Pulex
(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. Pulicid fleas occur as ectoparasites on mammals, including humans, domestic and companion animals and wildlife, especially rodents. Adult *Pulex* spp. lack genal (oral) and pronotal (thoracic) combs and infestations have been associated with skin lesions and dermal hypersensitivity in humans, pigs, dogs and cats.

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:	Pulicidae (parasites of mammals)
Genus:	*Pulex* (parasitic on skin of humans/dogs/cats)
Species:	various species cause pruritus and allergic dermatitis in humans and companion 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. 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 Hemipterodea (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	sensilium 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 Palaearctic
Malacopsyllidae	2 genera 2 species	armadillos	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	birds, rodents, pikas, carnivores, insectivores	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	elephant shrews	sensilium 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	Palaearctic, 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. Members of the family Pulicidae (syn. Archaeopsyllidae, Xenopsyllidae, Sarcopsyllidae p.p.) are characterized by compact bodies, small rounded heads and reduced chaetotaxy (small numbers of setae, spines and/or bristles). Over 20 genera have been recognized in 5 subfamilies: namely, Archaeopsyllinae (*Aphropsylla*, *Archaeopsylla*, *Centetipsylla*, *Ctenocephalides*, *Nesolagobius*), Moeopsyllinae (*Moeopsylla*), Pulicinae (*Delopsylla*, *Echidnophaga*, *Pulex*), Spilopsyllinae (*Actenopsylla*, *Cediopsylla*, *Euchoplopsyllus*, *Hoplopsyllus*, *Ornithopsylla*, *Spilopsyllus*), and Xenopsyllinae (*Parapulex*, *Pariodontis*, *Procaviopsylla*, *Pulicella*, *Synopsyllus*, *Synosternus*, *Xenopsylla*). Various pulicid species and genera are considered to be important parasites of medical and veterinary significance either as parasites in their own right (blood-sucking behaviour causing anaemia, dermatitis and hypersensitivity reactions) or as vectors for other infectious micro-organisms (including bacteria and helminths). Pulicid genera are differentiated mainly on the basis of whether the thoracic segments are very short (*Echidnophaga*), whether both genal (head) and pronotal (thorax) ctenidia (combs) are present (*Ctenocephalides, Spilopsyllus*) or absent (*Pulex, Echidnophaga, Xenopsylla*), and whether the axis of the genal comb is horizontal (*Ctenocephalides*) or vertical (*Spilopsyllus*).

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

Pulex spp. are characterized primarily by morphological features of adult flea stages, notably their small smooth rounded heads and setate bodies lacking genal and pronotal ctenidia (combs). Some 12 species have been described from mammals (mainly rodents, insectivores, marsupials, carnivores, sometimes humans) and some birds; many species being found on a range of hosts, often not closely-related but sharing similar habitats. Some authorities recognize 2 subgenera: *P.* (*Pulex*) comprising those species with shorter heads, medium mouthparts, large eyes, and a single bristle in place of the genal comb; and *P.* (*Juxtapulex*) comprising those species with longer heads, longer mouthparts, smaller eyes, and 2 short angulate spines in place of the genal comb. The human flea, *P. irritans*, once prevalent and widespread in human communities, is now found mainly on pigs and poultry in rural areas in developing countries. Health authorities continue to monitor distribution patterns, as the flea has previously been shown to act as a vector for the transmission of various bacterial diseases (notoriously including bubonic plague) as well as dog tapeworms.

***Pulex* species**	**Hosts**	**Clinical signs**	**Distribution**
P. (*Juxtapulex*) *alvarezi*	Perissodactyla: tapirid (Baird's tapir); Didelphimorphia: didelphid (common opossum)		Central America
P. arizonensis	Rodentia: murid (silvery mouse)		North America
P. brunneri	Rodentia: sciurid (Columbian ground squirrel)		South America
P. (*Juxtapulex*) *echidnophagoides*	Cingulata: dasypodid (nine-banded armadillo); Didelphimorphia: didelphid (gray four-eyed opossum); Carnivora: felid (cougar)		Americas
P. gillettei	Strigiformes: strigid (eastern screech owl)		North America
P. howardi	Rodentia: sciurid (woodchuck, flying squirrel), murid (silvery mouse)		Americas
P. (*Pulex*) *irritans* (syn. *P. conepati, orientalis, vulgaris*) (human flea)	Primates: hominid (human); Chiroptera: molossid (broad-eared bat), phyllostomid (big-eared woolly bat); Carnivora: canid (dog, culpeo, red fox), felid (cat), ailurid (red panda), mustelid (Eurasian otter, European badger); Artiodactyla: suid (pig); Perissodactyla: equid (horse); Eulipotyphla: erinaceid (European hedgehog); Rodentia: cricetid (short-tailed field vole), heteromyid (Gaumer's spiny pocket mouse), murid (brown rat, bush rat, house mouse, wood mouse); Dasyuromorphia: dasyurid (western quoll); Diprotodontia: phalangerid (common brushtail possum), pseudocheirid (western ringtail possum); Monotremata: tachyglossid (short-beaked echidna); Didelphimorphia: didelphid (Virginia opossum); Anseriformes: anatid (mallard); Charadriiformes: scolopacid (Eurasian woodcock); Galliformes: phasianid (chicken); Passeriformes: hirundinid (welcome swallow)	dermatitis (+ vector for bubonic plague, murine typhus, trench fever, spotted fevers, dog tapeworm, mouse tapeworm)	worldwide

P. (*Pulex*) *larimerius*	[fossil in amber]		Dominican Republic
P. multispinosus	Lagomorpha: leporid (cottontail rabbit)		Americas
P. (*Juxtapulex*) *porcinus*	Artiodactyla: tayassuid (peccary); Carnivora: felid (cougar, jaguar); Didelphimorphia: didelphid (common opossum); Cingulata: dasypodid (nine-banded armadillo)		Americas
P. (*Pulex*) *simulans* (syn. *P. dugesii*)	Primates: hominid (human); Artiodactyla: suid (pig), cervid (mule deer); Carnivora: canid (wolf, gray fox, savannah fox), mephitid (striped skunk); Rodentia: sciurid (ground squirrel, prairie dog); Didelphimorphia: didelphid (common opossum); Pilosa: myrmecophagid (collared anteater)	dermatitis	Americas
P. (*Pulex*) *sinoculus*	Rodentia: geomyid (giant pocket gopher), sciurid (squirrel)		Central America

A number of other flea species were originally described as belonging to the genus *Pulex* but were subsequently transferred to other genera: including *P. coloradensis* to *Tarsopsylla, P. divisus* to *Typhlopsylla, P. grossiventris* to *Malacopsylla, P. hirsutus* to *Opisocrostis, P. ignotus* to *Foxella, P. keeni* to *Opisodasys, P. lutzii* to *Rhopalopsyllus, P. montanus* to *Oropsylla (Diamanus), P. penetrans* (syn. *P. penetrates*) to *Tunga, P. penicilliger* to *Trichopsylla, P. sciurorum* to *Monopsyllus,* and *P. segnis* to *Leptopsylla,* as well as two species names (*P. pungens* and *P. vespertilionis*) declared invalid.

Parasite morphology: Pulicid fleas form 4 different types of morphological stages during their development: eggs; larvae; pupae; and adults. The eggs are ovoid measuring around 0.5 mm long and appear pearly white in colour. Larvae emerge as elongate vermiform (worm-like) stages that become progressively larger as they moult through 3 instars growing from 1.5 to 4-6 mm in length by 0.5 mm in width. They are eruciform having soft cylindrical bodies (yellow-white in colour) with darker sclerotized heads with powerful mandibles and mandibular teeth well-adapted for biting and chewing. Larvae have 13 segments (3 thoracic, 10 abdominal) with bristles on each segment and the posterior segment having 2 small brown hooks. They lack eyes and legs but are active stages, the final instar folding back on itself prior to pupation. They become enclosed within loosely-woven silken cocoons which are initially white to yellow in colour but become brown as they are sticky and collect adherent debris. The cocoons range in size from 2-5 x 1-3 mm and contain pupae undergoing profound changes. The larval head and last 3 segments are lost during pupation and the body becomes compressed (shorter and wider). They are exarate pupae and their legs appear free from the body wall (in contrast to many other insects which form obtect pupae whose appendages are fused to the body wall). Pupae come to resemble adult fleas without wings but with elongated mouthparts, short antennae, inconspicuous eyes, and developing setae and bristles. Adult fleas emerge as characteristically laterally-compressed stages that are heavily chitinized with hard plates (called sclerites) which make them very resistant to being squashed. Adults of different species range in size from 1.5-4.0 mm in length and are often shiny dark brown in colour, sometimes tan-red particularly after feeding. The sclerites have distinctive patterns (chaetotaxy) of setae, spines and/or bristles, usually facing backwards so as to not impede forward movement through pelage or plumage, but catching on hairs or feathers when dragged backwards by host grooming. Other flea genera possess comb-like rows of spines either on the head (genal ctenidia), on the thorax (pronotal ctenidia) or on both sites, but they are absent on *Pulex* spp. All adults have 3 separate body parts, with a small anterior head, a short thorax and an elongate abdomen (the latter 2 being almost continuous). The head is small and shield-like with a smoothly rounded frons (forehead), no frontal tubercle (brow), and gena (cheeks) with broad ventral lobes. They possess a pair of simple noncompound eyes (clusters of ocelli), a pair of short club-like antennae (3-segmented) held in protective grooves (fossae), and 3 strong bristle-like setae on each side; one on the genal margin, one behind the antennae, and one below the eye (in contrast to *Xenopsylla* spp. which have an ocular bristle in front of the eye). Early workers recognized 2 subgenera on the basis of morphometric differences: *P.* (*Pulex*) with shorter heads, medium mouthparts, large eyes, and a single genal bristle, and *P.* (*Juxtapulex*) with longer heads, longer mouthparts, smaller eyes, and 2 short angulate genal spines. All adults have conspicuous ventral piercing-sucking mouthparts (lacking mandibles and teeth) located between sensory palps used to probe the host skin for suitable feeding sites. The palps consist of a pair of long 4-segmented maxillary palps arising from the top of short blade-like maxillary lobes (stipes) as well as long 5-segmented labial palps arising from a short basal labium. The actual mouthparts (fascicle) consist of 3 long slender stylets: the 2 outer stylets (maxillary laciniae) being blade-like and serrated (sometimes with coarse teeth) and used to puncture the skin; and the third central stylet (labrum-epipharynx) being an outgrowth of the body wall (unique to fleas) and used to enter a capillary. 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 laciniae in *Pulex* spp. are elongate and extend halfway down the forecoxae in *P. irritans* and three-quarters the length of forecoxae in *P. simulans*. The alimentary tract comprises a tubular foregut (with anterior pharynx, salivary glands inserted apically, elongate oesophagus, and small globular proventriculus armed with spines to prevent regurgitation), a large expandable midgut (a simple undivided organ (without diverticula or caeca) for the storage, digestion and absorption of bloodmeals, unlike the more elaborate divided midguts of most other haematophagous arthropods), and a tubular hindgut (with excretory Malpighian tubules, and rectum). The thorax possesses 3 dorsal sclerites (pronotum, mesonotum, and metanotum) but does not have a meral rod (vertical thickening). Ventrally, the thorax is the point of attachment for 3 pairs of strong legs; each composed of 5 segments (coxa, trochanter, femur, tibia, and tarsus) and ending in 2 claws. The hind-coxae bears a patch of small spines (8-12 spines in females, 7-10 in males). The third pair of legs are much longer and well-adapted for jumping using unique elastic resilin pads to store energy under compression (rather than muscular contraction).

The oval abdomen contains 10 segments, most with lateral respiratory spiracles and a single row of setae, but the last 3 segments highly modified by genital structures. Both males and females have a flat dorsal plate-like organ (sensilium or pygidium) with a number of pitted and setate dome-like structures (sensory organs detecting air movement, vibrations and temperature gradients). A pair of anal stylets bearing apical setae and short bristles is also located behind the sensilium. Males are generally smaller than females (1.5-2.5 v. 2.5-4.0 mm long) and they have highly elaborate genitalia (arguably the most complex in the animal kingdom). Males have modified abdominal segments forming an exterior protective shield and movable claspers (each with a large central process covering 2 smaller processes). They have 2 testes connected by tubules to a seminal vesicle and ejaculatory duct leading to the genital apparatus consisting of an aedeagal apodeme (penis plate) with extendable penis rods coiled and retracted within an endophallic sac. The penis is thin and wispy and cannot enter the female without the support of the rods and claspers. Females have 2 ovaries with tubular oviducts connected to a globular uterus and vagina with a bursa copulatrix (depression to receive male organ) and subglobular spermatheca (for sperm storage after mating). During mating, the male aedeagus dorsal lobe extends to the vagina, the thicker penis rod penetrates deep into the bursa copulatrix and the thinner penis rod penetrates deeper into the spermathecal duct. The thinner penis rod also has a cobra-shaped head thought to convey sperm as well as scoop out rival sperm.

Site of infection: Only the adult stages of *Pulex* spp. are obligate ectoparasites on warm-blooded vertebrates, while the eggs, larvae and pupae are free-living in the external environment (often associated with host resting places such as dens, beds and nests). Adult fleas require bloodmeals to become sexually mature and complete their development. Adults are very agile and may move rapidly though host pelage or plumage, feeding on blood through the skin at multiple sites. Nonetheless, they are transient ectoparasites feeding on hosts for 5-10 minutes and then often leaving the host to rest in the surrounding environment. Most species are stenoxenous or euryxenous feeding on the blood of a small range of mammals and birds, particularly rodents, insectivores, small carnivores, humans and non-passerine birds.

Pathogenesis: Adult fleas are haematophagous and use their mouthparts to pierce the skin and suck blood from their hosts, often taking more blood than they can digest. During feeding, they inject saliva containing vaso-active compounds, including anticoagulant, vasodilatory and anti-inflammatory substances. Bites often appear in clusters or small rows as the fleas feed at frequent intervals, causing traumatic skin damage at the puncture point (tiny purplish spot known as purpura pulicosa) surrounded by focal inflammation (known as roseola pulicosa). The lesions are often intensely pruritic (itchy) and may persist as urticarial and vesicular papules causing discomfort for several weeks. Individual hosts may also develop hypersensitivity responses to bites resulting in eczematous skin disease known as flea allergy dermatitis. Obviously, flea bites represent a considerable nuisance to their hosts with persistent irritation and annoyance, often leading to biting stress. Hosts attempt to relieve the irritation by aggressive self-grooming (biting, pecking, scratching, rubbing), sometimes causing self-trauma and hair/feather loss, making them more susceptible to secondary bacterial infections. Heavy infestations may also cause a slow but progressive anaemia due to sustained blood loss. In addition to being parasites in their own right, *Pulex* spp. have become notorious for the transmission of many infectious microbial diseases, including bacterial bubonic plague, rickettsial murine typhus, feline spotted fever, Rocky Mountain spotted fever and Mediterranean spotted fever, trench fever, cat scratch fever, tularemia (rabbit fever), and erysipeloid skin infection. The fleas have also been shown to act as intermediate hosts for larval stages of the dog tapeworm *Dipylidium caninum* and the mouse tapeworm *Vampirolepis nana*.

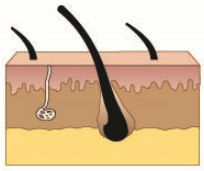
Developmental cycle and mode of transmission: *Pulex* spp. have holometabolous life-cycles where grub-like larvae undergo complete metamorphosis in pupae to become adults. The adults feed on host blood and void faeces containing partially-digested blood (called flea dirt) which usually fall off the host. Gravid female fleas lay non-sticky eggs in small batches (2-8) which also usually fall off the host, contaminating the immediate environment (often host resting places, burrows, or nests). Provided adequate moisture is present (humidity usually >70%), the eggs hatch in 3–6 days (up to 14 days in colder conditions) releasing larvae. The maggot-like larvae avoid sunlight and keep to dark humid places (sand, loose soil, cracks, crevices, carpets, bedding, etc.) feeding on organic debris (vegetable material, dead insects, faeces, especially flea dirt). The larvae develop through 3 instars over 4-18 days under ideal conditions, but the duration depends on prevailing temperatures and humidity, and may be delayed for several months (in some cases up to 200 days) in cooler drier conditions. Mature larvae then curve back on themselves forming a U-shape and weave silken cocoons (pupae) which become covered by debris from the environment (sand, pebbles, etc.). Within the pupae, the fleas undergo complete transformation into adult stages, with pupation occurring in as little as 4-10 days, but often taking longer in more adverse conditions (several weeks in colder conditions). The pre-emergent adults wait within their pupae for suitable occasions to emerge and engage hosts, sometimes waiting for several months for the right combination of stimuli. They have numerous sensory organs and are triggered to eclose (emerge) by the close proximity of hosts as detected by changes in carbon dioxide concentrations, certain odours, heat, vibrations, air currents, and light patterns. Indeed, the passing of a warm-blooded animal may trigger the mass emergence of adults from pupae. Once emerged, adult fleas must find a host and feed within several days (although there a few reports of unfed fleas surviving up to 100 days in cool humid conditions). Adults are anautogenous and require a bloodmeal to become sexually mature, as the meal stimulates dissolution of a testicular plug in males and maturation of the ovaries in females. Unfed fleas cannot mate and virgin females may lay nonviable eggs. Fed adults may mate several times and it is thought that males may use their long thinner penis rods to scoop out sperm left in the female spermatheca by rivals. Fertilized females lay eggs in small batches (2-8) after each bloodmeal. They usually live for 2-3 months and may produce over 400 eggs, but they do not have to reside on hosts and actually spend much of their time off hosts between feeds. It has been estimated that only 5% of the

adult flea population occurs on a host at any given time. If a continuous food supply is available and females feed regularly, some have been found to live up to a year under ideal conditions of temperature and humidity.

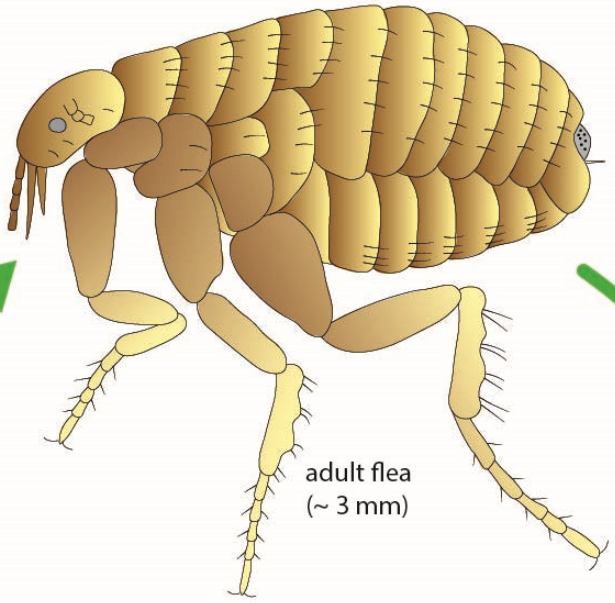
Differential diagnosis: Infestations may be suspected on clinical grounds by the detection of pruritic papular bites on hosts exhibiting biting stress. Careful visual examination usually reveals the presence of adult fleas in the pelage or plumage, particularly when fine combs are used to part hairs or feathers. The fleas are very agile and hard to catch for macroscopic or microscopic examination, but they are very hardy and can withstand considerable pinch pressure. Different taxa are readily identified by their morphological characteristics, particularly with respect to the presence of absence of genal and/or ctenidial combs. Molecular biological techniques have been used for generic and species differentiation and phylogeny following polymerase chain reaction (PCR) amplification of nuclear (18S and 28S ribosomal DNA, internal transcribed spacer regions 1 and 2, elongation factor 1-alpha) and mitochondrial (cytochrome c oxidase subunit I, cytochrome b, 16S ribosomal DNA) gene sequences.

Treatment and control: Clinical infestations may be treated by removing or killing fleas on hosts using various grooming strategies and the application of insecticidal chemicals, but long-term management depends on preventing rapid re-infestations by free-living stages. Washing hosts in immersion baths may remove and drown fleas. Flea soaps can also be used as they contain fatty acids acting as detergents to remove the waxy coats of fleas making them susceptible to subsequent desiccation. Many different types of flea combs have been developed and hair conditioners may be used to help untangle matted coats, although recourse if often taken to clipping or shaving severely affected regions. A wide range of insecticides have been used to treat flea infestations, many as topical preparations (sprays, shampoos, washes, powders, mousses, dips, dusts) or as systemic products (oral, spot-on, impregnated collars). Good results have been obtained using organochlorines (dichloro-diphenyl-trichloroethane (DDT), lindane), organophosphates (coumaphos, chlorfenvinphos, diazinon, dioxathion, fenchlorvos, malathion, phosmet, stirofos, trichlorfon), carbamates (carbaryl), neonicotinoids (dinotefuran), chloronicotinyles (nitenpyram, imidacloprid), spinosyns (spinosad), pyrethrin and synthetic pyrethroids (permethrin, cyfluthrin, cypermethrin, etofenprox), macrocyclic lactones (selamectin, ivermectin), semicarbazones (metaflumizone), phenylpyrazoles (fipronil), benzoylphenylureas (lufenurin) and some insect growth regulators (methoprene, pyriproxyfen), although some resistance have been reported against many conventional formulations (some organochlorines, organophosphates and pyrethroids). The use of products with long residual activities has done much to simplify treatment protocols, as they only need to be treated once and do not become rapidly re-infested when returned to contaminated environments. However, it is important to regularly re-treat hosts with formulations with short residual activities. All in-contact hosts should be treated at the same time, and any hosts with severe lesions should be given supportive therapies in the form of anti-pruritics, anti-inflammatories (anti-histamines or glucocorticoids) and possibly antibiotics in the event of secondary bacterial infections. Human patients may seek relief from flea bites by using various cooling preparations, such as menthol, camphor, calamine, propylene glycol, vaseline or even ice. Some personal protection can be afforded to individuals by the application of insect repellents (such as diethylmethylbenzamide (DEET), ethyl butylacetylaminopropionate (EBAAP, or IR3535), and permethrin) to skin or clothing. The prevention of flea infestations relies on decontamination of the environment by removing or killing flea eggs, larvae, pupae and adults by physical and/or chemical cleaning processes. Flooring, especially carpets, should be regularly cleaned and vacuumed (which also stimulates adults to eclose from pupae), bedding and clothing should be thoroughly washed or replaced, and inanimate objects (including grooming equipment) can be sterilized by steam-cleaning or using stringent disinfectants. Various insecticidal chemicals with good residual activity can be used indoors (and sometimes outdoors) as sprays (organophosphates, pyrethroids, and insect growth regulators methoprene or pyriproxyfen with permethrin and pyrethrin synergists) and powders (pyriproxyfen, linalool and pyrethrin synergists), although many commercial flea bombs and foggers (methoprene or pyriproxyfen with permethrin, pyrethrins or esfenvalerate synergists) have proven to be not as effective against pulicid fleas. Other methods of reducing flea populations have involved the use of various traps (intermittent light traps, sticky traps, and pan traps), spreading desiccants in animal bedding or rest areas (diatomaceous earth, sodium polyborate), restricting animal movements (quarantine, preventing pets from roaming) and implementing rodent control (with many attendant public health benefits).

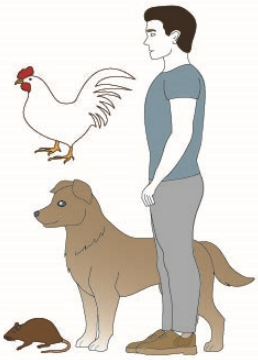
Pulex



skin/pelage
(pruritus, dermatitis, anaemia, allergy)
(vectors for infectious microbial diseases)



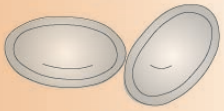
adult flea
(~ 3 mm)



Definitive Hosts
(mammals, birds)

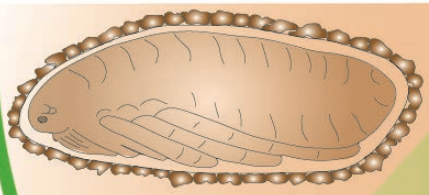
adult ectoparasitic on host
(feeding on blood)

eggs drop off host



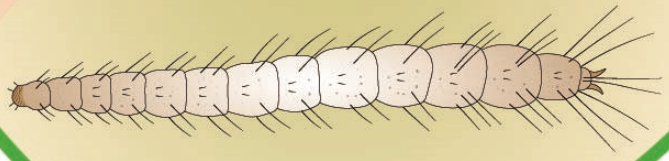
eggs
(~ 0.5 mm)

hatch



pupa
(~ 3 mm)

eclosion



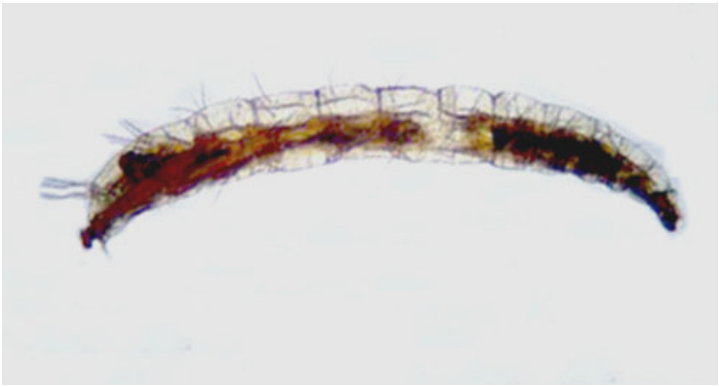
larva
(~ 4 mm)

encasement

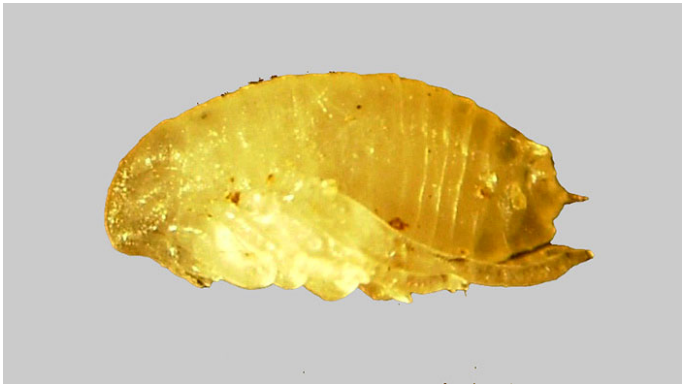
free-living in litter, bedding

Pulex adult

Pulex eggs



Pulex larva



Pulex pupa