow. Genetic sequencing is costly and has limited throughput compared with traditional morphological identification, but it may be warranted for high consequence situations. The cost of the equipment and the specialised expertise required to perform the testing limit its use to laboratories that can provide such financial and technical support.

3. Serological tests

Researchers have shown that *Sarcoptes scabiei* and *Psoroptes ovis* infestations cause measurable specific antibody responses in hosts, namely pigs, sheep, dogs, and camels (Falconi *et al.*, 2002; Lower *et al.*, 2001; Lowenstein *et al.*, 2004); this makes possible serological detection of sarcoptic and psoroptic manges. Enzyme-linked immunosorbent assays (ELISA) that detect antibodies to *Sarcoptes* in pigs and dogs are commercially available in some countries and have been used for serodiagnosis of scabies (Lowenstein *et al.*, 2004) in Sweden and Switzerland to support scabies eradication programs in swine. Recombinant antibodies for *S. scabiei* and *P. ovis* are commercially available, and they seem to give more consistent test results than whole mite preparations. Although the only unequivocal proof of mange is finding and identifying the offending mites this traditional (direct) method is being augmented by better and better biochemical (indirect) methods.

C. REQUIREMENTS FOR VACCINES

There are no commercial vaccines for mange. Experimentally, inoculation with *Psoroptes ovis* antigen has reduced the severity of mange. This introduces the future possibility of controlling the effects of mange without the use of acaricides (Nesbet & Huntley, 2006; Smith *et al.*, 2002).

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NB: FIRST ADOPTED IN 1991. MOST RECENT UPDATES ADOPTED IN 2019.