

Nosopsyllus
(insect: flea)

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. Insects are hexapods with three pairs of uniramous legs, three tagmata (head, thorax, abdomen), ectognathous mouthparts with whole-limb mandibles, and one pair of antennae. Siphonaptera (fleas) are bilaterally-flattened wingless insects whose hindlimbs are enlarged and specially adapted for jumping (using elastic resilin pads rather than muscles). Fleas are holometabolans and undergo complete metamorphosis whereby grub-like larvae form pupae from which adult fleas emerge. The larvae are not parasitic but feed on debris associated mainly with bedding, den or nest material, whereas the adult stages are parasitic and feed on host blood. Ceratophyllid fleas occur as ectoparasites on small rodents and birds, many being associated with nest habitats so adult fleas are transient parasites. Infestations by *Nosopsyllus* spp. have been associated with irritation, pruritus and allergic dermatitis in small mammals (esp. rodents) and birds.

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: Hexapoda (three tagmata, three pairs uniramous legs, whole-limb mandibles, Malpighian tubules)
Class: Insecta (ectognathous mouthparts (bases lie outside head capsule), single pair antennae, many with wings)
Superorder: Holometabola (Endopterygota) (young do not resemble adults, pupae, with internally developing wings)
Order: Siphonaptera (fleas, wingless, laterally compressed, third pair of legs adapted for jumping)
Family: Ceratophyllidae (parasites of small rodents and birds)
Genus: *Nosopsyllus* (parasitic on skin of rats)
Species: various species cause allergic dermatitis

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. Insects are hexapods with six legs, three distinct body parts, two antennae and mouthparts with whole-limb mandibles. Insects are the most biodiverse group on the planet, with millions of species described in numerous taxa. Notorious ectoparasitic species belong to four orders in two superorders: the Hemipteroidea (Exopterygota) containing the orders Hemiptera (bugs) and Phthiraptera (lice); and the Holometabola (Endopterygota) containing the orders Siphonaptera (fleas) and Diptera ('true' flies). Fleas are small wingless insects that undergo complete (holometabolous) metamorphosis with vermiform larvae undergoing pupation in silk cocoons. The adults are ectoparasitic and use siphon-like mouthparts to feed on blood from warm-blooded vertebrates [the name 'Siphon-aptera' literally translates as 'siphon' and 'wingless']. All adult fleas are further characterized by having laterally compressed bodies (allowing movement through hair/feathers), backward-pointing hairs and bristles (resisting grooming by host), strong tarsal claws (for grasping), and enlarged hindlegs (adapted for jumping). Around 2,200 flea species have been described in 250 genera on the basis of morphological and biological differences, and recent molecular phylogenetic studies have indicated some 18 families may occur in 4 infra-orders.

Siphonapteran families	Biodiversity	Hosts	Characters	Biogeographical distribution
Infraorder: Pulicomorpha (compact body, small thorax, pronotum with entire undivided ventral margin)				
Pulicidae (common fleas)	22 genera 207 species	carnivores, lagomorphs, rodents, artiodactyls, birds	sensillum with at most 14 pits, coxa with spiniform setae	pan-Tropical, cosmopolitan
Tungidae (sand fleas)	5 genera 23 species	rodents, insectivores, bats, suids, humans, birds	compression of 3 thoracic segments, neosomy	Neotropical, Holarctic
Vermipsyllidae	3 genera 39 species	carnivores, pikas, ungulates	frontal tubercle, large spiracles, reduced tergites	Holarctic
Ancistropsyllidae	1 genus 3 species	artiodactyls	metanotum and abdominal tergites with spinelets	Oriental
Coptopsyllidae	1 genus 19 species	rodents	combless, 2 spermathecae, tergal spinelets absent	Southern Palaeartic
Malacopsyllidae	2 genera 2 species	insectivores	high mesonotum, metanotum without spinelets	Patagonian
Rhopalopsyllidae	14 genera 126 species	rodents, insectivores, birds	metanotum and abdominal tergites with spinelets	Neotropical, Australasian
Infraorder: Ceratophyllomorpha (elongate body, long thorax, head without intergenal process, interantennal dimorphism)				
Ceratophyllidae	47 genera 540 species	rodents, pikas, carnivores, insectivores, birds	genal combs absent, males with interantennal suture	cosmopolitan
Ischnopsyllidae (bat fleas)	20 genera 125 species	bats	genal comb with 2-4 flattened spines, interantennal furrow	cosmopolitan
Leptopsyllidae	29 genera 260 species	insectivores, lagomorphs, rodents, carnivores, birds	head with tentorial arch, males with interantennal suture	Holarctic, Australasia
Xiphlopsyllidae	1 genus 8 species	rodents, shrews	squamulum absent, simple interantennal wall	Eastern African
Infraorder: Hystrichopsyllomorpha (elongate body, long thorax, head with intergenal process, clasper without process)				
Chimaeropsyllidae	8 genera 26 species	rodents, shrews	sensillum with 14 pits, hind coxa with spiniform setae	African
Hystrichopsyllidae (nest fleas)	46 genera 582 species	rodents, insectivores, pikas, marsupials	highly variable structures, 2 spermathecae	cosmopolitan
Macropsyllidae	2 genera 2 species	rodents	single head comb, 4 abdominal combs, 2 spermathecae	Australian
Stephanocircidae (helmet fleas)	9 genera 51 species	rodents, marsupials, birds	helmet (frons) with 2 separate combs, single spermatheca	Neotropical, Australian
Infraorder: Pygiopsyllomorpha (elongate body, long thorax, head with intergenal process, metanotum without spinelets)				
Pygiopsyllidae	10 genera 48 species	rodents, marsupials, birds	unique articulation between digitoid and main part of clasper	Australasian, Neotropical
Lycopsyllidae	4 genera 8 species	marsupials	genal lobe, simple interantennal wall, single mesopleural rod	Australian
Stivaliidae	23 genera 110 species	rodents, marsupials	strongly developed basal arm of Y-sclerite	Palaeartic, Australasia

Fleas from several families are found as ectoparasites on domestic and companion animals around the world: particularly those belonging to the families Pulicidae and Tungidae on mammals, and the family Ceratophyllidae on birds. Ceratophyllid fleas are characterized by their elongate laterally-compressed bodies, the absence of genal combs but the presence of pronotal combs. Some 45 genera have been identified in 2 subfamilies: Ceratophyllinae (*Aenigmopsylla*, *Aetheca*, *Amalaraeus*, *Amaradix*, *Amphalius*, *Baculomeris*, *Brevictenidia*, *Callopsylla*, *Ceratophyllus*, *Citellophilus*, *Dasyopsyllus*, *Eumolpianus*, *Glaciopsyllus*, *Hollandipsylla*, *Igioffius*, *Jellisonia*, *Kohlsia*, *Libyastus*, *Macrostylophora*, *Malaraeus*, *Margopsylla*, *Megabothris*, *Megathoracipsylla*, *Mioctenopsylla*, *Myoxopsylla*, *Nosopsyllus*, *Opisodasys*, *Orchopeas*, *Oropsylla*, *Paraceras*, *Paramonopsyllus*, *Pleochaetis*, *Plusaetis*, *Rostropsylla*, *Rowleyella*, *Smitipsylla*, *Spuropsylla*, *Syngenopsyllus*, *Tarsopsylla*, *Thrassis*, *Traubella*, *Psittopsylla*) and Dactylopsyllinae (*Dactylopsylla*, *Foxella*, *Spicata*). Species from several genera are considered to be serious pests of domestic poultry and companion animals, while the remainder infest a wide range of wild animals.

Genera	No. spp.	Hosts	Ctenidia (combs)		Disease	Vector
			Genal (head)	Pronotal (thorax)		
Ceratophyllidae						
<i>Nosopsyllus</i>	52	rodents, carnivores, some birds	absent	present	irritation	plague, erysipeloid, rat tapeworm
<i>Ceratophyllus</i>	64	birds, rodents, carnivores, ungulates	absent	present	irritation, reduced productivity	
Pulicidae						
<i>Pulex</i>	12	humans, carnivores, marsupials, rodents, birds	absent	absent	irritation, dermatitis, anaemia	plague, typhus, spotted fevers, tapeworms
<i>Echidnophaga</i>	23	birds, rodents, carnivores, marsupials	absent	absent	inflammation, ulceration	rickettsioses, plague, myxomatosis
<i>Xenopsylla</i>	76	rodents, carnivores, marsupials, birds	absent	absent	irritation	plague, typhus, rat tapeworms
<i>Ctenocephalides</i>	12	carnivores, rodents, rabbits, insectivores, ungulates, birds	horizontal	present	pruritus, anaemia, hypersensitivity (flea-bite allergy)	bartonellosis, typhus, plague, dog tapeworm, filarial nematode
<i>Spilopsyllus</i>	1	rabbits, rodents, carnivores, birds	vertical	present	irritation	myxomatosis, tularemia
Tungidae						
<i>Tunga</i>	13	humans, insectivores, rodents, carnivores	absent	absent	inflammation, ulceration	<i>Staphylococcus</i> , <i>Wolbachia</i> , tetanus

The genus *Nosopsyllus* contains some 54 species allocated to 4 subgenera: namely, *N. (Nosophyllus)* with 32 spp., *N. (Gerbillophilus)* with 17 spp., *N. (Nosinius)* with one sp., and *N. (Penicus)* with one sp. (the remaining species are unplaced). These fleas were described from a range of rodents, mostly small terrestrial murine or cricetine species distributed throughout Palaearctic and Oriental regions, occasionally Africa. Several species are now cosmopolitan in their distribution due to their transport on synanthropic rodents and their dispersal through human activities. In particular, the northern rat flea, *N. fasciatus*, is found on domestic rats and house mice throughout North America and Europe, but has now become common in most temperate regions where it may infest wild rodents, and sometimes feed on humans.

<i>Nosopsyllus</i> species	Hosts	Clinical signs	Distribution
<i>N. (G.) abramovi</i>	Rodentia: murid (Tamarisk jird, Libyan jird, gerbil)		Central Asia
<i>N. aegaeus</i>	Rodentia: murid (black rat, eastern broad-toothed field mouse)		Europe
<i>N. afghanus</i>	Rodentia: murid (midday jird, Libyan jird)		Asia
<i>N. (N.) alladinis</i>	Rodentia: sciurid (Indian palm squirrel)		India
<i>N. (N.) antakyaicus</i>	Rodentia: cricetid (Gunther's vole, Turkish hamster)		Asia
<i>N. apicoprominus</i>	Rodentia: murid (midday jird)		China
<i>N. (G.) aralis</i>	Rodentia: murid (Tamarisk jird, midday jird)		Russia
<i>N. (N.) arcotus</i>	Rodentia: sciurid (Indian palm squirrel)		India
<i>N. (N.) argutus</i>	Rodentia: murid (house mouse), sciurid (Indian palm squirrel)		India
<i>N. (N.) atlantis</i>	Rodentia: sciurid (Barbary ground squirrel)		North Africa
<i>N. (G.) baltazardi</i>	Rodentia: murid (great gerbil, Libyan jird)		Middle-East
<i>N. (N.) barbarus</i>	Rodentia: murid (house mouse, black rat, Barbary striped grass mouse); Eulipotyphla: soricid (Osorian shrew)		North Africa
<i>N. (G.) bunni</i>	Rodentia: murid (Sundevall's jird), dipodid (lesser Egyptian jerboa)		Middle-East
<i>N. (N.) ceylonensis</i>	Rodentia: sciurid (Indian palm squirrel)		India
<i>N. chayuensis</i>	host unknown		China
<i>N. (N.) consimilis</i>	Rodentia: cricetid (social vole, European water vole), murid (wood mouse)		Russia
<i>N. (N.) durii</i>	Rodentia: cricetid (social vole, Gunther's vole, Persian vole)		Middle-East
<i>N. (N.) elongatus</i>	Rodentia: murid (black rat)		China
<i>N. (G.) eremicus</i>	Rodentia: murid (Sundevall's jird)		Afghanistan
<i>N. (N.) farahae</i>	Rodentia: cricetid (social vole)		Middle-East

<i>N. (N.) fasciatus</i> (syn. <i>Ceratophyllus fasciatus</i>) (northern rat flea)	Rodentia: murid (black rat, brown rat, bush rat, Australian swamp rat, rakali, house mouse, yellow-necked mouse, wood mouse, Eurasian harvest mouse), cricetid (bank vole, short-tailed field vole, common vole, Cabrera's vole, golden hamster), sciurid (eastern grey squirrel, red-bellied tree squirrel); Eulipotyphla: erinaceid (European hedgehog), soricid (common shrew, lesser white-toothed shrew), talpid (European mole); Dasyuromorphia: dasyurid (eastern quoll); Lagomorpha: leporid (European rabbit, European hare); Artiodactyla: bovid (sheep); Carnivora: felid (cat), canid (dog, red fox), mustelid (stoat, ferret, least weasel, European polecat, American mink); Primates: hominid (human); Columbiformes: columbid (stock dove); Passeriformes: fringillid (common chaffinch), motacillid (meadow pipit), passerid (house sparrow), troglodytid (Eurasian wren)	pruritus, allergic dermatitis (+ vector for rat tapeworm, rat trypanosome)	worldwide in temperate zones
<i>N. (N.) fidus</i>	Rodentia: murid (house mouse, rat)		Central Asia
<i>N. (N.) geneatus</i>	Rodentia: murid (spiny mouse, golden spiny mouse)		Middle-East
<i>N. (G.) henleyi</i>	Rodentia: murid (Libyan jird, Tristram's jird, North African gerbil)		Middle-East
<i>N. (N.) incisus</i>	Rodentia: murid (common rufous-nosed rat, thicket rat, vlei rat, brush-furred mouse)		Africa
<i>N. (G.) iranus</i>	Rodentia: murid (Libyan jird, Tristram's jird, Vinogradov's jird, Sundevall's jird, Wagner's gerbil)		Middle-East
<i>N. (G.) laeviceps</i>	Rodentia: murid (Libyan jird, great gerbil), cricetid (northern mole-vole, Brandt's vole)		Asia
<i>N. (N.) londiniensis</i>	Rodentia: murid (black rat, brown rat, African grass rat, house mouse, wood mouse, silky mouse, New Holland mouse); Dasyuromorphia: dasyurid (fat-tailed dunnart); Diprotodontia: petauroid (honey possum); Carnivora: felid (cat), canid (dog)		Eurasia, Middle-East, Australia
<i>N. (G.) maurus</i>	Rodentia: murid (jird)		North Africa
<i>N. (N.) medus</i>	Rodentia: murid (black rat, brown rat, house mouse)		Middle-East
<i>N. (N.) mikulini</i>	Rodentia: murid (Libyan jird, Persian jird), cricetid (grey dwarf hamster)		Central Asia
<i>N. (N.) mokrzecky</i>	Rodentia: murid (house mouse, black rat), cricetid (grey dwarf hamster)		Russia
<i>N. (G.) monstrosus</i>	Rodentia: murid (jird, great gerbil)		Central Asia
<i>N. (N.) nicanus</i>	Rodentia: murid (black rat, brown rat, striped field mouse)		Asia
<i>N. (N.) nilgiriensis</i>	Rodentia: murid (black rat)		India
<i>N. (G.) oranus</i>	Rodentia: murid (Shaw's jird, gerbil)		North Africa
<i>N. (N.) philippovi</i>	Rodentia: cricetid (grey dwarf hamster, common vole); Lagomorpha: ochotonid (Afghan pika)		Central Asia
<i>N. (G.) pringlei</i>	Rodentia: murid (Wagner's gerbil, Sundevall's jird)		Middle-East
<i>N. (G.) pumilionis</i>	Rodentia: murid (Balochistan gerbil, Wagner's gerbil, Tristram's jird)		Middle-East
<i>N. (N.) punensis</i>	Rodentia: sciurid (Indian palm squirrel)		India
<i>N. (N.) punjabensis</i>	Rodentia: murid (house mouse, Turkestan rat, short-tailed bandicoot rat, Indian gerbil)		Palaearctic
<i>N. (N.) sarinus</i>	Rodentia: murid (house mouse, Tristram's jird), cricetid (Gunther's vole, grey dwarf hamster)		Middle-East
<i>N. (N.) simla</i>	Rodentia: murid (house mouse, field mouse, Turkestan rat); Eulipotyphla: soricid (Asian house shrew)		Palaearctic
<i>N. (N.) sinaiensis</i>	Rodentia: murid (lesser Egyptian gerbil)		Egypt
<i>N. (N.) sincerus</i>	Rodentia: cricetid (Gunther's vole), spalacid (Middle-East blind mole-rat)		Middle-East
<i>N. (N.) tamilanus</i>	Rodentia: murid (black rat)		Sri Lanka
<i>N. (G.) tersus</i>	Rodentia: murid (great gerbil)		Russia
<i>N. (G.) turkmenicus</i>	Rodentia: murid (Persian jird, Libyan jird, midday jird, great gerbil)		Central Asia
<i>N. (N.) vauceli</i>	Rodentia: murid (soft-furred rat)		India
<i>N. (G.) vlasovi</i>	Rodentia: murid (jird, great gerbil)		Central Asia
<i>N. (N.) wualis</i>	Rodentia: murid (roof rat)		China
<i>N. (G.) ziarus</i>	Rodentia: murid (Persian jird, great gerbil)		Middle-East

Parasite morphology: These rodent fleas form 4 different types of stages during their developmental cycles; namely, eggs, larvae, pupae and adults. Eggs are ovoid stages measuring up to 0.5-0.6 mm long and have a white translucent appearance. Larvae are elongate vermiform (worm-like) stages which develop through 3 instars growing from 0.5-3.0 mm long. They are eruciform with cylindrical bodies with darker sclerotized heads containing powerful mandibles and mandibular teeth adapted for biting and chewing. They have 13 segments, each with prominent bristles projecting posteriorly. Mature larvae form silken ellipsoidal cocoons around 2 mm long which are sticky and become covered with particulate matter from the surrounding environment. The enclosed stages have lost the larval head and last 3 segments and the body has become compressed (shorter and wider). Although covered by debris, the pupae are exarate as their appendages are free from the body wall (in contrast to many other insects which form obtect pupae whose appendages are fused to the body wall). The emergent adults have elongated laterally-flattened bodies measuring 3-4 mm in length, although the females of a few species may grow up to 9 mm long. Adults fleas are usually shiny brown in appearance and have heavily chitinized plates (sclerites) adorned with numerous strong setae, spines and bristles facing backwards so they do not hinder forward movement of the flea through the pelage. In particular, *Nosopsyllus* spp. have distinctive horizontal pronotal ctenidia, i.e. comb-like rows of 9-10 spines on each side of the first thoracic segment (they lack genal ctenidia which are present on *Ctenocephalides* and *Spilopsyllus* spp.). The head has a rounded forehead (frons) with a small frontal tubercle conspicuous on both sexes. The frons is integricipit (without an interantennal suture) and contains a pair of short 3-segmented club-like antennae located in protective grooves (fossae). A pair of small simple noncompound eyes (clusters of ocelli) are located below the antennae but above rows of 3 stout setae. Adults have ventral piercing-sucking mouthparts (lacking mandibles and teeth) located between 2 pairs of sensory palps (4-segmented maxillary palps and 5-segmented labial palps). The mouthparts (fascicle) consist of 3 long slender stylets: the 2 outer stylets (maxillary laciniae) appearing as serrated blades and the third central stylet (labrum-epipharynx) being an outgrowth of the body wall (unique to fleas). All 3 stylets join to form a tube-like canal to inject saliva (via salivary pumps) and suck blood (via cibarial and pharyngeal pumps). The alimentary tract consists of a tubular foregut (anterior pharynx, salivary glands inserted apically, elongate oesophagus, proventriculus armed with sclerotized teeth), a large expandable midgut (simple undivided digestive organ, unlike the more elaborate divided midguts (with diverticula and caeca) of most other haematophagous arthropods), a tubular hindgut (with excretory Malpighian tubules) and rectum. The thorax has 3 dorsal sclerites: a rectangular pronotum bearing the pronotal ctenidia, a short middle mesonotum, and a rectangular metanotum bearing marginal spinelets. The middle ventral thoracic sclerite has a vertical thickening known as a meral rod (also present in *Xenopsylla*, *Leptopsylla*, *Ceratophyllus* and *Ctenocephalides* spp.). The ventral thorax is the point of attachment for 3 pairs of strong legs, each consisting of 5 segments (coxa, trochanter, femur, tibia, and tarsus), the hind femur bearing 3-4 bristles on the inner surface and all tarsi terminating in a pair of claws. The hindlegs are enlarged and well-adapted for jumping (using unique elastic resilin pads to store energy under compression, rather than muscular contraction). The abdomen is elongate and has 8 visible segments (each with more than one row of dorsal setae and lateral respiratory spiracles) plus another 3 posterior segments modified by sensory and genital structures. Both sexes have a flat dorsal plate-like organ (sensillum or pygidium) from which antesensillial setae project. Males are generally smaller than females and are usually readily distinguished by the presence of long penis rods coiled within the abdomen. Male flea genitalia are highly elaborate (probably the most complex in the animal kingdom) and consist of an aedeagal apodeme (penis plate) with extendable penis rods coiled and retracted within an endophallic sac. The flea penis is thin and delicate and cannot enter the female without the support of the rods and posterior claspers. Males have 2 testes joined by tubular vas deferens to a seminal vesicle with an ejaculatory duct leading to the penis. Female fleas are often readily identified by the presence of a dark reniform spermatheca (for sperm storage after mating) located within the posterior abdomen. Females have 2 ovaries with tubular oviducts leading to a globular uterus opening to the vagina located in a bursa copulatrix (depression to receive male organ) with associated spermatheca.

Site of infection: Flea eggs, larvae and pupae are non-parasitic stages that live free in the environment, particularly nests, burrows and hides used by rodents. Adult fleas are external parasites on mammalian hosts, although they can spend much time off their hosts resting between bloodmeals. All *Nosopsyllus* spp. are parasitic on small terrestrial rodents (particularly murids, cricetids and sciurids) with records for several species also extending to eulipotyphlans (shrews, hedgehogs and moles), lagomorphs, several marsupials and some small carnivores (felids, canids and mustelids). The species *N. fasciatus* has also occasionally been detected on sheep, humans and several birds (mainly ground-foraging species). These rodent fleas are particularly numerous throughout Palearctic and Oriental regions and occasionally Africa, but several species have become common in most temperate regions due to numerous translocations. Fleas prefer to feed on the sacral and pelvic regions of rats and rarely move anteriorly.

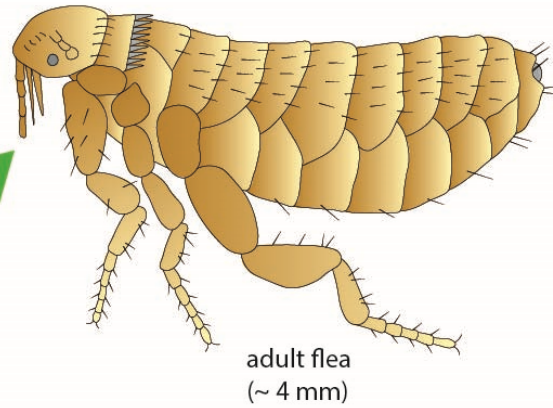
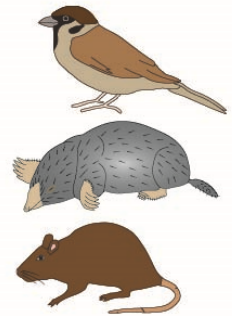
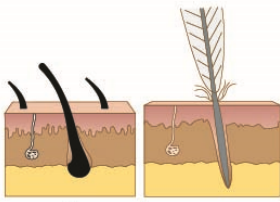
Pathogenesis: Adult fleas are haematophagous ectoparasites that use their mouthparts to pierce the skin and suck blood from small blood vessels (solenophagy). They jump onto hosts and feed for 2-3 hours even though they are able to take a full bloodmeal in as little as 10 minutes (they are often disturbed by host activity and must repeatedly find suitable blood vessels). Females take larger bloodmeals than males (up to 9-fold more). Flea bites cause significant irritation to their hosts with traumatic skin lesions, inflammation, pruritus, restlessness and even anaemia in heavy infestations. When feeding, fleas inject saliva containing vaso-active compounds and some hosts exhibit hypersensitivity reactions to the saliva with the development of allergic dermatitis. Laboratory studies on gerbils and voles have shown that *Nosopsyllus* infestations reduce host fitness as evidenced by reductions in body mass, impaired immune defences and the induction of iron deficiency. Epidemiological and experimental studies have also shown that several *Nosopsyllus* spp. may act as vectors for a variety of infectious micro-organisms: including those causing yersiniosis (plague), rickettsioses, bartonellosis, salmonellosis, and erysipeloid (Rosenbach's disease) in humans; tularemia, Q fever and myxomatosis in lagomorphs; and a nonpathogenic rat trypanosome (*T. lewisi*). Rat fleas have also been shown to act as intermediate hosts for the rat tapeworm *Hymenolepis diminuta* and the dwarf tapeworm *Hymenolepis nana*.

Developmental cycle and mode of transmission: Rat fleas exhibit holometabolous development whereby grub-like larvae undergo complete metamorphosis in pupae to form adult fleas. The fleas show strong nidicolous behaviour as they are usually intimately associated with the nests, burrows or dens of their hosts. Gravid female fleas may lay eggs on or off their hosts but they are not very sticky and generally drop off into the nest. The eggs are able to tolerate wide temperature variations (from 5-29°C) and hatch within 7 days. The emergent larvae feed on organic debris, particularly on flea dirt (faecal pellets of dried blood excreted by adults which also drop into the nest). They grow through 3 larval instars over 60 days and survive best in dark cool humid spaces filled with detritus containing numerous hiding places. Workers have also noticed a unique feeding behaviour where larvae solicit faecal bloodmeals from adult fleas by grasping their posterior regions with their mandibles which stimulates the adults to excrete semi-liquid stored blood which is ingested by the larvae. Mature larvae then form silken cocoons in which they undergo pupation for around 2 weeks. Adult fleas may remain in their pupal cases for many months and will not emerge at low temperatures. When they do emerge, they seek hosts on which to feed. Adult fleas have been observed to mate year round with copulation usually occurring off the host. Some researchers think fleas need to feed first in order to mate (requiring blood, warmth or both), but others have reported that unfed fleas kept under warm conditions were able to successfully mate. Gravid female fleas lay 2-8 eggs after each bloodmeal and they may live for 4-17 months depending on ready access to food and cryptic resting sites with moderate temperatures and high humidity. The whole life-cycle may be completed in 80 days, but it often takes longer in less favourable conditions. Infestations are generally more prevalent during the summer months due primarily to the greater abundance and increased activities of suitable mammalian hosts.

Differential diagnosis: Many infestations remain asymptomatic or subclinical and are often overlooked. Clinical infestations may be suspected when hosts exhibit furtive grooming behaviours and skin lesions become apparent. Diagnoses are made by the direct demonstration of fleas in the pelage and confirmed by microscopic examination of specimens dislodged from hosts. Molecular biological techniques have been used to characterize flea species and infer phylogenetic relationships following the polymerase chain reaction (PCR) amplification of nuclear (18S ribosomal DNA and internal transcribed spacer regions 1 and 2) and mitochondrial (cytochrome c oxidase 1 and cytochrome b) gene sequences.

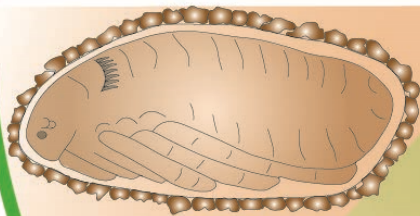
Treatment and control: Infestations in urban and peri-urban areas that may represent public health threats to human populations are generally controlled by vermin eradication (through trapping and/or baiting). Humans experiencing flea bites may be treated symptomatically with anti-inflammatory agents (glucocorticoids), cooling preparations (menthol, camphor, calamine, ice compresses) together with antibiotics for secondary bacterial infections. Infestations in laboratory animals and pets may be treated with insecticidal chemicals, including organophosphates (coumaphos, diazinon, malathion), pyrethroids (permethrin, cypermethrin), chloronictinyles (imidacloprid), arylpyrazoles (fipronil), and macrocyclic lactones (selamectin). Because rat fleas are nidicolous and usually develop in rodent nests, attempts should be made to decontaminate the immediate environment using residual insecticides. Some success has been reported spraying substrates with organophosphates, pyrethroids or insect growth regulators (methoprene, pyriproxyfen), but aerosol preparations (like foggers and flea bombs) have limited efficacy as they do not penetrate well into cryptic resting sites. Infested houses should be thoroughly cleaned by washing hard substrates with disinfectants and by vacuuming and steam-cleaning carpets. Animal holding facilities should also be cleaned regularly, nesting and bedding materials should be changed frequently, and wild animals should be excluded using suitable barriers and traps. Appropriate screening and quarantine procedures should also be used to avoid outbreaks in laboratory animal colonies.

Nosopsyllus

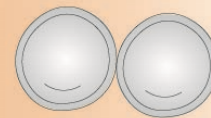


adults are often nidicolous and transient
ectoparasites (feeding on host blood)

eclosion

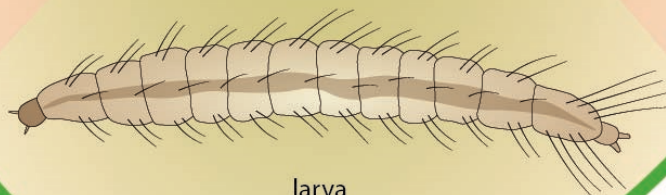


encasement



eggs drop
off
host
or
laid
on
soil,
plants

hatch



free-living in external environment
(esp. bedding, nests, burrows, hides)



Nosopsyllus adult