Notoedres
(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 *Notoedres* spp. are found mainly in the ears of cats and may cause mild dermatitis (notoedric mange).

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:	*Notoedres* (parasitic on skin of cats/rabbits/rats)
Species:	various species cause mange in cats

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 'morphoecotypes': 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 *Notoedres* (syn. *Chironyssus, Bakeracarus, Mysarcoptes p.p., Suncicoptes*) is characterized by small round mites with dorsal striations not broken by strong pointed scales, dorsal setae that are not spine-like, palps with 2 segments, short stubby legs without claws, long pretarsi on the 2 front pairs of legs, a dorsal anus, and females with genital openings appearing as transverse slits paralleling the body striations. Over 45 species have been described and assigned to 4 subgenera: namely, *N.* (*Bakeracarus*), *N.* (*Mesonotoedres*), *N.* (*Neonotodres*) and *N.* (*Notoedres*). The mites burrow into the living layers of skin on small mammals (cats, rabbits, rats, bats) and may cause pruritic lesions and dermatitis (condition known as mange).

***Notoedres* species**	**Hosts**	**Clinical signs**	**Distribution**
Subgenus *N.* (*Notoedres*)			
N. N. africanus	Chiroptera: emballonurid (African sheath-tailed bat)		Africa
N. N. alexfaini	Chiroptera: molossid (hairless bat, lesser naked bat)		Singapore
N. N. benoiti	Chiroptera: emballonurid (African sheath-tailed bat)		Africa
N. N. cati (syn. *N. minor cuniculi, Sarcoptes*) (notoedric cat mite)	Carnivora: felid (cat, European wildcat, serval, cheetah, snow leopard, tiger, Siberian tiger, ocelot, lynx, mountain lion, Florida panther, bobcat), viverrid (Formosan masked civet, palm civet, Asian palm civet), canid (dog, wolf, fox), procyonid (white-nosed coati, raccoon), herpestid (small Indian mongoose, Javan mongoose); Lagomorpha: leporid (European rabbit); Eulipotyphla: erinaceid (African pygmy hedgehog); Diprotodontia: phascolarctid (koala); Rodentia: caviid (guinea pig), cricetid (golden hamster); Primates: hominid (human)	notoedric mange (face mange, feline scabies), irritation, erythema, intense pruritus, scales, crusts, excoriation, thickened skin, systemic sequelae	worldwide
N. N. centrifera (syn. *N. douglasi*)	Rodentia: sciurid (black giant squirrel, western gray squirrel, eastern gray squirrel, fox squirrel, southern flying squirrel, eastern chipmunk), erethizontid (porcupine)	squirrel mange, dermatitis, pustules	Indonesia, North America
N. N. cheiromeles	Chiroptera: molossid (hairless bat)		Indonesia
N. N. chiropteralis (synonymized with *N. vanschaiki,* both recently transferred to *Prosopodectes)*	Chiroptera: vespertilionid (serotine bat, common noctule, common pipistrelle, Java pipistrelle, lesser Asiatic yellow bat, lesser bamboo bat)		Eurasia
N. N. dewitti	Chiroptera: molossid (wrinkle-lipped free-tailed bat, Malayan free-tailed bat, Angolan free-tailed bat, northern freetail bat, hairless bat)		Asia, Africa, Australia
N. N. dohanyi	Chiroptera: molossid (wrinkle-lipped free-tailed bat, Malayan free-tailed bat, hairless bat)		Asia

N. N. galagoensis	Primates: galagid (Demidoff's dwarf galago)	ear cysts	Africa
N. N. indicus (syn. *Suncicoptes*)	Eulipotyphla: soricid (Asian house shrew)		Asia
N. N. ismaili	Chiroptera: molossid (wrinkle-lipped free-tailed bat, Malayan free-tailed bat)		Asia
N. N. jamesoni	Rodentia: murid (lesser bandicoot rat, ricefield rat, Malayan field rat, Annandale's rat)		Asia
N. N. longisetosus	Chiroptera: molossid (hairless bat)		Asia
N. N. mimetilli	Chiroptera: vespertilionid (Moloney's mimic bat, Thomas's flat-headed bat)		Africa
N. N. miniopteri	Chiroptera: vespertilionid (common bent-wing bat, greater long-fingered bat, banana serotine)		Africa
N. N. muris (syn. *Sarcoptes*)	Rodentia: murid (brown rat, black rat, pale field rat, fawn-footed mosaic-tailed rat), cricetid (European hamster, European water vole, California vole, web-footed marsh rat), caviid (guinea pig); Peramelemorphia: peramelid (northern brown bandicoot); Diprotodontia: phalangerid (common brushtail possum); Eulipotyphla: erinaceid (European hedgehog)	irritation, erythema, crusts	worldwide
N. N. musculi	Rodentia: murid (house mouse, striped field mouse, yellow-necked mouse, white-footed mouse)	irritation, erythema, crusts	worldwide
N. N. myoticola	Chiroptera: vespertilionid (greater mouse-eared bat, lesser mouse-eared bat, long-fingered bat, Daubenton's bat)		Europe
N. N. myotis	Chiroptera: vespertilionid (cave myotis)		North America
N. N. namibiensis	Chiroptera: molossid (Egyptian free-tailed bat)		Africa
N. N. nigricans	Chiroptera: vespertilionid (black myotis)		South America
N. N. oudemansi	Rodentia: murid (black rat); Eulipotyphla: erinaceid (African hedgehog)	dermatitis	Africa
N. N. ovatus	Chiroptera: molossid (Angolan free-tailed bat)		Africa
N. N. pahangi	Rodentia: murid (ricefield rat, chesnut white-bellied rat, inland hill rat, African grass rat, Polynesian rat, Malayan wood rat, Hoffman's rat, Amami spinous rat, Bower's white-toothed rat, Namaqua rock rat)		Asia, Africa
N. N. paucipilis	Rodentia: murid (Creek groove-toothed swamp rat)		Asia
N. N. philippinensis	Chiroptera: vespertilionid (common bent-wing bat, greater bent-wing bat, little bent-wing bat)		Asia
N. N. pseudomuris	Rodentia: murid (house mouse, wood mouse, ricefield mouse), cricetid (transcaspian vole)	irritation, erythema, crusts	worldwide
N. N. rajamanickami	Chiroptera: molossid (hairless bat)		Malaysia
N. N. roesleri	Chiroptera: vespertilionid (black myotis)		South America
N. N. schoutedeni	Chiroptera: vespertilionid (white-winged serotine bat)		Africa
N. N. tadaridae	Chiroptera: molossid (gland-tailed freetail bat, northern freetail bat, Angolan free-tailed bat, Midas free-tailed bat, Malayan free-tailed bat), emballonurid (gray sac-winged bat)		Africa, Asia
N. N. tristis	Chiroptera: molossid (northern freetail bat)		Australia
N. N. vanschaiki (synonymized with *N. chiropteralis,* both recently transferred to *Prosopodectes*)	Chiroptera: vespertilionid (serotine bat, common noctule)		Europe
N. N. verheyeni	Chiroptera: emballonurid (African sheath-tailed bat)		Africa
N. N. yunkeri	Chiroptera: molossid (Coiban mastiff bat)		South America
Subgenus *N.* (*Bakeracarus*)			
N. B. americanus	Chiroptera: vespertilionid (little brown bat, black myotis, cave myotis, Yuma myotis, long-legged myotis)		South America
N. B. anisothrix	Chiroptera: molossid (velvety free-tailed bat)		South America
N. B. coreanus	Chiroptera: vespertilionid (Savi's pipistrelle)		Asia
N. B. corynorhini	Chiroptera: vespertilionid (Rafinesque's big-eared bat, Townsend's big-eared bat)		North America
N. B. eptesicus	Chiroptera: vespertilionid (Brazilian brown bat)		South America
N. B. helicothrix	Chiroptera: molossid (southern dog-faced bat)		South America

N. B. lasionycteris (syn. *Sarcoptes lasionycteris, myotis*) (incl. subspp. *lasionycteris*, *minimus*, *intermedius*)	Chiroptera: molossid (velvety free-tailed bat, black mastiff bat, Pallas's mastiff bat, free-tailed bat, Mexican free-tailed bat, broad-eared bat, little goblin bat), mormoopid (Macleay's mustached bat), vespertilionid (big brown bat, neotropical bat, silvery bat, cave myotis)		Americas
N. B. noctilionis	Chiroptera: noctilionid (greater bulldog bat)		Cuba
N. B. paraguayensis	Chiroptera: vespertilionid (black myotis)		South America
N. B. plecoti	Chiroptera: vespertilionid (brown long-eared bat)		Europe
Subgenus *N.* (*Mesonotoedres*)			
N. M. notoedres	Rodentia: cricetid (hamster)		Europe
Subgenus *N.* (*Neonotoedres*)			
N. N. elongatus	Chiroptera: molossid (hairless bat, lesser naked bat)		Indonesia

Parasite morphology: *Notoedres* spp. form 4 different types of morphological stages during their developmental cycles: namely, eggs, larvae, nymphs and adults. The eggs are ovoid transparent stages measuring around 100 μm in length. They hatch to release larvae which have oval flattened (discoid) bodies around 100 μm long and containing 3 pairs of ventral legs (2 short anterior pairs and one small posterior pair). Larvae moult to form nymphs which are larger in size measuring 150-200 μm long and possessing 4 pairs of ventral legs (having developed another small posterior pair). Two successive nymphal instars are formed (protonymphs and deutonymphs), both being similar in morphology to adult mites but lacking genital openings. Adult mites have small round dorsally-compressed bodies measuring 150-300 μm in length and covered by a finely-striated cuticle with dorsal concentric (thumb-print) patterns not interrupted by pointed spines/scales (like *Sarcoptes*). They have 2 main tagma: a small anterior gnathosoma (head) and larger posterior idiosoma (body). The gnathosoma bears short cutting-sucking mouthparts comprising a pair of 3-segmented chelicerae terminating in stylet-like chelae flanked by small sensory 2-segmented palps without terminal claws (apoteles). The oral opening (mouth) has a short square dorsal rostrum, a ventral buccal cone and an unbarbed hypostome. The alimentary tract comprises a tubular foregut (oesophagus, pharynx), saccular midgut (ventriculus with caeca), and tubular hindgut (with excretory Malpighian tubules) ending in a subterminal anus located on the dorsal surface (unlike *Sarcoptes* which has a terminal anus). The idiosoma lacks a precapsular dorsal shield (present in *Trixacarus* and *Sarcoptes*). The dorsal surface has group of rod-like setae and a few rounded backward-pointing scales (while *Trixacarus* has setose setae and *Sarcoptes* has spine-like setae). Adult *Notoedres* only have one pair of genital setae (while *Sarcoptes* and *Trixacarus* have 2 pairs). Like all members of the order Astigmata, respiratory stigmata and tracheae are absent as the mites breathe through their cuticles. The ventral idiosoma is the point of attachment for 4 pairs of legs, arranged in 2 anterior pairs projecting forwards just beyond the body margin and 2 small posterior pairs projecting backwards but not extending beyond the body. Each leg has 6 short segments (coxa, trochanter, femur, genu, tibia, and tarsus) with the coxae fused to body wall and sunk into body contributing to their short-legged appearance. The first 2 pairs of legs have thickened coxal apodemes (thickened ridges) joined in a Y-shape, while those on the hindlegs are not joined. Most legs have typical sarcoptiform pretarsi with long unsegmented pedicels bearing claw-like pulvilli. Male mites have small cup-shaped suckers (caruncles) on the ends of the first, second, and fourth pairs of legs, while females only have suckers on the first and second pairs of legs, the remaining legs terminating in long setae. Adult mites exhibit sexual dimorphism in body size (females larger than males, 200-300 v. 150-200 μm long), cuticular plates (mid-dorsal shield lacking in females) and genital structures. Males have genital apodemes (absent in *Sarcoptes*) and 2 testes with tubular vas deferens connected to an ejaculatory duct and long sheathed aedeagus (penis) which is located ventrally. Females have 2 ovaries with tubular oviducts joined to a globular uterus (with muscular shell-glands) and vagina (with accessory organs (bursa copulatrix, spermathecae) for sperm receipt and storage). The female gonopore (genital opening) appears as a transverse subterminal slit paralleling body striations and the cuticle behind the vulva is often pale and weakly striate.

Site of infection: These mites live in groups in deep burrows within the dermis of mammalian hosts. Almost 50 species have been described: mainly from bats (emballonurids, molossids, mormoopids, noctilionids, vespertilionids) as well as from various carnivores (canids, felids, herpestids, procyonids, viverrids) and some lagomorphs (leporids), shrews (erinaceids, soricids), diprotodontids (phascolarctids, phalangerids), peramelemorphs (peramelids), rodents (caviids, cricetids, erethizontids, murids, sciurids) and primates (galagids and hominids). The are found commonly on hairless or sparsely-haired regions of the body, such as the ear pinnae, nose, face, eyelids, head, neck, elbows, tail, and sometimes the perineum, external genitalia and legs.

Pathogenesis: While some infestations remain subclinical, many produce mild to severe clinical disease (known as notoedric mange, sometimes called 'feline scabies' in cats) with skin inflammation (dermatitis) and intense pruritus exacerbated by hypersensitivity reactions leading to self-mutilation, yellow crusted lesions, patchy alopecia, secondary bacterial infections, and sometimes death. The mites burrow into the skin, usually being restricted to the stratum corneum, but occasionally penetrating this layer giving rise to more severe skin reactions and serum exudation. The mites feed on epidermal cells and tissue fluids as they burrow through the skin. Their tunnels contain mites, mite eggs, mite secretions (saliva) and excretions (faeces) which provoke allergic hypersensitive responses involving the release of cytokines (especially interleukin-1) from damaged keratinocytes. The skin becomes inflamed locally with an influx of neutrophils, eosinophils, mast cells and sometimes lymphocytes. Lesions first appear as

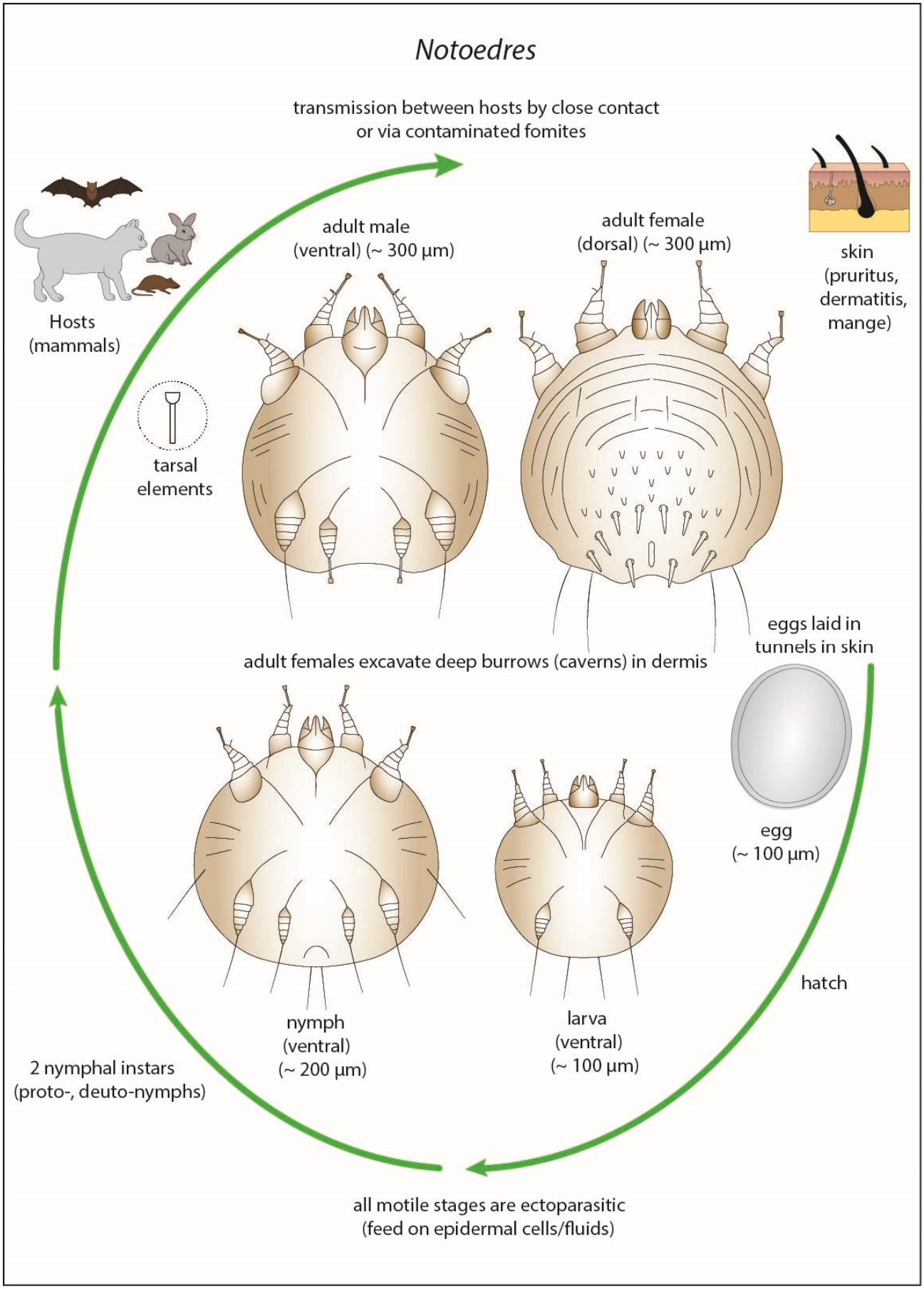
red papules and progress to erythematous vesicles, both typically accompanied by intense pruritus. Exudates dry to form thick adherent yellow-gray crusts and sometimes scabs overlying ulcers. Hyperkeratosis occurs as epidermal cells proliferate and gradually cornify resulting in thickened wrinkled skin (lichenification). Lesions first appear on the ear pinnae, and rapidly spread to the rest of the ear, face, eyelids, neck, and paws. In severe cases, the outer ear may be completely eroded. Perineal lesions are also common, particularly in animals that sleep in a curled position. Animals attempt to relieve the pain and irritation by vigorous self-grooming, leading to skin damage (excoriation), hair loss (alopecia), gross self-mutilation and behavioural changes in hunting and foraging activities. Lesions become susceptible to secondary bacterial infections and peripheral lymphadenopathy may occur. Changes in haematological and biochemical clinical parameters include mild anaemia, elevated ions (phosphates, sodium, chlorides), hypoglycaemia and low levels of serum creatinine, cholesterol, albumin and globulin (consistent with protein loss through the damaged skin). Chronically infested animals may become severely debilitated, depressed, dehydrated, anorexic, emaciated, and often die over 4-6 months. They do not appear to develop any protective immunity, although some individuals have been observed to undergo spontaneous recovery. Generally, notoedric mange in progressive and re-infestations are common after treatment. Infestations are more common in young, malnourished or immunosuppressed animals, or those with cognitive deficiencies or neuropathies that interfere with self-grooming.

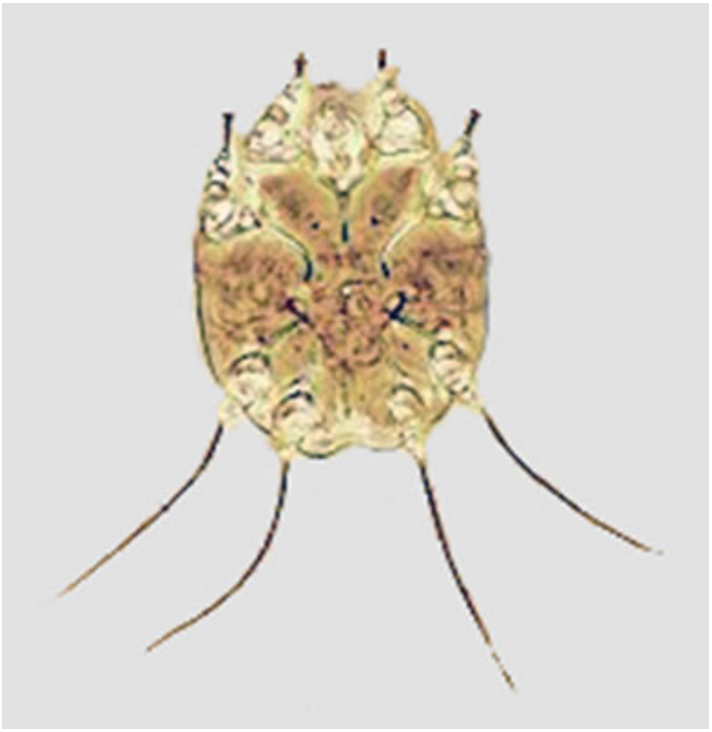
Developmental cycle and mode of transmission: *Notoedres* spp. undergo incomplete (hemimetabolous) metamorphosis whereby eggs hatch larvae that moult through nymphal stages to form adult mites. The entire life-cycle may be completed on the same host and transmission to other hosts mainly involves direct contact. Female mites excavate deep burrows in the epidermis laying eggs at regular intervals, sometimes in a semicircle in a larger cavern. The eggs hatch after 4-5 days releasing hexapod (6-legged) larvae which emerge onto the surface of the skin before digging their own shallow burrows (larvae rarely remain in the maternal burrow). The larvae feed for several days before moulting to the first octopod (8-legged) nymphal stages (protonymphs) which leave the larval burrows before digging their own shallow burrows. The protonymphs feed for several days before moulting to the second nymphal stages (deutonymphs) which similarly leave their nymphal burrows before digging a third burrow. The deutonymphs feed for several days and then moult to form adult mites, usually within 12-18 days of oviposition. Adult females tend to stay in the third nymphal burrow, whereas adult males emerge seeking mates on neighbouring burrows. Following copulation, fertilized females dig deeper into the skin and lay 3-4 eggs each day for several weeks. The whole life-cycle may be completed in 19-21 days, but may take longer. Infestations are highly contagious and transmission occurs by direct contact between hosts with the transfer or wandering larvae and nymphs. Motile stages have also been found to survive for several days off hosts in humid conditions, so some transmission may occur via the contamination of fomites (particularly animal sleeping and resting places and bedding).

Differential diagnosis: *Notoedres* infestations may be strongly indicated on clinical grounds (intensely pruritic dermatitis with crusted lesions) but they need to be differentiated from dermatitis caused by other ectoparasites (other mites, lice, fleas, mosquitoes), bacterial pyoderma, fungal infections, endocrinopathies, atopic dermatitis, auto-immune diseases (pemphigus, systemic lupus erythematosus) and even adverse food reactions. Diagnosis is afforded by the direct detection of mites in deep skin scrapings, usually following caustic digestion (10% potassium hydroxide) to break down skin and other organic debris (mite cuticles are impervious to digestion). Mites are often found at the edges of lesions, and may also occur in large numbers in crusts. Histopathology of skin biopsies may reveal mite fragments in the thickened stratum corneum with focal hyperkeratosis and superficial perivascular dermatitis. Coprological studies may also reveal mites or fragments in host faeces after centrifugal floatation, as mites ingested during grooming are subsequently passed in faeces. Molecular biological techniques have also been used to detect and characterize mite isolates from faeces and skin scrapings following the polymerase chain reaction (PCR) amplification of nuclear gene sequences (notably internal transcribed spacer 2 from ribosomal DNA).

Treatment and control: Clinical infestations have responded well to chemotherapy using chemical acaricides, including topical or systemic applications of lime sulphur, organophosphates (malathion), organochlorines (lindane), pyrethroids (flumethrin), phenylpyrazoles (fipronil), neonicotinoids (imidacloprid) and macrocyclic lactones (ivermectin, selamectin, doramectin, moxidectin). Treatment efficacy is greatly improved if animals are sprayed/bathed with antiseborrheic shampoos to soften or remove crusts before the application of the acaricides. However, repeated or prolonged acaricidal treatment may be required to eliminate mite stages subsequently emerging from burrows, particularly in persistent and generalized infestations. There have been a number of reports of mite populations developing resistance to some acaricides, including organochlorines and macrocyclic lactones. Treatment is best augmented by vitamin supplementation (especially vitamin K to prevent incidental anticoagulant toxicosis), steroid formulations (to manage self-trauma and hypersensitivity) and broad-spectrum antibiotic regimes (to combat secondary bacterial infections). All in-contact animals should be treated at the same time, particularly in infested households, kennels/catteries and laboratory animal facilities. Effective prevention and control relies on a combination of regular monitoring as a prelude to timely treatment with animal isolation and quarantine, environmental decontamination through stringent sanitation of fomites (animal housing and bedding), and the exclusion of wildlife from households and holding facilities using barriers or traps.

Notoedres


transmission between hosts by close contact
or via contaminated fomites
Hosts
(mammals)
tarsal
elements
adult male
(ventral) (~ 300 µm)
adult female
(dorsal) (~ 300 µm)
skin
(pruritus,
dermatitis,
mange)
adult females excavate deep burrows (caverns) in dermis
eggs laid in
tunnels in skin
egg
(~ 100 µm)
hatch
nymph
(ventral)
(~ 200 µm)
larva
(ventral)
(~ 100 µm)
2 nymphal instars
(proto-, deuto-nymphs)
all motile stages are ectoparasitic
(feed on epidermal cells/fluids)



Notoedres adult