***Sarcoptes***
(arachnid: mite)

**Overview**

Arthropods are coelomate metameric invertebrate animals with a chitinous exoskeleton and jointed limbs. They undergo protostomial embryonic development and grow by cuticular moulting (ecdysis). Three main subphyla are recognized: Chelicerata, Crustacea and Hexapoda. Arachnids have chelicerate mouthparts, two tagmata (cephalothorax and abdomen), four pairs of legs and slit sensilla, but no antennae or wings. All species exhibit incomplete metamorphosis whereby eggs hatch larvae which moult to nymphs and then adults. Acarines comprise the ticks and mites which have sac-like bodies with inconspicuous segmentation and their mouthparts are confined to an anterior gnathosoma. Four major groups are recognized primarily on the location of their respiratory stigmata: ixodid ticks (Metastigmata), gamesid mites (Mesostigmata), trombidiform mites (Prostigmata) and sarcoptiform mites (Astigmata). Ectoparasitic mites inhabit the skin of mammals and birds, feeding on fluids and/or tissues. Most spend their entire lives on individual hosts, so horizontal transmission between hosts is primarily by physical contact. Sarcoptiform mites lack stigmata but respire directly through the cuticle. They have unique legs which lack claws but have terminal sucker-like modifications. They are ectoparasitic on a range of birds and mammals and may cause severe dermatitis (known as mange). Sarcoptids are burrowing mites with circular bodies and the last two pairs of legs do not project beyond the body margin. Infestations by *Sarcoptes scabiei* are commonly found in the skin of many domestic animals, and humans, causing mild to severe dermatitis (sarcoptic mange, scabies in humans).

**Classification**:

| | |
|---|---|
| Domain: | Eukaryota (membrane-bound nucleus) |
| Supergroup: | Amorphea (unikonts with single flagellum, or nonflagellated amoebae) |
| Kingdom: | Metazoa (multicellular eukaryotes, heterotrophs, notably animals) |
| Group: | Protostomia (triploblastic, spiral cleavage) |
| Subgroup: | Ecdysozoa (cuticle moulted = ecdysis) |
| Phylum: | Arthropoda (chitinous exoskeleton, segmented body, jointed limbs, haemocoel) |
| Subphylum: | Chelicerata (chelicerate mouthparts, two tagmata, no antennae) |
| Class: | Arachnida (spiders & allies, four pairs of legs, slit sensilla, incomplete metamorphosis) |
| Subclass: | Acari (Acarina) (ticks and mites, segmentation inconspicuous, sac-like body, mouthparts on gnathosoma) |
| Superorder: | Acariformes (diverse group of mites, without posterior stigmata) |
| Order: | Astigmata [Sarcoptiformes] (mange mites, without stigmata, legs separated, with suckers) |
| Superfamily: | Sarcoptoidea (mites associated with mammals, ecto- or endo-parasitic) |
| Family: | Sarcoptidae (burrowing mites, circular bodies, third and fourth legs do not project beyond body margin) |
| Genus: | *Sarcoptes* (parasitic on skin of humans/dogs) |
| Species: | *S. scabiei* (causes scabies in humans) |

**Parasite biodiversity and host range**: Most Metazoa are multicellular triploblastic animals with differentiated tissues, many being bilaterally symmetrical with a body cavity. Most invertebrate animals are protostomes as their embryonic development involves spiral determinate cleavage. Those that moult their external cuticles during their life-cycles (process known as ecdysis) are grouped together in the unique clade Ecdysozoa, including the nematodes (roundworms), onychophorans (velvet worms), tardigrades (water bears) and arthropods (myriapods, chelicerates, crustaceans and hexapods). Arthropods have small segmented bodies encased in chitinous exoskeletons with articulated limbs. Most species are free-living in terrestrial and aquatic habitats, although a small range are ectoparasitic on other animals, some feeding on the blood or skin of vertebrates. Five subphyla are recognized: Chelicerata, Crustacea, Hexapoda, Myriapoda and Trilobita. The chelicerates typically have appendages (chelicerae) in the form of pincers or fangs anterior to the mouthparts, 2 body parts (cephalothorax and abdomen), but no antennae or wings. Three classes are recognized: Arachnida (spiders and allies), Merostomata (horseshoe crabs) and Pycnogonida (sea spiders). Arachnids have 8 legs, slit sensilla and life-cycles involving incomplete metamorphosis whereby larvae and nymphs resemble adults. They are classified in 4 orders: Acari (acarines), Araneae (spiders), Opiliones (harvestmen) and Scorpiones (scorpions). The Acari comprises the ticks and mites which have saccular bodies and mouthparts confined to an anterior gnathosoma. Four major groups are recognized primarily on the location of their respiratory stigmata (called spiracles in insects): ixodid ticks (posterior Metastigmata), gamesid mites (middle Mesostigmata), trombidiform mites (anterior Prostigmata) and sarcoptiform mites (without stigmata = Astigmata).

| Major parasitic families | Biodiversity | Hosts | Parasitic stages | Pathogenesis | Disease transmission |
|---|---|---|---|---|---|
| Superorder: Parasitiformes (ticks and some mites, with posterior stigmata) | | | | | |
| Order: Ixodida [Metastigmata] (ticks, macroscopic, stigmata posterior to legs) [3 families] | | | | | |
| Argasidae (soft ticks) | 5 genera, 193 species | birds, mammals | larvae, nymphs, adults | blood-sucking | viral, bacterial |
| Ixodidae (hard ticks) | 14 genera, 705 species | birds, mammals | larvae, nymphs, adults | blood-sucking, paralysis | viral, bacterial, protozoal |
| Order: Mesostigmata [Gamasida] (gamesid mites, stigmata between 2nd & 4th legs) [100 families, 662 genera, 5,360 species] | | | | | |
| Macronyssidae (sucking mites) | 26 genera, 127 species | birds, reptiles, mammals | nymphs, adults | blood-sucking | bacterial |
| Dermanyssidae (sucking mites) | 5 genera, 37 species | birds, mammals | nymphs, adults | blood-sucking | viral, bacterial |
| Halarachnidae (lung/ear mites) | 7 genera, 10 species | mammals | nymphs, adults | mucosal erosion | - |
| Raillietiidae (ear mites) | 1 genus, 7 species | mammals | nymphs, adults | ear wax | - |
| Rhinonyssidae (nasal mites) | 30 genera, 160 species | birds | nymphs, adults | inflammation | - |
| Varroidae (bee mites) | 1 genus, 5 species | bees | nymphs, adults | haemolymph-feeding | viral |
| Superorder: Acariformes (diverse group of mites, without posterior stigmata) [351 families, 32,000 species] | | | | | |
| Order: Prostigmata [Trombidiformes, Actinedida] (sucking mites, stigmata on gnathosoma) [121 families, 17,000 species] | | | | | |
| Demodecidae (follicle mites) | 7 genera, 65 species | mammals | larvae, nymphs, adults | inflammation | - |
| Cheyletidae (fur mites) | 80 genera, 500 species | mammals (dogs, cats, rabbits), birds | larvae, nymphs, adults | pruritus | - |
| Myobiidae (fur mites) | 46 genera, 185 species | mammals (rodents, bats, marsupials) | larvae, nymphs, adults | mange | - |
| Psorergatidae (itch mites) | 3 genera, 77 species | mammals (rodents, artiodactyls) | larvae, nymphs, adults | mange | - |
| Trombiculidae (chigger mites) | 71 genera, 3,000 species | mammals, birds | larvae | skin-feeding | bacterial |
| Order: Astigmata [Sarcoptiformes, Acaridida] (fur/feather/itch/dust mites, lacking stigmata) [230 families, 15,000 species] | | | | | |
| Sarcoptidae (itch mites) | 3 genera, 42 spp./ssp. | mammals | larvae, nymphs, adults | scabies, mange | - |
| Psoroptidae (scab mites) | 20 genera, species | mammals (carnivores, ungulates) | larvae, nymphs, adults | mange | - |
| Listrophoridae (fur mites) | 20 genera, 170 species | mammals (esp. rodents) | larvae, nymphs, adults | mange | - |
| Myocoptidae (fur mites) | 10 genera, 70 species | mammals (esp. rodents) | larvae, nymphs, adults | myocoptic mange | - |
| Cytoditidae (airsac/nasal mites) | 2 genera, 12 species | birds | larvae, nymphs, adults | respiratory signs | - |
| Knemidokoptidae (burrowing mites) | 7 genera, 16 species | birds | larvae, nymphs, adults | scaly face, scaly leg | - |
| Laminosioptidae (quill/skin mites) | 8 genera, 25 species | birds | larvae, nymphs, adults | flesh/skin lesions | - |

The superorder Acariformes comprises acarines without posterior respiratory stigmata and includes two major orders of parasites: trombidiform mites (order Prostigmata) with stigmata on the gnathosoma (capitulum) or propodosoma; and sarcoptiform mites (order Astigmata) which lack stigmata and peritremes and respire through their cuticles. Over 16,000 species of astigmate mites have been described in 230 families: with around 12,000 species in 154 families being free-living or predatory in terrestrial or aquatic environments (including a large assemblage of soil-dwelling oribatid mites); and some 4,000 species in 76 families occurring as commensals or parasites of arthropods and vertebrates (notably birds and mammals). Parasitic species may be ectoparasitic (on external surfaces of the host) or endoparasitic (within host epidermal or respiratory tissues) and their development often only includes 2 nymphal stages (in contrast to 3 nymphal stages in free-living species, sometimes including a specialized heteromorphic deutonymph (hypopus) adapted for phoretic dispersal or tolerance of adverse conditions). Common names for many of the parasitic groups include mange, itch, or scab mites as they may cause serious inflammatory skin conditions in their hosts.

Adult mites tend to be small, slow moving, whitish stages with soft cuticles and round-oval bodies (never vermiform) often with long setae. They possess chelate or dentate chelicerae, unbarbed hypostomes, small inconspicuous palps, legs with coxae fused to the body wall and tarsal segments bearing complex pulvilli (pad-like or trumpet-like) and empodia (claw-like or sucker-like, but never bearing tenet hairs). Most parasitic species may complete their entire life-cycles on individual hosts, so horizontal transmission between hosts is primarily by physical contact. A total of 10 astigmate superfamilies have been recognized (Acaroidea, Analgoidea, Canestrinioidea, Freyanoidea, Glycyphagoidea, Hemisarcoptoidea, Histiostomatoidea, Hypoderatoidea, Pterolichoidea, Sarcoptoidea) and an additional 2 families are currently unplaced (Cytoditidae, Heteropsoridae).

Early classification schemes identified different assemblages principally on the basis of host and site specificity; including bird-associated feather mites (e.g. Analgoidea); bird-associated skin mites (e.g. Knemidokoptidae), mammal-associated fur mites (e.g. Listrophoridae), mammal-associated skin mites (e.g. Psoroptidae); and mammal-associated skin-burrowing mites (e.g. Sarcoptoidea). However, phylogenetic studies (both cladistic and molecular) have revealed that many groups are not monophyletic but para- or poly-phyletic, so further studies are required to resolve the fidelity of most groups. Recently, molecular studies suggested that 16 sarcoptoidean families may belong to 2 main lineages: 13 families identified in a 'sarcoptid' complex (Atopomelidae, Audycoptidae, Chirodiscidae, Chirorhynchobiidae, Galagalgidae, Gastronyssidae, Lemurnyssidae, Listrophoridae, Listropsoralgidae, Myocoptidae, Pneumocoptidae, Rhyncoptidae, Sarcoptidae), and 3 families in a 'psoroptid' complex (Lobalgidae, Paracoroptidae, Psoroptidae). Nevertheless, most families can still be categorized into 4 broad 'morpho-ecotypes': namely; fur mites (Atopomelidae, Chirodiscidae, Listrophoridae, Lobalgidae), skin mites (Chirorhynchobiidae, Myocoptidae, Psoroptidae), skin-burrowing and follicle mites (Rhyncoptidae, Sarcoptidae), and respiratory mites (Gastronyssidae, Lemurnyssidae, Pneumocoptidae). The family Sarcoptidae comprises the burrowing mites that invade the skin of mammalian hosts causing intense pruritus. These 'itch mites' have soft circular bodies and 4 pairs of legs, the posterior 2 pairs not projecting beyond the body margin. Numerous genera have been recognized and allocated to 3 subfamilies (Caenolestocoptinae, Diabolicoptinae, Sarcoptinae). although another 5 genera remain unplaced (*Chirophagoides*, *Grammolichus*, *Lophuromyopus*, *Rodentopus*, *Sclerolichus*). The subfamily Sarcoptinae contains 15 genera (*Chirnyssoides*, *Chirobia*, *Cynopterocoptes*, *Kutzerocoptes*, *Mysarcoptes*, *Notoedres*, *Nycteridocoptes*, *Prosarcoptes*, *Prosopodectes*, *Rousettocoptes*, *Sarcoptes*, *Satanicoptes*, *Teinocoptes*, *Trixacarus*, *Tychosarcoptes*). The genus *Sarcoptes* is characterized by small round mites with dorsal striations broken by strong pointed scales, strong spine-like dorsal setae, palps with 2 segments, short stubby legs without claws, a terminal posterior anus, and females with genital openings appearing as transverse slits paralleling the body striations.

Infestations by *Sarcoptes* mites cause the disease scabies in humans and sarcoptic mange in animals. Scabies has been known for a long time throughout human history having been described by ancient Greeks and Romans, but the aetiological agent was not discovered until the mid-19$^{th}$ century. It has been estimated that over 300 million people are affected worldwide. Scabies is endemic in Africa, South and Central America, India, Southeast Asia and Australia, but can be found in many other areas as sporadic cases or institutional outbreaks. Infestations have been recorded worldwide in more than 100 species of animals belonging to 10 mammalian orders; including primates (chimpanzee, gorilla, macaque, orangutan, gibbon), carnivores (dog, dingo, wolves, coyote, jackal, raccoon dog, fox, cat, cheetah, cougar, serval, lynx, lion, jaguar, leopard, tiger, martens, fisher, badger, stoat, polecat, red panda, coati, bears), artiodactyls (cattle, buffalo, sheep, goat, ibex, chamois, impala, hartebeest, springbok, oryx, gazelle, antelope, waterbuck, kudu, camel, lama, alpaca, guanaco, vicuna, moose, deer, giraffe, boar, pig, peccary), pinnipeds (seal), perissodactyls (horse, donkey, tapir), hyracoids (hyrax), rodents (rats, mice, guinea pig, capybara, porcupine, squirrels), lagomorphs (rabbits, hare), insectivores (hedgehogs) and marsupials (wombats, koala, wallabies, possums). Sarcoptic mange is epizootic in wild canids in North America, Europe and Australia, in wild cats in Europe and Africa, in great apes and wild bovids in Africa, in wild ungulates and boar in Europe, and in wombats and koalas in Australia. Early studies tentatively identified different *Sarcoptes* spp. principally on the basis of their host occurrence, but subsequent studies revealed them to be very similar morphologically (with some minor variations in their patches of dorsal and ventral spines). The genus *Sarcoptes* was therefore considered to be monotypic, with only one recognized species, *S. scabiei,* known variously as the scab, itch or scabies mite. Experimental cross-transmission studies indicated that many isolates may be specific for particular hosts, or at least adapted to particular hosts, so a range of varieties ('strains') were recognized; including *S. scabiei* var. *hominis* on humans, *S. scabiei* var. *canis* on dogs and *S. scabiei* var. *suis* on pigs. However, the fidelity of this apparent host specificity has been challenged by several observations: namely, the cross-infectivity of some varieties in epizootics involving sympatric wild animal populations (e.g. foxes to martens); the occurrence of transient infestations in heterologous hosts (e.g. dogs to humans); and the experimental cross-transmission of some varieties to closely-related hosts (e.g. goats to sheep) or to laboratory animals (e.g. dogs to rabbits). Immunological studies found both host-specific and cross-reactive molecules within and between different varieties, and recent molecular phylogenetic studies have indicated that the extent of genetic variation may be greater than anticipated (e.g. multiple clades of genotypes detected in humans).

| Varieties of *Sarcoptes scabiei* | Hosts (natural and experimental) | Clinical signs | Distribution |
|---|---|---|---|
| *S. scabiei* variety not determined | over 100 hosts from 10 mammalian orders (27 families) | scabies in humans, sarcoptic mange in animals | varied |
| *S. scabiei* var. *aucheniae* | Artiodactyla: camelid (llama, alpaca, vicuna, guanaco) | sarcoptic mange | South America |
| *S. scabiei* var. *bovis* | Artiodactyla: bovid (cattle) | sarcoptic mange, head mange | worldwide |
| *S. scabiei* var. *cameli* | Artiodactyla: camelid (camel) | sarcoptic mange | Middle-East |
| *S. scabiei* var. *canis* (syn. *S. canis*) | Carnivora: canid (dog, fox, wolf, coyote, jackal, dingo), felid (cat); Lagomorpha: leporid (rabbit); Rodentia: caviid (guinea pig); Artiodactyla: bovid (sheep, goat, cattle); Diprotodontia: vombatid (wombat), phascolarctid (koala); Primates: hominid (human) | sarcoptic mange | worldwide |
| *S. scabiei* var. *caprae* | Artiodactyla: bovid (goat, chamois, sheep); Perissodactyla (donkey) | sarcoptic mange | worldwide |
| *S. scabiei* var. *cuniculi* | Lagomorpha: leporid (rabbit); Rodentia: murid (mouse) | sarcoptic mange | worldwide |
| *S. scabiei* var. *equi* (syn. *S. equi*) | Perissodactyla: equid (horse, donkey) | sarcoptic mange | patchy |
| *S. scabiei* var. *hominis* | Primates: hominid (human, gorilla, chimpanzee) | scabies | worldwide |
| *S. scabiei* var. *ovis* (syn. *S. ovis*) | Artiodactyla: bovid (sheep, goat); camelid (camel) | sarcoptic mange | worldwide |
| *S. scabiei* var. *rupicaprae* | Artiodactyla: bovid (northern chamois); Accipitriformes: accipitrid (golden eagle) | sarcoptic mange | Europe, North America |
| *S. scabiei* var. *suis* | Artiodactyla: suid (pig, wild boar) | sarcoptic mange | worldwide |
| *S. scabiei* var. *vulpes* | Carnivora: canid (fox, wolf, raccoon dog); mustelid (marten); felid (lynx) | sarcoptic mange | worldwide |
| *S. scabiei* var. *wombati* | Diprotodontia: vombatid (common wombat, southern hairy-nosed wombat), macropodid (wallabies) | sarcoptic mange | Australia |
| *S. tapiri* | Perissodactyla: tapirid (South American tapir) | sarcoptic mange | South America |

Various *Sarcoptes* spp. have also been transferred to other genera on the basis of morphotypic and/or genotypic studies: *S. bovis p.p.* and *S. caprae* being transferred to the genus *Chorioptes*; *S. mutans* to *Knemidokoptes*; *S. musculinus* to *Dromiciocoptes; S. cynotis* to *Otodectes; S. laevis* to *Picicnemidocoptes; S. pitheci* to *Prosarcoptes; S. chiropteralis* to *Prosopodectes; S. scabiei* var. *cati, S. cati* and *S. minor cati* to *Notoedres cati*; *S. lasionycteris* and *S. myotis* to *Notoedres lasionycteris;* and *S. anacanthos* to *Trixacarus diversus.*

**Parasite morphology**: Mites form four developmental stages: eggs, larvae, nymphs and adults. The eggs are oval, measuring 175-250 µm in length by 150-200 µm in width, which is large compared to the size of the adult mites (about one third their length). Emergent larvae have three pairs of legs but undergo metamorphosis to form nymphs (protonymphs for males and females, then tritonymphs for females). Nymphs have four pairs of legs but pairs 3 and 4 do not project beyond the body margin. These developmental stages are variable in size but successively become larger. Adult mites have ovoid bodies that are ventrally flattened and dorsally convex (tortoise-like). They are creamy white in colour but may have darkened appendages and organs. Female mites range in size from 0.3-0.5 mm in length by 0.2-0.4 mm in width, while adult males are smaller measuring from 0.2-0.3 mm long by 0.16-0.21 mm wide. Both sexes have thin sclerotized integuments which are covered with coarse transversely-ridged cuticular striations. Mites respire through tegumental surfaces so distinct stigmata, tracheae and peritremes are absent. The dorsal surface has a precapsular shield, 6-7 pairs of cuticular spines, stout lateral and dorsal setae (spine-like hairs), a central patch of triangular scales, 2 pairs of genital setae and the anus is terminal (only slightly dorsal). Variations in body structure and chaetotaxy (patterns of setation) are used to differentiate the genera *Sarcoptes, Notoedres* (precapsular shield absent) and *Trixacarus* (idiosomal setae setose rather than spine-like), the latter 2 genera causing mange in cats and guinea-pigs respectively. In adult female *Sarcoptes*, the copulatory bursa is situated anterior to the anal opening, while the genital opening is on the mid-ventral surface and consists of a transverse slit through which the eggs are laid. Adult mites have two body parts, the anterior gnathosoma (capitulum) bearing small specialized mouthparts (short lateral 2-segmented palps, paired chelicerae, unbarbed hypostome), and the posterior idiosoma bearing four pairs of stumpy legs and elongate sensory setae. The idiosoma is divided into two parts by an integumentary fold, two pairs of legs arising ventrally from each region. The first two pairs of legs project forwards beyond the body margin and they possess cutting plates which are used (with the chelicerae) to assist in burrowing. The last two pairs of legs are well separated from the anterior pairs and they project backwards but not beyond the body margin and they are therefore not visible in dorsal view. The legs consist of 5 free segments (trochanter, femur, genu, tibia and tarsus) arising from the basal coxae. The legs do not bear claws but terminate in stalked claw-like empodia (spines) with bell-shaped pulvilli (suckers) borne on stalk-like pretarsi on the first two pairs of legs in

adult males and females (also on the fourth pair of legs in males), while the remaining legs terminate in long setae. The first segments of the first two pairs of legs have apodemes (cuticular flanges) joined in a Y-shape, while those of the last two pairs of legs have small unjoined apodemes. Mature females have 2 ovaries ('nutritive'-type) with tubular oviducts converging on a muscular shell-gland that opens into the cuticle-lined vagina. Females remain fertile after mating once and they have accessory organs for sperm receipt, storage and transport (bursa copulatrix and spermathecae). Mature males have testes connected by tubular vas deferens to an ejaculatory duct equipped with a long sheathed aedeagus (penis) opening to a postcoxal genital pore.

**Site of infection:** Sarcoptid mites are obligate parasites in the skin of their hosts. They are burrowing mites and live as endoparasites within the epidermis. Female mites burrow within the stratum corneum, sometimes down to the boundaries of the stratum granulosum, to lay their eggs. Infestations can occur anywhere on the body, but are more common in areas where the skin is thin and wrinkled, such as between the fingers, toes and genitals of humans, and the ears, muzzle and face of animals. Larvae, nymphs and adult male mites form moulting pouches usually in the hair follicles of their hosts.

**Pathogenesis**: *S. scabiei* causes ordinary (classical) or crusted scabies in humans as well as acute or chronic sarcoptic mange in animals. The mites cause direct damage to the skin and their secretions and excreta (scybala) cause inflammation and allergic hypersensitivity reactions involving both humoral and cell-mediated components and circulating immune complexes. In otherwise healthy hosts, cell-mediated immune responses are mounted against mite antigens and the resultant acquired immunity limits the spread of mites and prevents overwhelming infestations. Mites have also been shown to produce anti-inflammatory, anti-complement and anti-immune substances allowing them to circumvent host protective responses. Infestations in immunocompromised or undernourished hosts may become intense, extensive and severe. Mites excavate long winding burrows in the skin, in so doing, feeding on the horny layer of the epidermis and on intercellular fluids (lymph and serum) that seep into the burrow. Their burrowing/feeding activity causes intense agonizing itching (pruritus) with erythema and maculopapular rashes with occasional vesicles. The pruritus is characteristically nocturnal and aggravated by warmth. It leads to consequent scratching, excoriation and inflammation (dermatitis) accompanied by hair loss (alopecia), thickening (hyperkeratosis), scaling and crusting of the skin with dried serum exudates. Pruritic areas may be reddened, pink, brown or tan, and when evident, burrows appear as thin slightly-elevated straight or serpentine (S-shaped) lines up to 15 mm long, sometimes with an adult mite seen as a small dot towards one end. The severity of disease does not correlate well with the intensity of infestation. Most infested hosts only have 5-15 mites, but hypersensitivity reactions to just a few mites may induce intense pruritus and dermatitis. In patients with severe crusted lesions, mite populations may build up to thousands (even millions) but paradoxically they may cause little or no pruritus.

Infestations have been associated with people living in poor overcrowded communities practicing inadequate hygiene. Outbreaks have been documented in residential aged-care facilities, hospitals, prisons, disaster relief and refugee camps. Epidemics of scabies have been found to occur in human populations in 20-30 year cycles, putatively associated with fluctuations in 'herd immunity' over the same time-frame. Classic scabies (sometimes called papular scabies) is more prevalent in the young and the elderly, with the onset of symptoms 3-6 weeks after first infestation or 1-3 days after re-infestation. The most commonly infested sites are the interdigital (webbed) spaces on the hands, the ulnar margins of the wrists and the elbows, followed by the anterior axillae (armpits), breasts in females, waistline, buttocks, penis and scrotum in males, backs of knees, ankles and toes. Lesions are generally absent on the head, face, neck, palms and soles, although atypical scabies may develop in infants, characterized by acropustulosis with blisters and pustules extending to these areas. Many patients may also develop complications including impetigo, eczema, urticaria, folliculitis, cellulitis or abscesses, and extensive thickening and crusting of the skin may occur in immunocompromised patients. Open or cracked skin lesions are highly susceptible to secondary bacterial infections resulting in sepsis, pyoderma and even septicaemia. In some individuals, burrowing mites may cause vesicles in the epidermis to become enlarged to form bullae (macro-vesicles), a condition known as bullous scabies. Mites may sometimes penetrate to the dermis eliciting cellular infiltrates (primarily lymphocytes) and the formation of dark firm pruritic masses, a condition known as nodular scabies. A more severe form of disease known as crusted (or Norwegian) scabies may develop in immunocompromised people, particularly the elderly with physical or mental conditions that reduce pruritus or scratching (e.g. paralysis, sensory defects, mental impairment). This form of disease is characterized by massive orthokeratosis and parakeratosis affecting the great cutaneous surfaces showing multiple scales and crusts with large numbers of mites but paradoxically less intense itching. Crusts may be loose, scaly, flaky or thick and adherent, being localized (palms, elbows, scalp, ears, soles and toes) or more extensive (neck, face, eyelids, under nails). They appear as horny plaques 3-15 mm thick and being cream, grey, yellow-brown to yellow-green in colour. Complications may include pyoderma, impetigo, cellulitis, lymphangitis, lymphadenopathy and septicaemia. Mild transient infestations (pseudo-scabies) have also been attributed to the transmission of mites from infested animals to humans in close contact (e.g. herders, hunters, trappers, wildlife biologists, animal care personnel, pet owners). Most zoonotic infestations have been confined to areas of skin exposed to animals (or their carcases or hides) and they have been short-lived and self-limiting with clinical signs disappearing within days to weeks (mites often unable to complete their development and rarely forming burrows).

In animals, infestations may cause skin damage, fluid loss, allergic reactions (immediate (type I) and delayed (type IV) hypersensitivity) and secondary bacterial infections. Acute clinical signs include intense pruritus, erythematous eruptions, papule formation, seborrhea and alopecia, while chronic mange is characterized by skin thickening, crusting, hyperkeratosis, lichenification and foul aromatic odours with lymphadenopathy and subcutaneous oedema in severe cases. Lesions usually first appear on the head (esp. ears), neck and shoulders of most animals, then spread to the chest, abdomen, back, flanks and tail. The severity of infestation

ranges from asymptomatic carriage to vexing irritation and unthriftiness potentially leading to stress, anorexia, weight loss, emaciation, exhaustion, debilitation and death. Infested animals may exhibit frequent and aggressive grooming behaviours resulting in traumatic lesions and self-mutilation. Young growing pigs may develop acute disease with significant production losses while sows may develop chronic disease with thick crusted lesions. Hyperkeratosis is most notable in canids, with animals inflicting considerable self-trauma through scratching and rubbing leading to excoriations, ulcers, bleeding, scabs, hair-matting, alopecia and secondary infections. Infestations are rare in cats, often invoking crusted parakeratotic lesions with little or no pruritus. Infested livestock (sheep, cattle, horses) may exhibit severe pruritus with scales, lichenification, thickened and wrinkled skin and scratching leading to hide damage. Most infestations in wombats have been severe with extensive thickening and cracking of skin around the face and skin cracks or folds becoming secondarily infected. Many outbreaks of sarcoptic mange in domestic and zoo animals have been associated with intensive husbandry practices and crowded unsanitary conditions, while epizootics in wildlife have been linked to animal migrations, translocations, malnutrition and poor seasonal conditions.

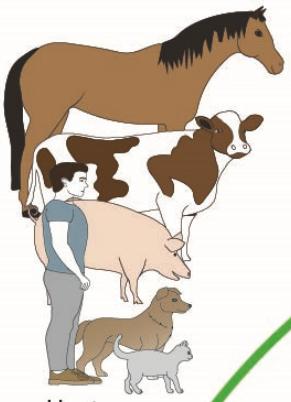
**Developmental cycle and mode of transmission**: Mites spend most of their lives in intimate contact with their hosts, indeed the entire life cycle can be completed on an individual host, so transmission between hosts is mainly by direct physical contact or via contamination of fomites (bedding, clothing). The females lay eggs in tunnels ranging from 5-15 mm in length in the stratum corneum of the skin. The eggs mature and hatch within 3-4 days. Emergent six-legged larvae may remain in their tunnel, form pockets or extensions of the tunnel or migrate to the skin surface where they form temporary shallow pits or invade hair follicles. These residences are used as moulting pouches as well as for food and shelter. The larvae moult within 3-4 days to form eight-legged protonymphs which then moult 3-4 days later to form larger tritonymphs (sometimes called deutonymphs) or adult males. Tritonymphs moult 3-4 days later to form adult females, thus males reach adulthood faster than females as they undergo one less moult. Mating usually occurs after the active male mites penetrate the moulting pouches of the adult females. All motile life stages have been observed to leave their burrows and wander around on the skin. Even with low numbers of mites present on a host, males and females find each other presumably via pheromones. The males often die after mating (although they can live for 9-11 days) and the fertilized females leave their pouches and search for suitable sites for permanent burrows. The females excavate characteristic serpentine (S-shaped) burrows at a rate of 2-5 mm per day, laying eggs in the process. Females live for about 30 days (sometimes up to 60 days) and they lay around 40-50 eggs at a rate of 1-3 eggs per day. Only about 10% of the eggs eventually give rise to adult mites, even under the most favourable conditions. The entire life cycle is usually completed within 2 weeks but can range from 1-3 weeks days depending on conditions. Adults dislodged from hosts use odour and thermal stimuli to seek new hosts but they are very susceptible to desiccation and can only survive for 24-36 hours at room (20°C) temperature with normal (40-80%) humidity, or longer (2-9 days) at lower temperatures with high humidity. Transmission only occurs when fecund female mites move between hosts, so host behaviours and activities that involve prolonged contact between individuals sharing common environments are most conducive to the spread of infestations.

**Differential diagnosis**: The presumptive diagnosis of scabies is clinical and confirmed by visualization of mites, eggs and faeces (scybala). Symptoms and signs typically include pruritus, rash and skin lesions (papules, pustules, burrows, nodules and occasionally plaques), with burrows being pathognomonic. While mite burrows may sometimes be observed by direct visual examination, they are better visualized after staining the skin with ink or by applying topical tetracycline and examining under ultraviolet illumination (Woods lamp) for fluorescence. More recently, high resolution videodermatoscopy has been used to reveal burrows by their characteristic ‘jet-with-contrail’ appearance and mites by their denser triangular ‘delta-wing’ mouthparts. Burrows, however, are not always easy to find and may be obscured by secondary lesions. Recourse is often made to the microscopic examination of skin scrapings for intact mites, mite fragments, eggs, eggshell fragments or mite faecal pellets. Deep skin scrapings may be mixed with glycerol or mineral oil and examined directly or they may be heated in potassium hydroxide solutions which digests skin but not mite cuticles. Finding and scraping infested lesions can be difficult so multiple sites should be examined from individual hosts. Nonetheless, negative results should not exclude diagnoses because scrapings may have missed low mite numbers, even in crusted lesions. A range of immunoserological tests (enzyme immunoassays) have been developed to detect host antibody isotypes against a range of crude and defined mite antigens with variable success depending on the kinetics and dynamics of infestation and the target antigen used. Phylogenetic studies have recently been used to characterize many mite isolates by polymerase chain reaction (PCR) amplification of specific gene sequences (internal transcribed spacer regions of nuclear ribosomal RNA, hypervariable microsatellite markers, mitochondrial cytochrome c oxidase subunit 1 and mitochondrial 16S ribosomal RNA).

**Treatment and control**: A wide variety of insecticides and acaricides have been used to treat scabies mite infestations in humans; including topical applications of macrocyclic lactones (ivermectin), pyrethroids (permethrin), benzoic esters (benzyl benzoate), anilides (crotamiton), organophosphates (malathion) and even sulphur ointment in petroleum jelly, and orally administered macrocyclic lactones (ivermectin, moxidectin). Topical lindane (gamma-benzene hexachloride) was used previously but has been replaced due to concerns over neurotoxicity. Current chemotherapy usually consists of combination treatment with topical permethrin and oral ivermectin, although the latter is not recommended during pregnancy or lactation nor in patients with liver disease. There are mounting concerns about the emergence of drug resistance in mite populations and there have been reports of some resistance to permethrin and ivermectin. A range of alternative therapies have been investigated with variable success when using neem oil, tea tree oil, lippia oil, tumeric, camphor oil, coconut and jojoba oil as topical treatments or repellents. Given the allergic and hypersensitivity responses involved in many infestations, topical steroids should not be used on humans. Symptomatic

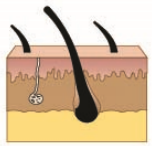
treatments include antihistamines for pruritus, emollients for dry skin, keratolytic agents (salicylic acid, urea, warm baths) for crusted lesions and broad-spectrum antibiotics for secondary bacterial infections and septicaemia. Treatments should also be extended to other people in close contact, including family members and at-risk healthcare personnel. Infestations in animals can be treated with topical (lotions, spray-ons or spot-ons) or systemic (oral, in-feed or injectable) acaricides, including traditional compounds (lime sulphur), organochlorines (bromocyclen, lindane), organophosphates (chlorfenvinphos, coumaphos, crotoxyphos, diazinon, fenchlorvos, malathion, methoxychlor, phosmet, trichlorfon), pyrethroids (permethrin), amidines (amitraz), arylpyrazoles (fipronil) and the macrocyclic lactones (moxidectin, ivermectin, selamectin, doramectin). Careful attention should be paid to pharmacological guidelines to avoid adverse side-effects (e.g. macrocyclic lactones in Murray grey cattle and collie dog breeds), accidental poisoning (e.g. oral ingestion of lindane), residues in food items, and environmental toxicity. Many formulations contain surfactants which serve to soften crusts and remove skin scales. Hair can also be clipped from affected areas; mechanical debridement of crusts may be attempted and the skin cleaned with anti-seborrhoeic shampoos prior to acaricide treatment. Lime-sulphur dips have also been used at 10 day intervals for treating dogs and cats. Treatments should be repeated weekly for several weeks to ensure newly emergent mites are killed. Infested animals should be isolated or treatments extended to animals in close proximity. Corticosteroids can also be used in severely distressed animals to reduce pruritus and prevent further excoriation. Some measure of environmental control should be attempted to prevent the spread of infestations via the contamination of fomites. Washing clothing and bedding in hot water followed by prolonged drying has been shown to be effective against dislodged developmental stages of *S. scabiei*, as has dry-cleaning, steam-cleaning, vacuuming and even sealing contaminated items in plastic bags for at least 3 days. Livestock and zoo animals can be quarantined and treated before being introduced into new facilities, and strategic treatments of pregnant females in breeding facilities should be used to prevent vertical transmission. Immunological studies have demonstrated a range of cellular and humoral immune responses in humans and animals against *Sarcoptes* antigens, but experimental vaccination studies with a range of candidate immunogens have not yet succeeded in generating any strong protective immunity against infection or disease, further highlighting the complex interactions between host immunocompetency and disease expression.

# *Sarcoptes*



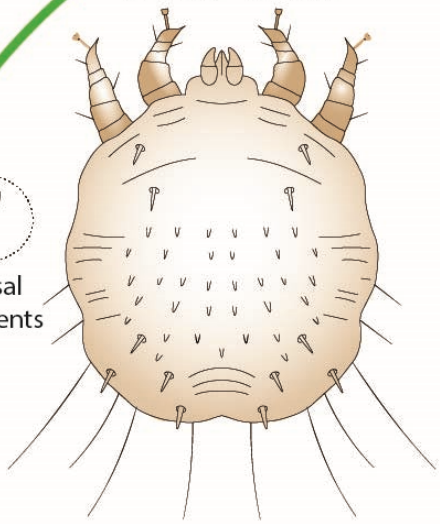
Hosts
(mammals)

transmission between hosts by close contact
or via contaminated fomites

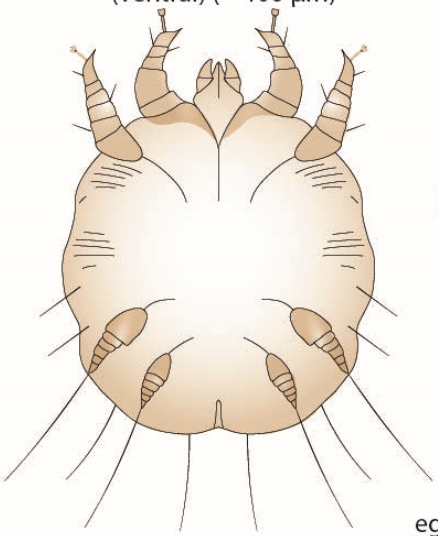


skin
(pruritus,
lesions,
dermatitis,
alopecia,
mange)
[scabies in
humans]

adult female
(dorsal) (~ 400 µm)



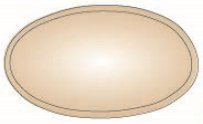
adult female
(ventral) (~ 400 µm)



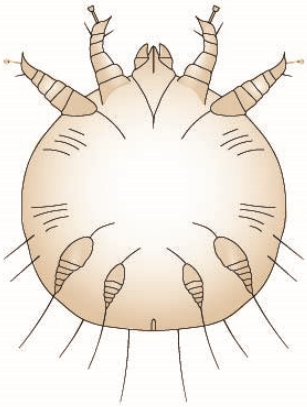
tarsal
elements

adult females excavate burrows in skin

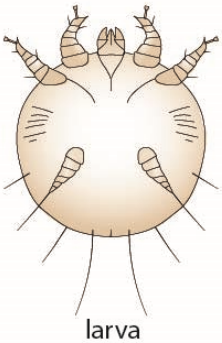
eggs laid in
tunnels in skin



egg
(~ 200 µm)



nymph
(ventral)
(~ 300 µm)



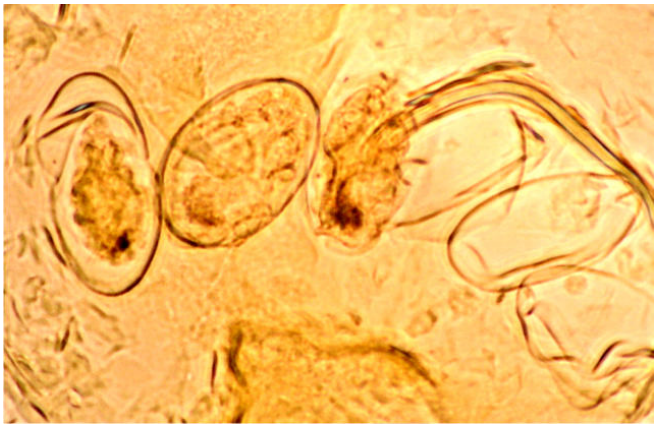
larva
(ventral)
(~ 250 µm)

hatch

2 nymphal instars
(proto-, trito- (= deuto-)
nymphs, form moulting pouches)

all motile stages are ectoparasitic
(feed on horny layer of epidermis)

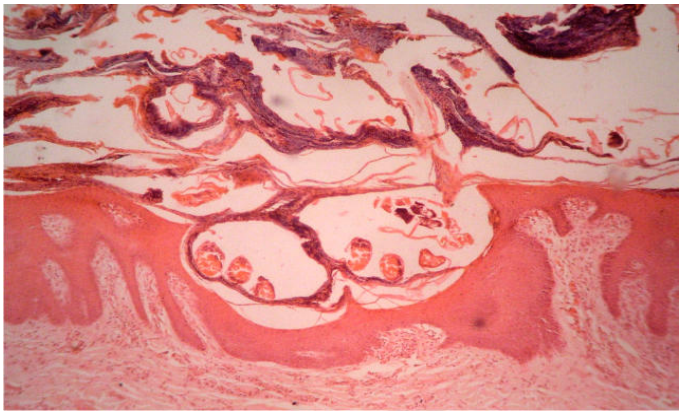
*Sarcoptes* adult



*Sarcoptes* eggs

*Sarcoptes* larva

*Sarcoptes* nymph



*Sarcoptes* skin lesion

*Sarcoptes* mange in dog