

Demodex
(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. Trombidiform mites have stigmata on the gnathosoma and distinct setae on their bodies and legs. Many species are free-living, some have been associated with allergy (including asthma), and several are obligate ectoparasites on mammals or birds. Demodecids are small follicle mites with elongate cigar-shaped bodies and stumpy anterior legs. Infestations by *Demodex* spp. occur on many mammalian hosts, sometimes associated with follicular, squamous or pustular dermatitis (demodectic 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: Prostigmata [Trombidiformes] (sucking mites, stigmata on gnathosoma)
Suborder: Eleutherengona (thumb-claw process, tube-like midgut, females with adjacent anal-genital openings)
Superfamily: Cheyletoidea (chelicerate with basal stylophore and stylet-shaped movable segments)
Family: Demodecidae (small follicle mites, elongate cigar-shaped body, 4 pairs stumpy legs at front of body)
Genus: *Demodex* (parasitic on skin/hairs of mammals)
Species: various species cause demodectic mange in animals

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 (chelicerate) 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 2 nd & 4 th 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 prostigmatid mites have been described: many species being free-living (including most trombiculids although some have parasitic larvae); and others being obligate ectoparasites on mammals or birds. Parasitic species spend their entire lives on individual hosts, so horizontal transmission between hosts is primarily by physical contact. Prostigmatid mites are characterized by having oval-ellipsoidal bodies (sometimes vermiform) with distinctive setation, piercing chelicerae (sometimes pincer-like), unbarbed hypostomes, well-developed palps, and short legs with coxae fused to the body wall and terminal tarsi with 1-2 claws (but lacking complex pulvilli). A total of 34 superfamilies have been recognized in 4 suborders: Anystina (with 17 superfamilies); Eleutherengona (10); Endeostigmata (3); and Eupodina (4). Many members of the suborders Anystina and Eleutherengona have legs with distinctive arrangements of the terminal

tibiotarsal segments referred to as the 'thumb-claw' process. Eleutherengone mites have simple tube-like postventricular midguts, small salivary glands (if present), females with anal and genital openings located close together posteriorly, and males with few glandular components of their testicular epithelia and accessory glands. Ten superfamilies are recognized (Cheyletoidea, Eriophyoidea, Pomerantzioidea, Pterygosomatoidea, Pyemotoidea, Pygmephorosidea, Raphignathoidea, Tarsocheyloidea, Tarsonemoidea, Tetranychosidea)

The superfamily Cheyletoidea comprises free-living predators, nidicolous forms and highly specialized ecto- or endo-parasites. Adult mites have chelicerae with basal segments fused into a single unit (stylophore), movable segments that are stylet-shaped, and the female anal and genital openings are located ventrally. A total of 8 families are recognized (Cheyletidae, Cloacaridae, Demodicidae, Harpyrhynchidae, Myobiidae, Ophioptidae, Psorergatidae, Syringophilidae). The family Demodicidae contains the follicle mites infesting the hair follicles and skin pores of mammals. They have unique elongate bodies, often referred to as cigar-, crocodile-, or worm-like (vermiform), with transverse annulations on the long posterior idiosoma. They have 4 pairs of short stumpy legs located at the front of the idiosoma, and highly reduced chaetotaxy (setae usually absent on body and legs). Eight genera have been recognized (*Apodemox*, *Demodex*, *Epimyodex*, *Ophthalmodex*, *Pterodex*, *Rhinodex*, *Soricidex*, and *Stomatodex*) differing primarily in their host specificity, tissue tropism and geographic distribution. Over 100 species have been described in the genus *Demodex*, most species being specific for individual mammalian hosts, including bats, rodents, lagomorphs, insectivores, carnivores, ungulates and primates (including humans). Many species are considered to be commensals living within the hair follicles of their hosts, but an increasing number have been associated with clinical disease (demodeciosis) characterized by inflammation (folliculitis) and sometimes skin lesions.

Demodex species	Hosts	Clinical signs	Distribution
<i>D. acutipes</i>	Artiodactyla: cervid (red deer)		Europe
<i>D. aelleni</i>	Chiroptera: vespertilionid (Daubenton's bat)		Europe
<i>D. agrarii</i>	Rodentia murid (striped field mouse)		Europe
<i>D. ailuropodae</i>	Carnivora: ursid (giant panda)		Asia
<i>D. antechini</i>	Dasyuromorphia: dasyurid (agile antechinus)		Australia
<i>D. apodemi</i>	Rodentia murid (wood mouse)		Europe
<i>D. aries</i>	Artiodactyla: bovid (sheep)		New Zealand
<i>D. artibei</i>	Chiroptera: phyllostomid (Aztec fruit-eating bat)		North America
<i>D. arvicolae</i>	Rodentia: cricetid (short-tailed field vole)		Europe
<i>D. aurati</i>	Rodentia: cricetid (golden hamster)		North America (lab.) ex: Europe
<i>D. bandicotae</i>	Rodentia: murid (bandicoot rat)		Asia
<i>D. bicaudatus</i>	Chiroptera: pteropodid (long-tongued nectar bat)		Australia
<i>D. bisonianus</i>	Artiodactyla: bovid (European bison)		Europe
<i>D. bovis</i>	Artiodactyla: bovid (cattle, European bison)	mange, caseous nodules, pyoderma, furunculosis, ulceration, crusting	worldwide
<i>D. brevis</i>	Primates: hominid (human)	subclinical, occasionally itching, inflammation, blepharitis	worldwide
<i>D. buccalis</i>	Rodentia: cricetid (bank vole)		Europe
<i>D. caballi</i>	Perissodactyla: equid (horse)	mange	worldwide (except Australia)
<i>D. cafferi</i>	Artiodactyla: bovid (African buffalo)		Africa
<i>D. canis</i>	Carnivora: canid (dog, wolf)	mange (squamous, pustular or follicular), alopecia, thickened skin, pustules (red mange ooze serum)	worldwide
<i>D. caprae</i>	Artiodactyla: bovid (goat)	mange, caseous nodules, pyoderma, furunculosis, ulceration, crusting	worldwide
<i>D. carollia</i>	Chiroptera: pteropodid (Seba's short-tailed bat)		South America
<i>D. cati</i>	Carnivora: felid (cat)	mange, alopecia, thickened skin, papules, scaling	worldwide
<i>D. caviae</i>	Rodentia: caviid (guinea pig)		South America
<i>D. cervi</i>	Artiodactyla: cervid (red deer)		Europe
<i>D. chiropteralis</i>	Chiroptera: vespertilionid (brown long-eared bat)		Europe
<i>D. conicus</i>	Rodentia: murid (house mouse)		Europe
<i>D. cornei</i>	Carnivora: canid (dog)		North America
<i>D. corniculatus</i>	Rodentia: murid (yellow-necked mouse)		Europe

<i>D. criceti</i>	Rodentia: cricetid (golden hamster)		North America (lab.) ex: Europe
<i>D. cricetuli</i>	Rodentia: cricetid (grey dwarf hamster)		North America (lab.) ex: Eurasia
<i>D. cuniculi</i>	Lagomorpha: leporid (European rabbit)		cosmopolitan
<i>D. cyonis</i>	Carnivora: canid (dog)		Japan
<i>D. dasypodi</i>	Cingulata: dasypodid (nine-banded armadillo)		North America
<i>D. desmodi</i>	Chiroptera: phyllostomid (common vampire bat)		South America
<i>D. equi</i>	Perissodactyla: equid (horse)	mange (squamous or pustular), papules, pustules, alopecia, scaling	worldwide (except Australia)
<i>D. erinacei</i>	Eulipotyphla: erinaceid (European hedgehog)		Europe
<i>D. erminae</i>	Carnivora: mustelid (stoat)		Europe
<i>D. flagellurus</i>	Rodentia murid (house mouse)		Europe
<i>D. folliculorum</i>	Primates: hominid (human)	subclinical, occasionally itching, inflammation, blepharitis	worldwide
<i>D. foveolator</i>	Eulipotyphla: soricid (lesser white-toothed shrew)		Europe
<i>D. fusiformis</i>	Rodentia: murid (house mouse)		Europe
<i>D. gapperi</i>	Rodentia: cricetid (southern red-backed vole)		North America
<i>D. gatoi</i>	Carnivora: felid (cat)	mange, alopecia	worldwide
<i>D. ghanensis</i>	Artiodactyla: bovid (cattle)	mange	worldwide
<i>D. glareoli</i>	Rodentia: cricetid (bank vole)		Europe
<i>D. gliricolens</i>	Rodentia: cricetid (European water vole)		Europe
<i>D. gracilentus</i>	Rodentia: murid (striped field mouse)		Europe
<i>D. huttereri</i>	Rodentia murid (striped field mouse)		Europe
<i>D. injai</i>	Carnivora: canid (dog, wolf)	mange, pruritus, alopecia	worldwide
<i>D. intermedius</i>	Scandentia: tupaiid (common treeshrew)		Asia
<i>D. kutzeri</i>	Artiodactyla: cervid (sika deer, red deer)		Europe
<i>D. lacrimalis</i>	Rodentia murid (wood mouse)		Europe
<i>D. leucogasteri</i>	Rodentia: cricetid (grasshopper mouse)		North America
<i>D. longior</i>	Rodentia murid (wood mouse)		Europe
<i>D. longissimus</i>	Chiroptera: pteropodid (Seba's short-tailed bat)		South America
<i>D. lutrae</i>	Carnivora: mustelid (European otter)		Europe
<i>D. macaci</i>	Primates: cercopithecid (rhesus macaque)		North America (lab: ex Asia)
<i>D. macroglossi</i>	Chiroptera: pteropodid (long-tongued nectar bat)		Australia
<i>D. marculus</i>	Rodentia: murid (mouse)		Europe
<i>D. marsupiali</i>	Didelphimorphia: didelphid (common opossum)		North America
<i>D. melanopteri</i>	Chiroptera: vespertilionid (Brazilian brown bat)		South America
<i>D. melesinus</i>	Carnivora: mustelid (European badger)		Europe
<i>D. mexicanus</i>	Chiroptera: vespertilionid (Mexican big-eared bat)		North America
<i>D. microti</i>	Rodentia: cricetid (common vole)		Europe
<i>D. molossi</i>	Chiroptera: molossid (velvety free-tailed bat)		South America
<i>D. muscardini</i>	Rodentia: glirid (hazel dormouse)		Europe
<i>D. musculi</i>	Rodentia: murid (mouse)	mange (follicular)	cosmopolitan
<i>D. mystacina</i>	Chiroptera: mystacinid (New Zealand lesser short-tailed bat)		New Zealand
<i>D. nanus</i>	Rodentia murid (black rat, brown rat)		cosmopolitan
<i>D. neomydis</i>	Eulipotyphla: soricid (Mediterranean water shrew)		Europe
<i>D. neopisthosomae</i>	Chiroptera: pteropodid (cave nectar bat)		Asia
<i>D. norvegicus</i>	Rodentia murid (brown rat)		Europe
<i>D. novazelandica</i>	Chiroptera: mystacinid (New Zealand lesser short-tailed bat)		New Zealand
<i>D. nycticeii</i>	Chiroptera: vespertilionid (evening bat)		North America
<i>D. odocoilei</i>	Artiodactyla: cervid (white-tailed deer)		North America
<i>D. ovis</i>	Artiodactyla: bovid (sheep)	mange, papular/nodular lesions, alopecia, scaling	worldwide
<i>D. peromysci</i>	Rodentia: cricetid (white-footed mouse)		North America
<i>D. phocidi</i>	Carnivora: phocid (harbor seal)		North America
<i>D. phodopi</i>	Rodentia: cricetid (winter white dwarf hamster)		North America

			(lab.) ex: Asia
<i>D. phylloides</i>	Artiodactyla: suid (pig)	mange, erythema, papules, thickened skin	worldwide
<i>D. phyllostomatis</i>	Chiroptera: phyllostomatid (greater spear-nosed bat)		South America
<i>D. plecoti</i>	Chiroptera: vespertilionid (brown long-eared bat)		Eurasia
<i>D. ponderosus</i>	Rodentia: murid (brown rat)		Europe
<i>D. pseudaxisi</i>	Artiodactyla: cervid (sika deer)		Asia
<i>D. rattii</i>	Rodentia murid (brown rat)		Europe
<i>D. ratticola</i>	Rodentia murid (brown rat)	mange (follicular)	Europe
<i>D. rosus</i>	Rodentia: murid (yellow-necked mouse)		Europe)
<i>D. sabani</i>	Rodentia murid (long-tailed giant rat)		Asia
<i>D. saimiri</i>	Primates: cebid (Guianan squirrel monkey)		South America
<i>D. sciurinus</i>	Rodentia: sciurid (red squirrel)		Europe
<i>D. sinocricetuli</i>	Rodentia: cricetid (Chinese striped hamster)		North America (lab.) ex: Asia
<i>D. soricinus</i>	Eulipotyphla: soricid (common shrew)		Europe
<i>D. spelaea</i>	Chiroptera: pteropodid (cave nectar bat)		Asia
<i>D. sungori</i>	Rodentia: cricetid (winter white dwarf hamster)		North America (lab.) ex: Asia
<i>D. talpae</i>	Eulipotyphla: talpid (European mole)		Europe
<i>D. tauri</i>	Artiodactyla: bovid (cattle)	mange	worldwide
<i>D. tigris</i>	Carnivora: felid (tiger)		Asia
<i>D. tortellinioides</i>	Dasyuromorphia: dasyurid (agile antechinus)		Australia
<i>D. uncii</i>	Carnivora: felid (snow leopard)		North America (zoo)
<i>D. ursi</i>	Carnivora: ursid (American black bear)		North America
<i>D. vibrissae</i>	Rodentia: murid (house mouse)		Europe
<i>D. zalophi</i>	Carnivora: otariid (California sea lion)		North America

Parasite morphology: *Demodex* spp. form 4 different types of morphological stages during their developmental cycles: eggs; larvae; nymphs (2 instars); and adults. Eggs are quite variable in size and shape depending on species, ranging from elliptical to fusiform to arrowhead-shaped and measuring from 25-88 μm in length (e.g. *D. folliculorum* arrowhead 80-100 x 40 μm , *D. brevis* fusiform 60 x 34 μm , *D. musculi* elliptical 25-45 x 10-21 μm). Larvae are elongate fusiform (spindle- or carrot-shaped) stages ranging in length from 45-200 μm (e.g. *D. folliculorum* ~150 μm , *D. brevis* ~100 μm , *D. musculi* ~60 μm). They have a small anterior gnathosoma (head or capitulum) bearing lateral supracoxal spines (minute sclerotized pegs) and short stout palps (terminating in 1-3 anterior spines). The posterior idiosoma (body) is semitransparent, colourless to beige-coloured and divided into the anterior podosoma (bearing legs) and the posterior opisthosoma (tapering to a blunt tail). Larvae are hexapods with 3 pairs of unsegmented legs, each ending in a single claw with 2-3 prongs (tines). They have 2-3 pairs of small shelf-like epimeral scutes located between each pair of legs and the opisthosoma usually lacks annulations. Several reports in the literature suggest that a second hexapod larval stage occurs, although others consider it to be the first nymphal instar (protonymph) that often only displays 3 pairs of legs (a rudimentary fourth pair can sometimes be observed). The protonymphs have small rectangular heads and elongate tapering bodies measuring from 60-200 μm in length depending on species (e.g. *D. folliculorum* 150-250 μm , *D. brevis* ~150 μm , *D. musculi* 60-140 μm). The first 3 pairs of legs are beginning to show segmentation and they terminate in one pair of claws with 3 denticles, while the fourth pair of legs (when present) appear as rudimentary stubs. Ventral epimeral scutes are present between each pair of legs and the opisthosoma shows lateral indentations consistent with developing annulations. Deutonymphs are larger in size ranging from 140-400 μm in length (e.g. *D. folliculorum* 250-400 μm , *D. brevis* 150-200 μm , *D. musculi* 140-200 μm). The gnathosoma has spatulate supracoxal spines, and short stout palps with 2 movable segments ending in a curved dorsal spine and 2 anteroventral spines. Deutonymphs have 4 pairs of short anteroventral legs projecting from the lateral body margins, each leg ending in 2 claws and each claw having 4 apices. There are 4 pairs of ventral epimeral scutes located between the legs and the annulations on the opisthosoma have become more evident. Adult *Demodex* mites have distinctive body profiles, being described variously as crocodile-like, carrot-like, cigar-like, oblanceolate, obovate to spathulate. Their bodies are slender, elongate, truncated anteriorly, gradually tapering posteriorly, flattened ventrally and convex dorsally. Different mite species vary in size from long- to short-bodied, most of it attributable to the length of the opisthosoma. Adult mites range in size from 80-400 μm in length (e.g. *D. bovis* up to 400 μm , *D. folliculorum* 300-400 μm , *D. injai* 330-370 μm , *D. canis* 180-300 μm , *D. cati* 180-220 μm , *D. brevis* 150-200 μm , *D. musculi* 118-193 μm , *D. gatoi* 80-115 μm). They are all bound by chitinous cuticles which are partially transparent and appear colourless to creamy white with slightly darker mouthparts and feet. Their bodies lack setae, antennae and wings. The anterior gnathosoma is rectangular to horseshoe-shaped, usually with large supracoxal spines, and bears short blunt mouthparts (paired chelicerae and central hypostome) flanked by sensory palps. The palps are stout and consist of 3 segments, the second segment often with lateral horn-like projections, and the terminal segment ending in a hyaline denticulus with a lateral horn and 2-3 claw-like ventral spines (apotele absent). The paired chelicerae are adapted for piercing and consist of 3-segmented needle-like stylets whose

basal segments were fused into a single stylophore. The oral opening (mouth) was pincer-like with a dorsal rostrum, ventral buccal cone and small unbarbed hypostome. The digestive tract was rudimentary and comprised a tubular foregut (oesophagus, pharyngeal bulb), saccular midgut (ventriculus and diverticulae), and a tubular hindgut (with excretory Malpighian tubules). Many early studies considered these mites to lack an anus (suggesting that faecal waste accumulated in the body during their brief lifespans and was only released when they died), but recent studies found they do have a minute subterminal anus located ventrally. Similarly, few descriptions recorded the occurrence of respiratory openings (stigmata), but like all prostigmatid mites, they are presumably located laterally near the ventral bases of the chelicerae. The idiosoma lacked sclerotized shields and was divided into an anterior trapezoidal podosoma and a posterior elongate opisthosoma (the latter usually comprising >50% of the total body length). The opisthosoma contained the reproductive organs and its exterior surface was distinctly annulated with many transverse striations. The ventral podosoma was the point of attachment for 4 pairs of short stout legs that projected laterally outwards, many having dorsal sensory setae (solenidia). The legs were segmented, with basal epimeral plates (coxal fields) fused to the body wall giving rise to 3 movable segments (some with spurs) and all ending in a tegumental fold with a pair of bifid claws and a recurved spur (complex pulvilli or suckers absent). Adult mites exhibited sexual dimorphism, with males being smaller than females and having genital openings located dorsally rather than ventrally like females. Mature female mites have ovaries joined by oviducts to a uterus that opens to a longitudinal slit-like vulva located on the ventral midbody just behind the last pair of legs. Mature male mites have testes connected by vas deferens to an ejaculatory duct leading to an elongate aedeagus (penis with bulbous base and long sheath) situated longitudinally along the dorsal idiosoma with the genital opening appearing as a longitudinal slit around the level of the first and second pair of legs.

Site of infection: *Demodex* mites are obligate ectoparasites in the skin of mammals, but they live sheltered within hair follicles, sebaceous glands, Meibomian glands and epidermal pits (whilst within the bulk of the skin, they are technically external to the epidermis and are considered ectoparasitic). Over 100 mite species have been described in mammals belonging to 31 families in 12 orders (particularly rodents, but also ungulates, carnivores, insectivores, lagomorphs, bats, and primates). Most mite species were oioxenous, (specific for individual host species) although a few were able to live on other closely-related hosts but not as successfully. A few hosts also had multiple mite species found on them, but they occurred in different sites (exhibited tissue tropism). For example, humans were found to host 2 species: *D. folliculorum* which occurs primarily in the follicular infundibulum of hairs (often in groups of up to 15 mites); and *D. brevis* which is found deeper within the follicle in the sebaceous gland where more oil is produced (usually as solitary mites). Infestations on humans have been found mainly in facial skin (forehead, scalp, cheeks, nose, eyebrows and eyelashes) but occasionally in the external ear canals, chest, nipples, mons veneris, buttocks, and even sebaceous glands in the buccal mucosa. Infestations on livestock and pets generally involve the face (muzzle, eyelids) and neck but may extend to the shoulders, flanks and legs.

Pathogenesis: Mites live embedded head-down in skin follicles and glands using their pincer-like chelicerate mouthparts to puncture epithelial and sebaceous cells to feed on sebum (oil) and cellular debris. In normal healthy hosts, *Demodex* mites occur in low numbers and most infestations are asymptomatic (often to the point that the mites are considered to be commensals rather than parasites). However, under certain conditions (when hosts are stressed or immuno-compromised), heavier infestations may develop causing clinical disease (known as demodicosis or demodectic mange). Feeding mites cause direct damage to the epidermis of hair follicles and glands resulting in inflammation, skin lesions, alopecia and predisposing to secondary bacterial infections. Hosts recognize mite antigens locally or in regional lymph nodes leading to humoral and/or cellular immune responses resulting in either protection or hypersensitivity. Two main types of skin lesions may develop: squamous and pustular lesions. The most common are squamous lesions that appear as dry scaly patches of skin with enlarged and inflamed hair follicles (folliculitis) exhibiting follicular hyperplasia and hyperkeratosis, mononuclear inflammatory cellular infiltrates, irregular thickening of the skin, variable pruritus (often developing secondary to bacterial infections), alopecia (due to follicular apoptosis) and skin pigmentation (increased sun exposure due to alopecia). Papular nodules may also occur when hair follicles or gland ducts become obstructed resulting in cyst-like swellings. The second type of lesions are pustular lesions that occur less commonly but are more severe. They appear as red pustules on thickened wrinkled skin and are the result of ruptured follicles and glands leading to more extensive inflammation with pruritus and secondary bacterial infections (commonly *Staphylococcus* spp.) leading to purulent exudates. In domestic animals, demodicosis is more common in dogs, pigs and goats, but rarer in horses, cats, cattle and sheep. Infestations may cause severe mange in dogs, especially immuno-compromised individuals which often develop concurrent staphylococcal pyoderma and fungal (*Malassezia*) dermatitis due to reduced T-cell function. This renders dogs susceptible to massive mite proliferation leading to generalized skin thickening with corrugations and alopecia. Infestations manifest differently depending on whether they are juvenile-onset (3-18 months of age, exacerbated by puberty and oestrus) leading to localized disease, or adult-onset (> 2 years old, often associated with underlying disease (diabetes, cancer) or immunosuppression (chemotherapy, excessive cortisone) leading to generalized disease. Localized demodicosis usually involves 1-2 areas on the head/limbs with circumscribed scaly lesions and erythematous alopecic areas. The occurrence of pruritus is variable and most localized infestations heal spontaneously. Generalized demodicosis is a more severe condition complicated by secondary bacterial infection (pyoderma) and involves multiple alopecic lesions over the body which frequently coalesce, leading to extensive folliculitis, erythema, comedones, scaling, crusting, plaques, and pruritus. There is often an underlying lymphadenopathy and mites around the ears may cause otitis externa. Mites have occasionally been found in internal tissues (lymph nodes, kidneys, intestinal walls, thyroid gland) after their dissemination by lymph or blood, but they have usually been killed by host responses. Infestations in pigs are frequently associated with papular skin nodules, and those in cats with underlying immuno-suppressive conditions are usually associated with mild localized self-limiting

disease on the head (including the eyelids and external ear canals) and neck. Infested ruminants may develop inflammatory and hypersensitive reactions leading to widespread thickening of the skin, including sebaceous glands which fill with mites and secretions (sometimes becoming caseous). Dermal papules and flat nodules may form on the neck, shoulders, brisket and forelegs, with occasional ulceration, abscess formation, crusting and alopecia occurring in conjunction with follicular rupture and/or secondary bacterial infections. Most infestations on rodents appear to be well tolerated, but those occurring in immunocompromised mouse breeds kept in laboratory animal colonies may progress to cause severe dermatitis with pruritus, alopecia, ulcer and/or abscess formation. The 2 mite species (*D. folliculorum* and *D. brevis*) found in humans are apparently very prevalent with reports suggesting that up to 50-95% of the population may be infested. The vast majority of infestations are asymptomatic, but those occurring in individuals with immuno-deficiencies (genetic or acquired due to chemotherapy, concomitant infections or disease) may contribute to dermatological and ocular conditions. Individuals may develop mild-severe inflammation, with squamous and/or pustular lesions, alopecia, pruritus, blepharitis, and sometimes granuloma formation. Infestations have tentatively been linked to rosacea, acne and perioral dermatitis in some humans. Studies have shown that *Demodex* mites may act as mechanical or biological vectors for the carriage and transmission of microbes causing disease, including the Gram-negative bacterium *Bacillus oleroniensis* associated with rosacea, and the Gram-positive bacteria *Mycobacterium leprae* causing Hansen's disease (leprosy) and *Staphylococcus* spp. causing opportunistic dermal or systemic infections.

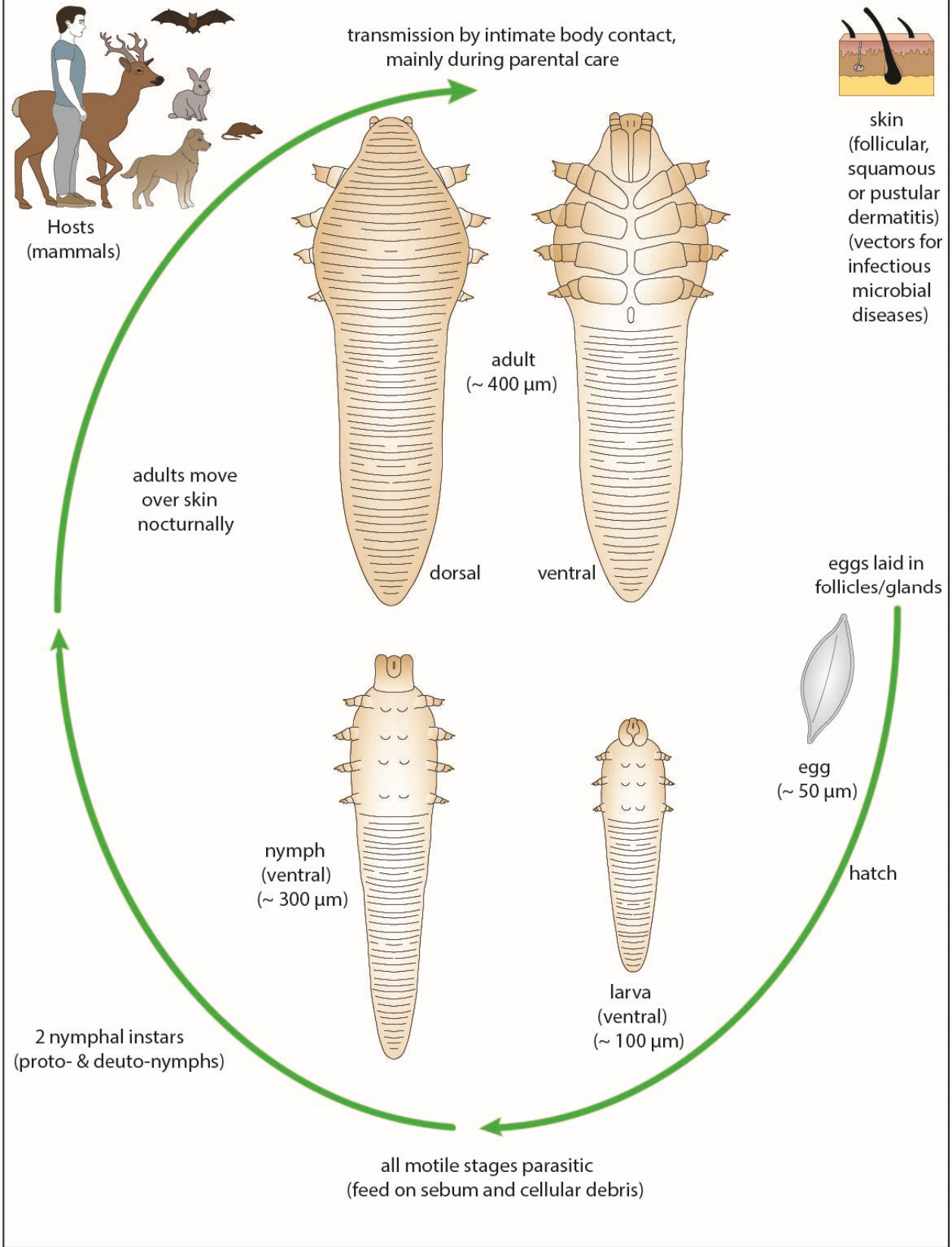
Developmental cycle and mode of transmission: Like all mites, *Demodex* spp. undergo incomplete (hemimetabolous) metamorphosis whereby eggs hatch larva that moult to nymphs and then to adult mites. The entire life cycle takes place within hair follicles and skin glands on the same host, and mites are transmitted between hosts by intimate body contact, predominantly during parental care. Mite eggs are laid in follicles/glands where they hatch after 5 days releasing hexapod (6-legged) larvae. The larvae feed and moult in 2 days to the first nymphal instar (protonymphs) which are usually hexapod (some reports have described a rudimentary fourth pair of legs, while a few have reported them to be octopod (8-legged)). The protonymphs feed in the follicle/gland and then move to the opening around 3 days later to moult to the second nymphal instar (deutonymphs), all described as octopod. The deutonymphs migrate to the surface of the skin and then re-enter follicles/glands to moult after 5 days to form adult mites. The adults are not sedentary but leave follicles/glands onto contiguous skin during the evening in search of mates or other food sources. They have been found to move at 8-16 mm/h during their nocturnal wanderings and they are negatively phototactic retreating back into follicles/glands in the presence of bright light. Mating occurs on the surface of the skin and in openings of follicles/glands. Gravid females then lay 20-40 eggs in follicles/glands, thus completing the whole life cycle in 18-35 days. Adults do not have long lifespans and die soon after mating/oviposition within 5 days. All mite stages are very sensitive to desiccation and are unable to survive off hosts. Transmission between hosts therefore only occurs through direct physical contact (skin-to-skin), particularly from parent to progeny during parental care (nursing, pacifying, cuddling, grooming, sleeping, etc.). Infestations are commonly found in adults as they produce more sebum than infants and some reports indicate that infestations are more common in developing countries due to lax hygienic practices.

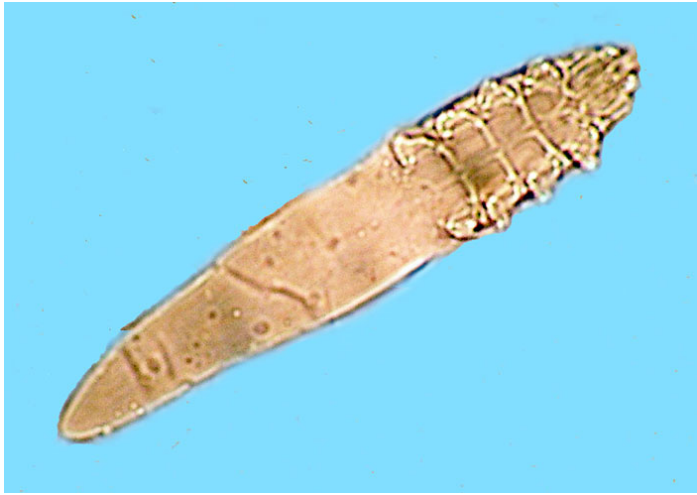
Differential diagnosis: Infestations may be suspected on clinical grounds (squamous or pustular lesions, alopecia), although other aetiological agents may be the culprits and secondary bacterial infections are common in clinical demodicosis. Differential diagnoses are conventionally made by the direct detection of mites in skin samples, particularly deep skin scrapings, and sometimes trichograms (hair plucks). Mites are resistant to caustic agents so skin samples are usually digested in warm 10% potassium hydroxide so sediments can be easily screened for mites using high contrast light microscopy. It is advised that multiple skin scrapings be examined from early primary lesions (follicular papules/pustules) or the periphery of active lesions, that the skin be squeezed before and during scraping, and that the area be scraped until capillary bleeding occurs. Superficial skin scrapings are inadequate, as are sticky-tape impressions or smears of expressed pustule contents. Skin biopsies have occasionally been used in cases where lesions are inaccessible for scraping or plucking (e.g. feet, eyes, ears). More recently, a range of molecular biological techniques have been applied to the diagnosis and characterization of mite species, strains and isolates by polymerase chain reaction (PCR) amplification of nuclear (18S ribosomal RNA, chitin synthase) and mitochondrial (16S ribosomal RNA, cytochrome c oxidase I) gene sequences.

Treatment and control: Most clinical cases of localised demodicosis resolve spontaneously within 6-8 weeks, but more severe or generalized infestations often require treatment with chemical acaricides (miticides). Successful treatments have been reported using sulphur-based preparations (e.g. lime sulphur), natural products (rotenone, tea tree oil), organo-chlorines (lindane (gamma-benzene hexachloride)), organo-phosphates (trichlorfon, malathion, fenchlorphos, phosmet), pyrethroids (permethrin), anilides (crotamiton), carbamates (carbaryl), formamidines (amitraz) and macrocyclic lactones (ivermectin, moxidectin, doramectin or milbemycin). Topical treatments may be improved by clipping the hair beforehand, or using shampoos (e.g. benzoyl peroxide) to clean the skin by removing oil and cellular debris. It is recommended that all animals in contact be treated at the same time and that attention be paid to any drug contra-indications regarding side-effects, toxicity issues and even with-holding periods in the case of meat/milk animals. Treatment often needs to be repeated as recurrences are common, although the use of acaricides with long-lasting residual activity helps to reduce treatment frequency. Generalized infestations may require lengthy and aggressive treatment, usually in conjunction with oral antibiotics and topical antiseptics to eliminate any concurrent pyoderma. Treatment efficacy should be assessed through regular (monthly) skin scrapings, and hosts should be screened for any underlying disorders that may compromise their immune function. The use of glucocorticoids to alleviate inflammation should be avoided as the resultant immuno-suppression may foster

generalized infestations and pyoderma. Animals should be placed on nutritious diets and kept as stress-free as possible to avoid reduced immune functions. Veterinarians may consider neutering severely affected animals as oestrus can precipitate disease. It has also been observed that the development of disease may have a genetic predisposition so breeding from affected animals should be discouraged. While transmission involves intimate body contact between hosts, some simple preventive precautions may help reduce risks, such as regularly washing with soap and water (helps considerably in cases involving blepharitis), maintaining strict hygiene when nursing/suckling, not sharing bedding or towelling, cleaning animal holding facilities (especially those used for breeding) and avoiding situations where skin pores may become blocked (body/facial lotions, cosmetics, cooking oil vapours, etc.).

Demodex





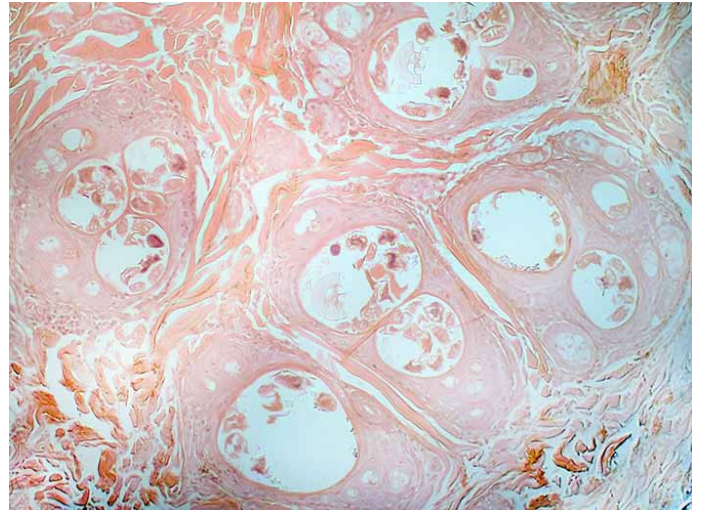
Demodex adult, ventral



Demodex adult, lateral



Demodex nymph



Demodex sections in dog skin