Ctenocephalides
(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 *Ctenocephalides* spp. have genal (oral) and horizontal pronotal (thoracic) combs and infestations have been associated with skin lesions, pruritus and flea-allergy dermatitis (hypersensitivity) in dogs, cats and humans.

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:	*Ctenocephalides* (parasitic on skin of dogs/cats/humans)
Species:	various species cause dermatoses in 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	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	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

The genus *Ctenocephalides* is classified within the Pulicidae together with other fleas of mammalian hosts, including humans. Adult fleas attach primarily to carnivores (especially canids and felids), but may also infest a range of other mammals (rodents, ungulates, lagomorphs, insectivores, primates, including humans) and occasionally some birds. Most flea species are considered to be host-preferential rather than host-specific – they have promiscuous feeding habits and will try to feed on any available host. The most common flea on cats and dogs is *C. felis*, but it will feed on many other mammals, including humans. In subtropical and temperate regions, infestations peak in prevalence and intensity in late summer and autumn, although fleas may often be found all year round.

***Ctenocephalides* species**	**Hosts**	**Clinical signs**	**Distribution**
C. arabicus	Hyracoidea: procaviid (rock hyrax)		Middle-East
C. brygooi	Carnivora: viverrid (civet)		Madagascar
C. canis (dog flea)	Carnivora: canid (dog, dingo, coyote, golden jackal, red fox, grey fox, crab-eating fox, South American grey fox), felid (cat, Iberian lynx, leopard), herpestid (meerkat, white-tailed mongoose), mephitid (eastern spotted skunk), otariid (brown fur seal), viverrid (common genet); Lagomorpha: leporid (European rabbit, European hare, scrub hare); Rodentia: cricetid (European water vole, common vole), hystricid (Cape porcupine), murid (black rat, brown rat, striped field mouse, wood mouse, house mouse); Eulipotyphla: erinaceid (European hedgehog, North African hedgehog, northern white-breasted hedgehog); Artiodactyla: bovid (goat, Asiatic mouflon), suid (pig); Peramelemorphia: peramelid (long-nosed bandicoot); Hyracoidea; procaviid (rock hyrax); Primates: cercopithecid (yellow baboon), hominid (human); Galliformes: phasianid (chicken)	wheal, pruritus, anaemia, flea-allergy dermatitis (+ vector for dog tapeworm, mouse tapeworm)	worldwide
C. chabaudi	Artiodactyla: bovid (duiker)		Africa
C. connatus	Carnivora: viverrid (meerkat, yellow mongoose); Rodentia: sciurid (African ground squirrel); Lagomorpha: leporid (hare); Eulipotyphla: erinaceid (hedgehog)		South Africa
C. crataepus	Rodentia: sciurid (African ground squirrel); Eulipotyphla: erinaceid (hedgehog)		Africa
C. craterus	Hyracoidea: procaviid (southern tree hyrax)		Africa

C. felis [incl. subspecies *felis, strongylus, damarensi, orientalis*] (cat flea)	Carnivora: felid (cat, wildcat, bobcat, Asian golden cat, lion, jaguar, jaguarundi, cougar, leopard, caracal, ocelot, oncilla, serval, cheetah), canid (dog, dingo, maned wolf, black-backed jackal, side-striped jackal, red fox, gray fox, hoary fox, crab-eating fox, Ruppell's fox), hyaenid (spotted hyaena), herpestid (meerkat, marsh mongoose, yellow mongoose, Egyptian mongoose, small Asian mongoose, common dwarf mongoose, crab-eating mongoose, white-tailed mongoose, banded mongoose, Selous's mongoose), mustelid (striped polecat, tayra, beech marten, honey badger, Burmese ferret-badger, least weasel, African striped weasel, European polecat, American mink), mephitid (striped skunk, eastern spotted skunk), procyonid (South American coati, raccoon, crab-eating raccoon), ursid (brown bear), viverrid (common genet, Cape genet, civet cat, African civet); Rodentia: murid (black rat, brown rat, rakali, Tinfield's rock rat, house mouse, wood mouse, Kemp's spiny mouse, typical striped grass mouse, Misonne's soft-furred mouse, fringe-tailed gerbil, Shaw's jird), caviid (guinea pig, capybara, Spix's yellow-toothed cavy), cricetid (hispid cotton rat, cotton mouse, Yucatan deer mouse, terraced rice rat, Serra do Mar grass mouse, Atlantic forest climbing mouse, hairy-tailed bolo mouse, delta pygmy rice rat, black-footed pygmy rice rat, marsh rice rat, Robert's hocicudo, angular hocicudo), echimyid (common punare, Fischer's guara, white-spined Atlantic spiny rat), hystricid (Cape porcupine, crested porcupine), nesomyid (Mearn's pouched mouse), pedetid (South African springhare), sciurid (Brazilian squirrel, fox squirrel, striped ground squirrel, Cape ground squirrel), thryonomid (greater cane rat); Lagomorpha: leporid (European rabbit, European hare, Cape hare, scrub hare, Natal red rock hare, Jameson's red rock hare, common tapeti, eastern cottontail); Artiodactyla: bovid (goat, sheep, Asiatic mouflon, cattle, gaur, common duiker, red forest duiker, mountain gazelle, Rhim gazelle, hartebeest, klipspringer, Cape grysbok, harnessed bushbuck), cervid (mule deer, marsh deer), suid (desert warthog); Perissodactyla: equid (horse); Eulipotyphla: erinaceid (North African hedgehog, South African hedgehog, European hedgehog), soricid (lesser red musk shrew); Hyracoidea: procaviid (southern tree hyrax, rock hyrax); Cingulata: dasypodid (nine-banded armadillo); Pilosa: myrmecophagid (southern tamandua); Macroscelidea: macroscelid (rufous elephant shrew, western rock elephant shrew, four-toed elephant shrew); Didelphimorphia: didelphid (white-eared opossum, big-eared opossum, common opossum, Virginia opossum, big lutrine opossum, gray short-tailed opossum); Dasyuromorphia: dasyurid (eastern quoll); Diprotodontia: macropodid (eastern grey kangaroo, red-legged pademelon), phalangerid (common brushtail possum), potoroid (rufous rat-kangaroo); Peramelemorphia: peramelid (southern brown bandicoot, long-nosed bandicoot); Chiroptera: vespertilionid (southeastern myotis); Primates: atelid (Columbian red howler), cercopithecid (Guinea baboon, Chacma baboon), hominid (human); Galliformes: phasianid (chicken, red junglefowl), numidid (helmeted guineafowl); Strigiformes: strigid (lesser horned owl)	wheal, pruritus, anaemia, flea-allergy dermatitis (hypersensitivity) (+ vector for several bacterial infections, dog tapeworm, mouse tapeworm)	worldwide
C. grenieri	Hyracoidea: procaviid (rock hyrax)		Africa
C. orientis (Oriental cat flea)	Carnivora: felid (cat), canid (dog); Artiodactyla: bovid (sheep, goat)		India, Australia
C. paradoxuri	Carnivora: viverrid (palm civet)		Sri Lanka
C. rosmarus	Hyracoidea: procaviid (rock hyrax)		Ethiopia

Parasite morphology: Fleas form four different types of developmental stages: eggs; larvae; pupae and adults. The eggs are pearly-white ovoid bodies measuring 0.25-0.5 mm in length. Larvae are eruciform with slender cylindrical white-brown bodies 1-5 mm long. They have darker sclerotized heads with powerful mandibles and mandibular teeth well-adapted for biting and chewing. Their bodies are segmented (3 thoracic and 10 abdominal segments), each bearing a ring of bristles, and the caudal segment bearing 2 hooked processes (anal struts) used for gripping in locomotion. Pupae are opaque ellipsoidal stages around 0.5 mm long surrounded by thin silk cocoons, often with detritus adherent to the external surface. The larval head and last 3 segments are lost during pupation and the body becomes compressed (shorter and wider). They are exarate pupae with appendages free of the body wall (in

contrast to many other insects which form obtect pupae whose appendages are fused to the body wall). Pupae have begun to develop elongated mouthparts, short antennae, inconspicuous eyes, and numerous body setae and bristles. Adult fleas are wingless insects with heavily chitinized laterally-compressed bodies ranging in size from 2-3.5 mm long. Their shiny brown bodies are highly setate, with many spines and bristles usually facing backwards so as to not impede forward movement of the flea through pelage or plumage, but catching on hairs or feathers when dragged backwards by host grooming. Their chaetotaxy includes prominent comb-like rows of spines on the cheeks of the head (genal ctenidia) and on the thorax (pronotal ctenidia), the spacing of the spines generally correlated to the hair diameter of their hosts. The genal ctenidia are horizontal and have 5-9 vertical spines on each side, those of *C. felis* being similar in length, but the first spine of *C. canis* being shorter than the rest. The pronotal ctenidia are located along the posterior of the first thoracic segment and are vertical with 8-9 horizontal spines on each side. Adult fleas have 3 distinct body parts; a small flat head, a short thorax; and a globular abdomen. The dorsal profile of the head is smoothly rounded, being strongly convex in C. canis, and less convex and more elongate in C. felis (especially females). The frons (forehead) lacks a frontal brow but has a conspicuous club-shaped internal incrassation. The head also possesses a pair of simple noncompound eyes (clusters of ocelli), a pair of short club-like antennae (3-segmented) held in protective grooves (fossae), and genal (cheek) processes with small sharp 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 alimentary tract consists of an elaborate foregut (anterior pharynx, salivary glands inserted apically, elongate oesophagus, small globular proventriculus armed with spines to prevent regurgitation), a large expandable midgut (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 contains 3 distinct dorsal sclerites (pronotum, mesonotum, metanotum) and there is a vertical thickening of the exoskeleton (meral rod) on the mid-thoracic segment. The ventral thorax gives rise to 3 pairs of strong legs, each composed of 5 segments (coxa, trochanter, femur, tibia, and tarsus) and all terminating in paired claws. There are 6 notches bearing setae along the dorsal border of the hind (metathoracic) tibia in *C. felis*, but 8 seta-bearing notches in *C. canis*. In all species, the hindmost pair of legs are greatly enlarged for jumping, using unique elastic resilin pads to store energy under compression (rather than muscular contraction) allowing fleas to jump some 50-200 times their own body length. The abdomen is ovate with 10 segments, some with lateral respiratory spiracles, and the numbers of spines reducing posteriad. Both sexes have a flat dorsal plate-like organ (sensilium or pygidium) with a number of dome-like structures from which bristles project. Fleas exhibit considerable sexual dimorphism, with males being smaller than females and having conspicuous posterior abdominal segments bearing copulatory structures. Indeed, male genital structures are highly elaborate and perhaps the most complex in the animal kingdom. Males have 2 testes connected by vas deferens to a seminal vesicle and ejaculatory ducts. They then have an aedeagal apodeme (penis plate) with extendable penis rods which are 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 posterior claspers. Females have 2 ovaries with tubular oviducts connecting them to a globular uterus with a bursa copulatrix (depression to receive the male organ) and saccular spermatheca (for sperm storage after mating) located behind the vagina and vulva.

Site of infection: Adult fleas are obligate haematophagous ectoparasites living amongst the hair/fur on the skin of their hosts. They can also live off their hosts for extended periods in suitable micro-habitats (bedding, carpets, etc.) awaiting the arrival of new hosts on which to jump. Most species have preferred hosts but they do exhibit broad host specificity and may feed on a wide range of hosts as available (mainly mammals but including some birds). Adult fleas are agile and highly mobile and may infest many different regions of the body. Flea eggs, larvae and pupa are found in the external environment usually in the immediate vicinity of infested hosts, notably in their resting places.

Pathogenesis: Infestations by *Ctenocephalides* spp. are a major cause of skin disease in their natural hosts (dogs and cats), and they may also cause significant irritation when feeding or attempting to feed on other host species (even though they may not be able to complete their life-cycles feeding solely on aberrant hosts). Adult fleas are blood suckers that cause traumatic damage at the bite site. They have piercing mouthparts composed of cutting laciniae (back-and-forth action) and a stabbing epipharynx which enters small blood vessels. Saliva is ejected into the general area and bite sites develop erythematous (reddened) papules or wheals surrounding the central puncture site. Wounds may persist for days to several weeks and develop a crust of dried exudate. Host responses range from mild irritation to intense pruritus (itching) with restlessness, irritability, anaemia and weight loss. However, flea bites are often associated with severe allergic reactions; especially in inbred strains of dogs and cats and in young children. Flea-allergy dermatitis (FAD) is the result of hypersensitivity (immediate (type I), basophil, but mostly delayed (type IV)) reactions to flea salivary chemicals (enzymes, histamines, polypeptides and amino acids) injected into the skin. Reactions in sensitized individuals include intense pruritus, urticarial papules, excoriations, dermal infiltrates and rash. The skin may react to persistent inflammation by hardening and crusting with lichenification (thickening) and hyperpigmentation. Animals aggravate these conditions by inflicting self-trauma through over-grooming, barbering, licking, biting, chewing and scratching (itchy-scratchy syndrome) leading to significant hair loss (alopecia) and moist dermatitis (wet eczema). Secondary bacterial infections may lead to focal ‘hot-spots’ with or without pyoderma. Clinical signs are more common in mature dogs and cats and lesions are distributed

more on the caudal half of the body. *Ctenocephalides* spp. tend to bite humans predominantly on the lower legs and ankles, often with several bites in a row. Adult fleas are voracious feeders and may ingest up to 15 µl blood per day, so persistent heavy infestations in companion animals may cause iron-deficiency anaemia, especially in small young animals. The intensity of infestation may vary considerably, with most infested hosts having few fleas (often < 20, rarely > 100). The severity of disease does not correlate well with the intensity of infestation, for it only takes one or several flea bites to cause serious allergic/hypersensitivity reactions in sensitized individuals. Two distinct clinical manifestations have been associated with flea allergy in cats: miliary dermatitis (crusted papules with variable hair loss, especially across the dorsum and trunk) and feline symmetrical alopecia (skin appear normal but distal hair tips become fractured by excessive grooming).

In addition to directly causing disease, *Ctenocephalides* fleas have also been shown to act as vectors for a range of bacterial diseases: including several bartonelloses (*Bartonella henselae, B. clarridgeiae, B. quintana, B. koehlerae*), haemobartonellosis (*Mycoplasma haemofelis*), murine typhus (*Rickettsia typhi, R. felis*), Lyme disease (*Borrelia burgdorferi*) and possibly even bubonic plague (*Yersinia pestis*) that are transmitted variously to dogs, cats and humans. Fleas also serve as intermediate hosts for several helminth parasites, harbouring larval cysticerci of the dog tapeworm (*Dipylidium caninum*), the mouse tapeworm (*Vampirolepis nana*) and infective larvae of the filarial nematode (*Dipetalonema reconditum*), that are ingested during flea-grooming by dogs and cats, or accidentally by humans.

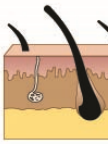
Developmental cycle and mode of transmission: Fleas have a holometabolous life cycle and undergo complete metamorphosis (egg-larva-pupa-adult). Only the adult fleas are ectoparasitic as all other life cycle stages occur in the environment. After feeding and mating, female fleas begin laying the first of hundreds of eggs in small groups of 4-8 eggs usually directly on the host. Egg production occurs at the rate of 20-50 eggs per day for several weeks, although it has sometimes been found to last up to 50-100 days. The eggs are not sticky and therefore drop off the host, usually in rest or sleeping areas frequented by hosts (bedding in dens, lairs, nests or hides). The eggs hatch within 2-21 days depending on prevailing environmental conditions (faster in warm moist conditions but unable to survive dry conditions). Hatched eggs release vermiform larvae which are legless and eyeless. The larvae avoid light by moving down into their surrounding substrata. They cannot close their spiracles and are therefore sensitive to low humidity and desiccation. They feed on dead skin and other debris within bedding materials, notably on flea dirt (excreta from adult fleas containing partially digested blood). The larvae moult through three larval instars over 8-150 days before forming pupae in silky cocoons which become covered in dust and debris. The pupa completes development to an adult over several days to weeks, although low temperatures and high humidity can extend larval and pupal stages for several months. Adults may remain in the cocoon for some time (usually 3-4 weeks but ranging from 14-170 days) until a passing host triggers their emergence via physical and chemical stimuli (vibration, heat, carbon dioxide). The hind-limbs of adult fleas are greatly enlarged and specially adapted for jumping, they possess elastic resilin pads which can be compressed and cocked, to be released with explosive force enabling them to make prodigious leaps (up to 100 times their own length). Newly emergent adults may jump onto a host immediately and begin feeding, or wait for a passing host after climbing on top of their surrounding substrata (vegetation, carpet pile, etc.) but they can only survive for several days without a blood meal. When feeding, adult fleas may consume up to 15 times their body weight in blood per day, but it transits the digestive tract very rapidly resulting in partially digested blood being excreted as reddish-black faecal pellets. This flea dirt falls off the host and acts as a food source for larval stages in host bedding. The whole life cycle may be completed under optimal conditions in as little as three weeks but it can be extended in suboptimal conditions for as long as 3-6 months. Adult fleas rarely leave their hosts so transmission is more reliant on hosts sharing contaminated environments than by direct host-host contact. The intensity of infestation can increase significantly over time but is restricted by the low survival of larval stages contaminating the environment, unless bedding or nesting behaviours and frequency provide suitable conditions for their persistence, thus leading to an aggregated distribution and focal points for transmission.

Differential diagnosis: Animals attempt to groom infested areas, and an 'itchy-scratchy' syndrome may develop, sometimes associated with intense inflammation or allergic reactions. Adult fleas and flea dirt can often be found in infested areas by visual examination (manually parting hairs or using a fine-toothed comb), although flea numbers on animals with FAD may be low or remain undetected. Flea dirt contains partially digested blood so when placed on moist filter paper it will often stain the surrounding area red. Using low power magnification, the species *C. felis* and *C. canis* may be differentiated on the basis of the length of the first two genal ctenidia (equal for *C. felis*, unequal for *C. canis*) and the number of seta-bearing notches on the dorsal margin of the hind limb tibia (six for *C. felis*, eight for *C. canis*). Several immunological tests have been developed to assist in the diagnosis of flea-allergy dermatitis (FAD) in pets, including intra-dermal skin tests with a panel of antigens to differentiate from atopic dermatitis (AD), and serological tests for specific immunoglobulins (IgE) against flea antigens. Molecular biological tests have been used to characterize flea isolates using polymerase chain reaction (PCR) amplification of specific gene sequences (nuclear 18S and 28S ribosomal RNA, internal transcribed spacer regions 1 and 2, elongation factor 1-alpha, mitochondrial cytochrome oxidase II, mitochondrial 16S ribosomal RNA).

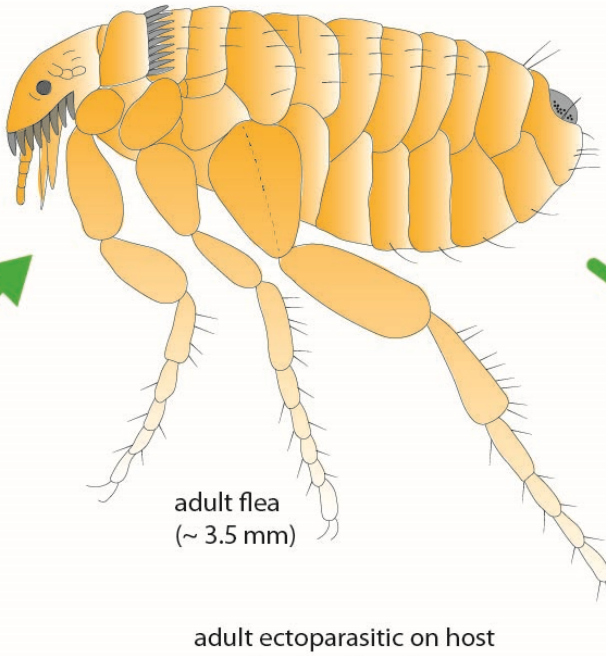
Treatment and control: Many chemicals have been developed to kill fleas, most acting on neurotransmitters, some on insect cuticle and several insect growth regulators (IGR). These insecticides may be used variously as tablets, in-feed medications, powders, washes, shampoos, sprays, pour-ons or impregnated into collars. Most conventional treatments consist of topical organophosphates (coumaphos, chlorfenvinphos, diazinon, dioxathion, fenchlorvos, crotoxyphos, malathion, phosmet, stirofos,

trichlorfon), carbamates (carbaryl), and pyrethrum and its pyrethroid derivatives (permethrin, cypermethrin, cyfluthrin). Several new generation ectoparasiticides have also been developed as topical spray or spot-on formulations, including arylpyrazoles (fipronil), chloronicotinyles (imidacloprid), macrocyclic lactones (selamectin), neonicotinoid (dinotefuran), oxadiazine (indoxacarb), semicarbazone (metaflumizone) and juvenile hormone mimetics (methoprene, pyriproxyfen). Oral formulations include chloronicotinyles (nitenpyram), spinosyns (spinosad), isoxazoline-substituted benzamide derivatives (fluralaner) (dogs only), isoxazoline (afoxolaner) (dogs only) and benzoylphenylureas (lufenuron), the latter also available as an injectable for use in cats only. Most drugs act on adult fleas (adulticides), although many of the newer preparations also act against eggs (ovicides). Ideally, topical or systemic insecticides with good residual activity should be used to kill existing infestations (curative treatment) as well as to reduce environmental contamination and prevent re-infestation (prophylaxis). However, treatments should be repeated regularly (7-14 days) to avoid re-infestation from larval and pupal stages already present in the environment. Drug efficacy should also be monitored as there are growing reports of insecticide resistance developing in flea populations. Human patients may seek relief from bite site reactions by using various cooling preparations, such as menthol, camphor, calamine, propylene glycol, vaseline or even ice. Corticosteroids (glucocorticoids, prednisone) are often used topically or systemically for palliative treatment of flea-bite allergy. Antibiotics may also be required to manage secondary bacterial infections and pyoderma. Experimental vaccination studies have shown some success in limiting infestations on dogs, cats and rabbits injected with midgut antigens of cat fleas. Control measures should include environmental management such as the provision of clean bedding, vacuuming carpets (which also stimulates adults to emerge from cocoons), rodent control and restricting pet roaming. Several methods of environmental decontamination have been developed including the use of intermittent light traps, insecticidal room foggers or flea bombs for confined indoor areas (flubenzuron, pyriproxyfen, methoprene), insecticidal sprays for small outdoor (organophosphates, pyrethroids, imidacloprid, cyfluthrin, fenvalerate) and even spreading desiccants (diatomaceous earth, sodium polyborate) in areas where animals rest.

Ctenocephalides



skin/pelage
(irritation, pruritus, dermatitis, ulceration, anaemia, allergy)
(vector for infectious microbial diseases)

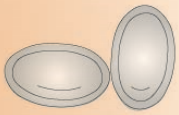


adult flea
(~ 3.5 mm)

Definitive Hosts
(mammals, some birds)

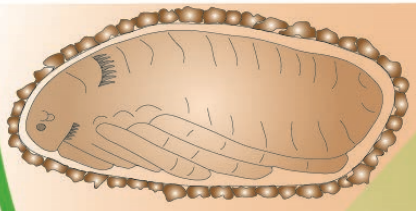
adult ectoparasitic on host
(feed on blood)

eggs drop off host



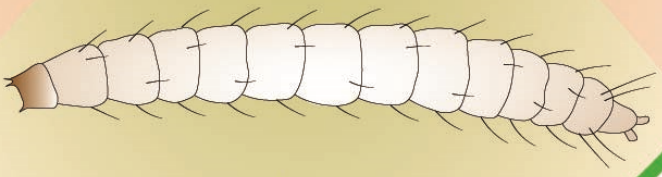
eggs
(~ 0.4 mm)

hatch



pupa
(~ 1 mm)

eclosion

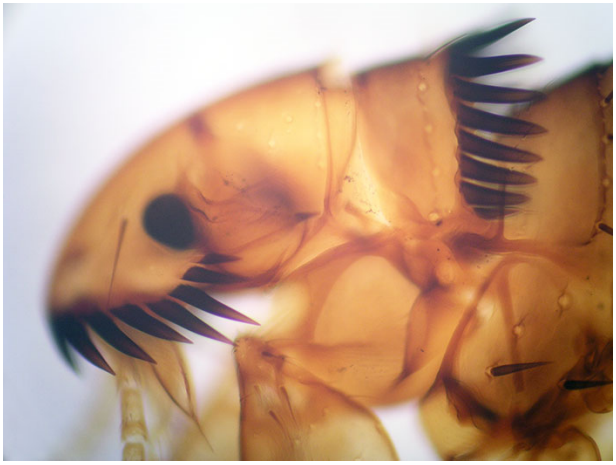


larva
(~ 4 mm)

encasement

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

Ctenocephalides adult



Ctenocephalides adult head

Ctenocephalides larva

Ctenocephalides pupa

Ctenocephalides egg