Varroa
(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. Gamesid mites have anterior legs with respiratory stigmata located between the second and fourth legs. Most species are predatory, but some are ectoparasitic on mammals, birds and insects. They usually have a large sclerotized dorsal shield and a series of smaller ventral shields. Varroid mites have flat discoid bodies and feed on haemolymph from bees. Infestations by *Varroa* spp. have been associated with mortalities in honeybees.

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:	Parasitiformes (ticks and some mites, with posterior stigmata)
Order:	Mesostigmata (gamesid mites, legs grouped anteriorly, stigmata between second and fourth legs)
Suborder:	Dermanyssina (sclerotized shields, reduced setae, legs with claws)
Superfamily:	Dermanyssoidea (elongate edentate chelicerae, diverse life-styles)
Family:	Varroidae (bee mites, flat button shape, red-brown colouration, suck haemolymph)
Genus:	*Varroa* (parasitic on cuticle of bees)
Species:	various species cause mortalities in honeybees

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 Parasitiformes comprises acarines with posterior respiratory stigmata and includes two major orders: the ixodid ticks (order Metastigmata) with stigmata located posterior to the legs; and the gamesid mites (order Mesostigmata) where they are located between the legs, sometimes associated with sinuous processes (peritremes). Mesostigmatid mites are further characterized by possessing unbarbed hypostomes, and long legs with free coxae (not fused to the body wall). The order Mesostigmata contains thousands of mites, with over 5,000 species recognized in 660 genera and 100 families. Nine suborders are recognized (Antennophoria, Arctacarina, Cercomegistina, Dermanyssina, Epicriina, Microgyniina, Parasitina, Sejina, and Uropodina). The suborder Dermanyssina contains robust mites with distinct sclerotized dorsal and ventral shields, reduced setae, palps with 2-tined apoteles, and legs with tarsal claws. Five superfamilies are recognized (Ascoidea, Dermanyssoidea, Eviphidoidea, Rhodacaroidea, and Veigaioidea). The superfamily Dermanyssoidea contains a diverse array of mites including free-living predators, nidicoles in the nests of vertebrates and insects, obligate and facultative ectoparasites of vertebrates and arthropods, and even respiratory and auditory endoparasites of mammals, birds, and some reptiles. The mites have elongated chelicerae (long first or second segment) with small edentate digits and concave interior margins (functioning as a tube when in opposition). A total of 11 families are recognized (Dermanyssidae, Haemogamasidae, Halarachnidae, Hirstionyssidae, Ixodorhynchidae, Laelapidae, Macronyssidae, Raillietiidae, Rhinonyssidae, Spinturnicidae, and Varroidae), many of them exclusively parasitic.

The family Varroidae contains relatively large hairy mites that are ectoparasitic on wild and domestic honeybees. The mites possess modified chelicerae (lacking fixed digits), stigmata without peritremal plates, and discoidal bodies with sclerotized dorsal and ventral shields sporting unique patterns of striations and chaetotaxy (setae). Two genera have been differentiated primarily by differences in the dentition of the deutosternal groove (denticles absent in *Varroa,* present in *Euvarroa*) and the occurrence of sternal pores (present in *Varroa,* absent in *Euvarroa*). Mites feed on the fat bodies and haemolymph of bees (pupae and adults) and infestations have been associated with significant bee mortalities and reduced honey production in many countries around the world.

Parasite species	Hosts	Clinical signs	Distribution
Varroa			
V. destructor (parasitic bee mite)	Hymenoptera: apid (*Apis mellifera*, western honeybee; *Apis cerana*, Asian honeybee)	mortalities (plus vector for deformed wing virus, Israeli acute paralysis virus)	worldwide (except Australia)
V. jacobsoni (syn. *V. ricinus, Myrmozercon reidi*)	Hymenoptera: apid (*Apis indica*, Indian honeybee)	mortalities	Asia
V. rindereri	Hymenoptera: apid (*Apis koschevnikovi*, Koschevnikov's honeybee)		Malaysia
V. underwoodi	Hymenoptera: apid (*Apis cerana*, Asian honeybee)		Nepal
Euvarroa			
E. sinhai	Hymenoptera: apid (*Apis florea*, dwarf honeybee)		India, South-East Asia
E. wongsirii	Hymenoptera: apid (*Apis andreniformis*, black dwarf honeybee)		Thailand

Parasite morphology: *Varroa* mites form 3 different types of morphological developmental stages: namely, eggs; nymphs (2 instars); and adults. The eggs are small oval-rounded stages measuring from 0.3-0.5 mm in length and surrounded by a thin milky-white shell. They hatch to release the first nymphal instar (protonymphs) which have circular discoidal bodies measuring 0.4-0.6 mm long. Protonymphs are transparent white in colour and have 4 pairs of short stumpy legs located anteroventrally and a small anterior gnathosoma (head or capitulum) bearing mouthparts with pointed chelicerae. Both male and female stages occur but they are indistinguishable without dissection. Protonymphs moult to form the second nymphal instar (deutonymphs) which are larger (0.5-0.8 mm long) and have oval discoidal bodies. They are cream-tan in colour and have 4 pairs of longer stouter legs and longer mouthparts with pointed chelicerae. In most respects, deutonymphs resemble adult mites but are slightly smaller and have fewer setae. Adult *Varroa* mites have distinctive oval bodies (wider than long) that are flattened ventrally but convex dorsally (while *Euvarroa* mites have broadly triangular bodies that are wider posteriorly). Adults range in dimensions from 1.0-1.8 mm long and 1.5-2.0 mm wide and they exhibit conspicuous sexual dimorphism, with females being larger than males (1.0-1.8 x 1.5-2.0 mm cf. 0.7-1.0 x 0.7-0.9 mm) and females having reddish-brown to dark-brown ovate bodies, while males have yellowish-white spherical bodies with lightly tanned legs. The small anterior gnathosoma lack eyes and bears piercing mouthparts (paired chelicerae and central hypostome) flanked by sensory palps. The palps consisted of 5-6 segments (like other mesostigmatid mites) with the terminal segment bearing an apotele with setae having 2 unequal tines. The basal palpal segments were fused to form a basis capitulum supporting the mouthparts, and the ventral basis capitulum possessed a smooth longitudinal median (deutosternal) groove lacking denticles (whereas the groove in the genus *Euvarroa* had 13-14 small triangular denticles). The chelicerae had 3 segments ending in claw-like chelae with slender movable dentate digits but lacking fixed digits. Male chelicerae become modified at the final moult and change to hollow tubes used to transfer packets of sperm to female mites. The mouth was located ventrally and had a dorsal rostrum, ventral buccal cone, central unbarbed hypostome and a pair of slender horn-like lateral projections (corniculi). The digestive tract included a tubular foregut (oesophagus and pharynx), saccular midgut (ventriculus with gastric caeca), tubular hindgut (with excretory Malpighian tubules) and rectum opening through a terminal anus. The idiosoma possessed heavily sclerotized plates (shields), one dorsal and 3 ventral (sternal, genitoventral, and anal). The single dorsal shield was entire (covering the entire dorsum) and had narrow thickened margins. It was ornamented with an extensive polygonal network of striations and was covered by a dense pattern of setae which were simple or barbed, and stouter around the margins (cf. *Euvarroa* had fewer (47-54) long lanceolate setae). The ventral idiosoma had a weakly-developed bifurcate tritosternum just anterior to the well-developed sternal shield which was strongly curved (inverted-U-shaped) and had 5-6 pairs of setae (3 pairs in *Euvarroa*) and 4-6 pores (absent in *Euvarroa*). The middle genitoventral shield was large and pentagonal-shaped with a rounded anterior margin and more than 10 setae. The posterior anal shield was small and triangular to semicircular with 3 setae (while that of *Euvarroa* was broader). The anteroventral surface of the idiosoma was the point of attachment for 4 pairs of stout legs which usually exhibited a distinctive configuration, the forelegs being thinner and projecting forwards, while the remaining pairs were stouter and curved laterally. Each leg consisted of 6 segments (coxa, trochanter, femur, genu, tibia, and tarsus) and ended in a short stalked pretarsus with an expanded apparatus (ambulacrum) bearing paired claws and a central empodium (pad-like pulvillus). Adult mites had a pair of respiratory stigmata located laterally between coxae III and IV with strongly looped peritremes directed posteriorly or laterally near coxae IV. Mature males had paired testes with tubular vas deferens leading to the ejaculatory duct and sheathed aedeagus. The male genital opening (gonopore) was located anteriorly near the sternal shield and males used modified mouthparts used to transfer packets of sperm to females. Mature female mites had 2 ovaries (with ovarioles) joined by tubular oviducts to a globular uterus (with accessory shell-glands) and vagina (with accessory bursa copulatrix and spermathecae for sperm reception and storage). The female gonopore was located on the genitoventral shield approximately level to the bases of the third pair of legs.

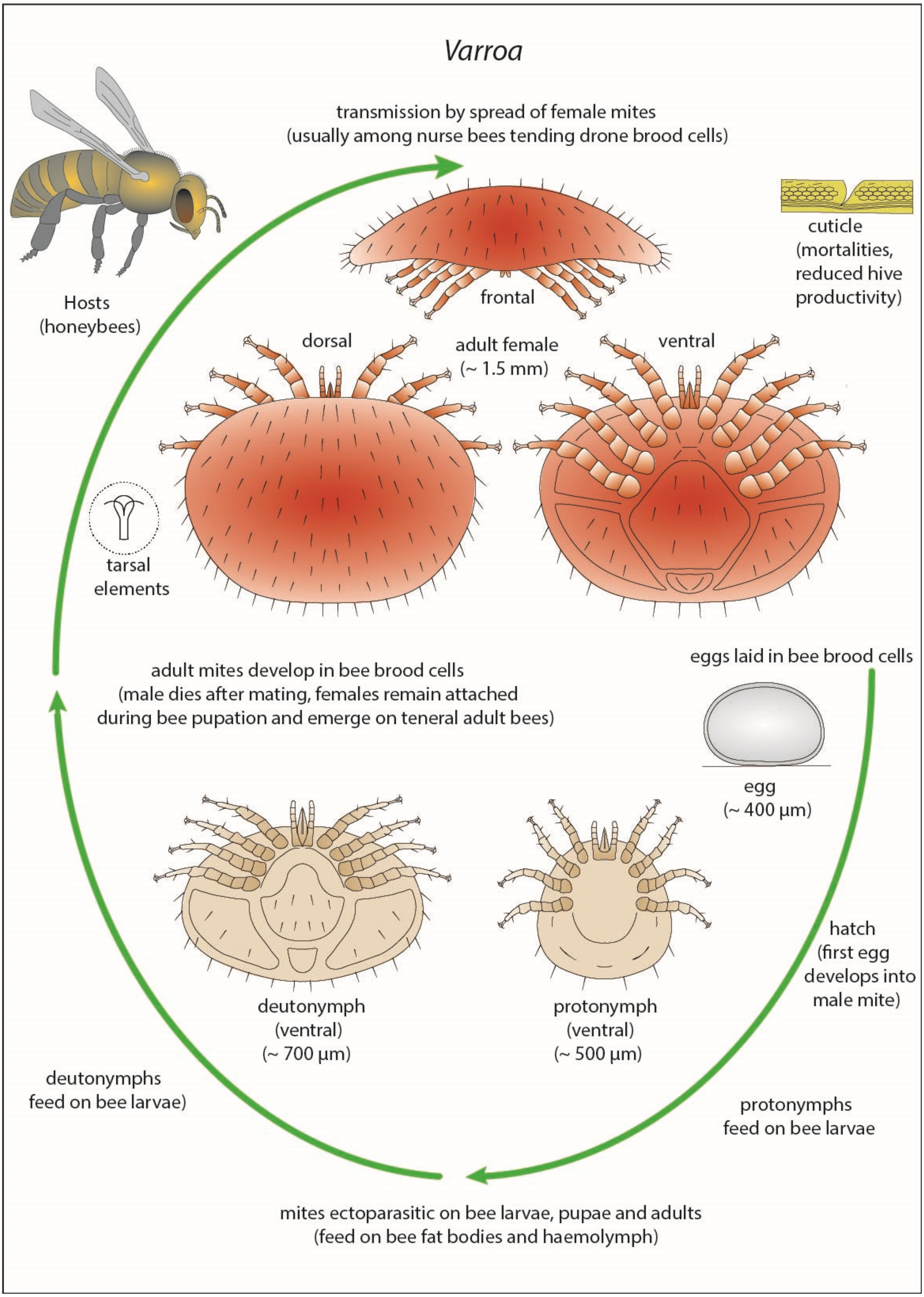
Site of infection: Bee mites are obligate ectoparasites of honeybees *Apis* spp., with adult mites attaching to the abdomen between ventral sclerites, particularly the underside of the metasoma. Their flat domed bodies fit well into abdominal folds of the adult bee and they are held fast by their abundant setae. Nymphal stages of the mites are mainly found in brood cells on bee larvae, pupae or developing adults, particularly on drones. Four *Varroa* spp. have been described from 4 honeybee species, with infestations usually being quite host specific. Another 2 species infesting dwarf honeybees have been allocated to the sister genus *Euvarroa* on the basis of differences in parasite morphology (sclerotization, chaetotaxy) and biology (host specificity and biogeography).

Pathogenesis: The species *V. destructor* originally infested *Apis cerana* (eastern or Asian honeybee) which over time evolved natural defenses to infestations (via more efficient grooming, brood hygiene (removal of infested pupae) or physiological resistance mechanisms). In the mid-1900s, however, this mite species expanded its host range to *A. mellifera* (western honeybee) which did not have a co-evolutionary history and had not developed natural defenses. These bees are more commonly used throughout the world for crop pollination, and infestations have now become almost cosmopolitan in distribution. Many countries impose strict quarantine procedures to lessen the chances of mite importation as *V. destructor* is considered to be a devastating pest for apiaries in particular and horticulture in general. Infestations have pronounced economic impacts on the beekeeping industry through mortalities, lost production and increased maintenance costs. Mites tend to invade colonies in summer leading to high mite populations in autumn which can cause a crisis when drone rearing ceases and mites are forced to switch to worker larvae, precipitating rapid population crashes and even hive death. *Varroa* mites have piercing mouthparts that are used to feed on fat body tissues, and possibly extracellular fluid (haemolymph), in immature and adult honeybees. Bees have large fat body reserves just beneath the cuticle of the ventral metasoma which is a major predilection site for feeding mites. Fat bodies are nutrient-rich stores essential for many physiological functions, including energy regulation, hormone production, immune responses and even pesticide detoxification. Adult honeybees only become infested by female mites, whereas bee larvae, pupae and young adults still in brood cells may be infested by nymphal and adult mites of both sexes. Adult bees are rarely killed but they do lose weight and become weakened with impaired flying and navigational abilities, and generally have shorter lifespans (infested bees are absent from the hive more frequently). Most infestations in brood cells do not compromise bee pupation and eclosion, but the presence of numerous mites in a brood cell can result in larval or pupal death (disease condition called varroosis, or varroatosis). Pathogenicity is correlated to the intensity of brood cell infestation - the more mother mites (or foundresses) in a cell, the less likely the immature bee will develop successfully and emerge as an adult. Infestations are also thought to suppress innate immune responses in bees, thus predisposing them to a range of concomitant infections. Adult mites are highly motile and move between bees leaving open wounds, thus making them efficient vectors for the transmission of debilitating viral pathogens, including deformed-wing virus, acute bee-paralysis virus, Kashmir bee virus, black queen cell virus and possibly many more.

Developmental cycle and mode of transmission: *Varroa* spp. undergo incomplete (hemimetabolous) metamorphosis in which eggs hatch protonymphs that moult to deutonymphs and then to adults. The mites only reproduce when honeybee brood is present in hives. Honeybees reproduce using hexagonal brood cells constructed of waxy matrix in which the queen bee deposits eggs that hatch in 3 days. The emergent bee larvae feeds on brood food placed in the cell and worker bees close the cell with a waxy cap once the larvae reach a certain age. The encased larvae develop into prepupae and then pupae in which complete metamorphosis occurs forming adult bees which eclose after several weeks (16, 21 or 24 days for queen bees, worker bees and drone bees). The bee mites use these brood cells for their own reproductive purposes. Mated female mites (called mother mites or foundresses) enter brood cells containing mature bee larvae just before they are capped. The mites move to the bases of the cells and submerge themselves in the brood food. When the cells are capped, the bee larvae consume the rest of the brood food thus freeing the mother mites. The mites climb onto the bee larvae and begin feeding intermittently on haemolymph and fat body tissues. The mother mites then begin laying up to 5-6 mite eggs in the brood cell, the first egg being unfertilized and deposited after 60-70 hours, whereas the remaining eggs are fertilized and deposited every 25-30 hours thereafter. The first egg always develops into a male mite, while all subsequent eggs develop into daughter female mites. The long interval between the deposition of individual eggs means that mites at different stages of development will occur in the one cell. The mite eggs hatch within 12 hours releasing protonymphs that feed on the bee larvae, often at the same site as the mother mite. The protonymphs moult to form larger deutonymphs which also feed and then moult to form adult mites. It takes about 5–6 days for male mites to develop and 7–8 days for female mites to develop. Mating occurs in the brood cell, with the single male mite mating with his sisters (usually producing 1-2 mated daughter mites in worker bee brood cells, and 2-3 mated daughter mites in drone bee brood cells which take longer to mature). Male mites then die inside the brood cell shortly after mating, and mated female mites undergo reproductive modifications that prevent further mating. When the newlyformed adult bee emerges from the brood cell, the mother mite and her young daughter mites also leave, often on the emerging bee, and spread to other bees. Female mites are highly mobile and readily transfer between adult bees to attach and feed on fat bodies and haemolymph (often called 'phoretic' mites). They usually attach to young worker bees tending brood cells (i.e. nurse bees) for several weeks until brood cells of a suitable age become available for them to detach and enter in order to reproduce. Because nurse bees spend more time tending drone brood cells that take longer to mature than worker bee brood cells, many more drone cells become infested with mites (10-12 times more frequently). When the bee colony is not breeding and brood cells are absent, female mites may survive attached to adult bees for 2-3 months (sometimes over-wintering for up to 5 months). However, female mites do not survive long away from host lasting only up to 5 days without food. Because mites are mobile and regularly seek hosts by crawling over combs, infestations may spread between bee colonies during normal apiary management practices when infested hives, equipment and bees (brood, queens and adults) are interchanged. Infestations are not spread in honey, but they may be spread during other normal bee behaviours, including brood nursing, comb construction and repair, foraging, swarming, robbing (taking nectar from other hives) and drifting (entering another hive by mistake). In the case of foraging, mites have been known to move onto flowers and then attach to other bees or insects visiting the same flower. Mites have been found incidentally on some bumble bees, flower flies, wasp larvae and scarab beetles, but their role in any phoretic transfer remains speculative. Mite population dynamics exhibit exponential growth when bee broods are available, and exponential decline when broods are absent. Various factors have been found to affecting mite population growth, including geographic location and climate (temperature, photoperiod), bee colony strength (species, vitality, innate resistance), and the incidence of other pests/pathogens (especially viruses). Mite populations grow faster in warmer regions where broods are available year-round, and slower in cooler areas where brood are not present over-winter. Mites weaken and kills colonies typically by out-reproducing their hosts. Bee populations usually peak in spring-summer with a steady decline thereafter, while mite populations follow suit but offset by a number of weeks. This means mite populations are peaking when bee populations are declining, thus precipitating colony collapse.

Differential diagnosis: Infestations are diagnosed by the direct detection of mites on bees or in hives using a range of examination techniques. Visual examination of adult bees may readily reveal reddish-brown mites attached to the abdomen or crawling over the body, although some think that the stress of bee capture and sedation may encourage mites to detach and drop off. Close inspection of bee brood, especially drones, may reveal dark mites on white developing bee stages. Authorities recommend regular screening of colonies (at least quarterly) to facilitate prompt action, and there have been several suggestions to adopt quantitative diagnostic methods, the most popular being sticky screens, ether rolls, or sugar shakes. Sticky screens involve coating pieces of cardboard in vaseline or petroleum jelly, covering them with fine-wire mesh (3 mm) and placing them under combs for 1-3 days to collect any dislodged mites (technique therefore samples from whole colony rather than from a small subset of bees). Ether rolls involve placing around 300 bees in a glass jar, spraying with ether and rolling the jar so dislodged mites adhere to the inside walls of the jar. Sugar shakes involve placing about 300 bees in a jar with a tablespoon of powdered sugar (icing sugar), gently shaking for several minutes and then tipping out the sugar onto white paper or dissolving it in water to reveal dislodged mites. Other variations involve submerging dead bees in alcohol (70% or higher) and then examining the washings for mites. A range of molecular biological techniques have been used to detect and characterize mite species and populations by polymerase chain reaction (PCR) amplification of random amplified polymorphic DNA (RAPD) or nuclear (18S ribosomal RNA) and mitochondrial (12S and 16S ribosomal RNA, cytochrome oxidase) gene sequences. Next generation sequencing has also been used to determine the while nuclear and mitochondrial genome, thus facilitating proteogenomic studies on proteins differentially expressed across developmental stages and following various acaricidal treatments.

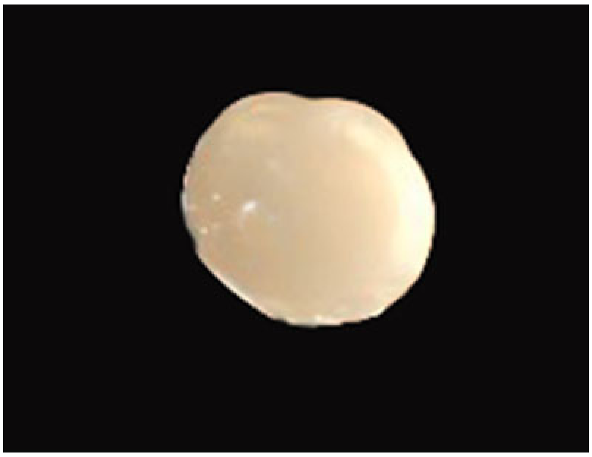
Treatment and control: Traditionally, infestations in bee hives have been controlled by the application of chemical acaricides (miticides) as fumigants (vapours released from strips, pads, gels), sprays (water or oil based), powders or in medicated food sources (sugars). Variable successes have been reported following treatments with organophosphates (coumaphos), pyrethroids (fluvalinate), amidines (amitraz), organic acids (oxalic acid, formic acid, beta acid) and mineral oil or essential oils (lemon, mint, thyme). Careful attention should be paid to any treatment contra-indications to minimize the contamination of honey and prevent any side-effects that may include reduced longevity and fecundity of queen bees and/or drones. Regrettably, there are growing numbers of reports of mite populations developing resistance to pyrethroid and organophosphate acaricides, particularly those used as general insecticides in horticulture to which bees may be exposed (e.g. sprays used in orchards, gardens, etc). An alternative treatment strategy that yielded variable results was the application of powdered sugar or talcum powder (grain size 5-15 μm) to bees which apparently interfered with mite respiration. There have also been numerous suggestions for non-chemical (physical) methods to control mite populations, mostly by changing beehive architecture and comb maintenance. The installation of perforated bottom boards or open screen floors (3 mm holes or mesh) in hives so that dislodged mites fall through has been credited with 10-20% reductions in mite populations, particularly if glue traps or sticky boards are also included so that mites do not crawl back into the hive. Experimental studies have shown that heating hive frames to at least 40 C for several hours causes mites to drop from bees, and several ventures are currently exploring engineering options. Mite populations have also been reduced by manipulating bee broods by the regular removal of capped broods every 9 days for several cycles, by selectively excising drone broods (identified at the 'purple-eye' stage of development along the bottom and outer margins of frames) or by removing and freezing capped broods for 48 hours (which kills both drones and mites). While these methods change both bee population dynamics (numbers) and kinetics (time course), nurse bees clean out dead brood, drones are usually in excess and queen bees replace lost brood. Government agencies in many countries have declared *Varroa* mite infestations as notifiable diseases with specific courses of action to be undertaken in the event of outbreaks, including strict quarantine, compulsory treatment and even hive destruction. Sentinel bee populations have also been established for biosecurity purposes near possible points of ingress, notably airports and wharves. Beekeepers are urged to practise good sanitation and hygiene by obtaining brood stock from reputed pest-free sources, regularly disinfecting hives and equipment using hot washing soda or hypochlorite bleaches, and regularly inspecting and replacing brood combs. There have been several interesting developments in bee breeding programmes, with encouraging results obtained breeding from bees with enhanced grooming behaviours (self- and allo-grooming), heightened brood hygiene (better able to detect problems with brood even if capped, and abort the affected brood), and bee strains that have developed a general resistance or tolerance to mites (e.g. bees from endemic Russian regions have greater resistance/tolerance). Recent molecular biological studies have also begun to examine the possibility of using RNA interference techniques to knock out genes in *Varroa* mites.



Varroa
transmission by spread of female mites
(usually among nurse bees tending drone brood cells)
Hosts
(honeybees)
frontal
cuticle
(mortalities,
reduced hive
productivity)
dorsal
adult female
(~ 1.5 mm)
ventral
tarsal
elements
adult mites develop in bee brood cells
(male dies after mating, females remain attached
during bee pupation and emerge on teneral adult bees)
eggs laid in bee brood cells
egg
(~ 400 μm)
hatch
(first egg
develops into
male mite)
deutonymph
(ventral)
(~ 700 μm)
protonymph
(ventral)
(~ 500 μm)
deutonymphs
feed on bee larvae)
protonymphs
feed on bee larvae
mites ectoparasitic on bee larvae, pupae and adults
(feed on bee fat bodies and haemolymph)

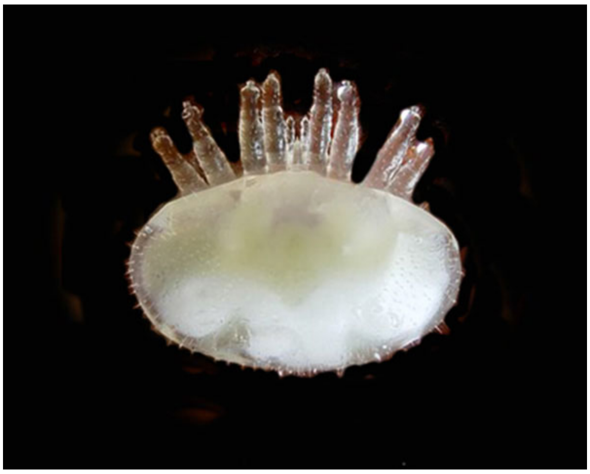
Varroa adult on bee pupa

Varroa adult



Varroa egg

Varroa protonymph



Varroa deutonymph