Syphacia
(helminth: nematode)

Overview

Nematodes are triploblastic pseudocoelomate unsegmented worms that undergo protostomial embryonic cleavage and grow by cuticular moulting (ecdysis). Two groups identified by the presence/absence of sensory phasmids have partly been ratified by molecular studies recognising three subclasses: Enoplia and Dorylaimia (both without phasmids) and Chromadoria (most with phasmids). Many phasmidian parasites of vertebrates are grouped in the chromadorian order Rhabditida; including tylenchinids, rhabditinids and spirurinids. The latter contains the infraorder Oxyuridomorpha which includes the oxyuroids (pinworms) characterised by their small tapering shape, pointed tails, oesophagus with a terminal bulb, and the males are non-bursate with a single spicule. They have simple direct life-cycles involving faecal-oral transmission of eggs containing infective larvae. The eggs may be passed in faeces or oviposited around the anus (perineum) where they are subsequently dislodged. Pinworms are common in the large intestines of many mammals, birds, reptiles, amphibians and some insects. Infections by *Syphacia* in rodents are generally asymptomatic, but their presence in laboratory colonies can be problematic.

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:	Nematoda (unsegmented, pseudocoelomate roundworms, tubular digestive tract, dioecious)
Class:	Chromadorea (spiral amphids, three oesophageal glands, usually annulated bodies, free-living and parasitic)
Order:	Rhabditida (Secernentea, Phasmidea) (secretors, with phasmids, bipartite oesophagus, single testis)
Suborder:	Spirurina (mostly parasitic in vertebrate hosts)
Infraorder:	Oxyuridomorpha (small pinworms, pointed tails, oesophagus with terminal bulb, males with single spicule)
Superfamily:	Oxyuroidea (common in mammals, birds, reptiles, amphibians)
Family:	Oxyuridae (direct cycle, females deposit sticky eggs around anus, infection by ingestion of egg)
Genus:	*Syphacia* (parasitic in large intestines of rodents)
Species:	*S. obvelata* (causes subclinical infections in mice)

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, all with jointed limbs). Nematodes (roundworms) are unsegmented tubular worms with a fluid-filled body cavity (pseudocoelom) that acts as a hydrostatic skeleton. They have longitudinal muscles and typically exhibit a sideways thrashing motion. They have well developed digestive tracts with various partitions: the foregut comprising the mouth (often with lips and papillae), buccal capsule (sometimes with ridges, rods, plates, spears, stylets or teeth) and oesophagus (glandular, muscular or both); the midgut (nonmuscular absorptive section); and hindgut (rectum) emptying through a subterminal anus (cloaca in males). Most nematodes are dioecious and form separate sexes. Male worms have a single testis (sometimes 2), an elongate vas deferens often equipped with a seminal vesicle and ejaculatory duct (glandular and/or muscular), 1-2 copulatory spicules (sometimes with an accessory gubernaculum), and bursate species with elaborate posterior claspers. Female worms are usually didelphic (some monodelphic or polydelphic) with 2 ovaries, 2 oviducts usually with spermatheca, 2 uteri opening into a common vagina and a vulva often equipped with a muscular ovejector. Female worms are oviparous or viviparous and produce numerous eggs or larvae, respectively. Larval stages undergo several moults (L1-L4) before maturing into adult worms. Some nematodes have direct life-cycles where eggs or larvae infect definitive hosts (per os or per cutaneous), but many have indirect cycles where larvae first develop in invertebrate intermediate hosts before infecting definitive hosts (by ingestion, injection or deposition). Many nematode species are free-living in terrestrial and aquatic habitats, while some species from diverse groups have become plant or animal parasites. Two nematode groups identified by the presence/absence of sensory phasmids have partly been ratified by molecular studies recognising three subclasses: Enoplia and Dorylaimia (both without phasmids) and Chromadoria (most with phasmids). Most Enoplia are free-living marine organisms but some are found in freshwater, and on land as plant parasites. The Dorylaimia comprise numerous freshwater and terrestrial species, including major groups of plant and animal parasites. The Chromadoria is represented by many marine groups as well as a terrestrial group of plant and animal parasites. The taxonomic ranks of many nematode assemblages vary considerably depending on which classification system has been followed. Molecular phylogenetic studies, however, have supported the separate

classification of most groups, particularly at the level of superfamily. Collectively, species from at least 16 superfamilies are considered to pose serious threats to human and animal health as infectious diseases.

CLASSIFICATION* OF SUPERFAMILIES OF PARASITIC NEMATODES
Class: Enoplea (Aphasmidea, Adenophorea) (gland-bearers, cylindrical oesophagus, no phasmids, setae, two testes)
Subclass: Dorylaimia (five or more oesophageal glands, buccal stylet (odontostyle), free-living or parasitic)[clade I(2)]
Order: Trichinellida (Trichocephalida, Trichurida) (single spicule, stichosome oesophagus, L1 with buccal stylet)
Superfamily: Trichinelloidea (oesophagus with short anterior muscular and long posterior glandular portions)
Class: Chromadorea (spiral amphids, 3 oesophageal glands, usually annulated bodies, free-living and parasitic)
Order: Rhabditida (Secernentea, Phasmidea) (secretors, phasmids present, amphids anterior, bulbous oesophagus)
Suborder: Rhabditina (free-living or parasitic in invertebrates/lower vertebrates)[clade V(9)]
Infraorder: Rhabditomorpha ('rod-shaped' buccal cavity)
Superfamily: Rhabditoidea (open tube stoma, excretory system with lateral canals)
Superfamily: Strongyloidea (bursate males, prominent buccal capsules, parasites of mammals, birds, reptiles)
Suborder: Spirurina (animal parasites, many use invertebrate intermediate hosts (IH))[clade III(8)]
Incertae sedis Superfamily: Dracunculoidea (elongate parasites of vertebrate tissues, freshwater crustacean IH)
Infraorder: Ascaridomorpha (large roundworms, three large lips, numerous caudal papillae)
Superfamily: Ascaridoidea (ascarids, eggs thick-shelled, larvae may undertake hepato-pulmonary migration)
Superfamily: Heterakoidea (preanal sucker anterior to cloaca in males, direct cycle, infection by egg ingestion)
Infraorder: Gnathostomatomorpha ('jaw-mouthed' due to unique bulbous armed heads)
Superfamily: Gnathostomatoidea (first IH copepod, often use paratenic hosts)
Infraorder: Oxyuridomorpha (pinworms, pointed tails, oesophagus with terminal bulb, males with single spicule)
Superfamily: Oxyuroidea (common in mammals, birds, reptiles, amphibians)
Infraorder: Spiruromorpha (enigmatic clade linked by molecular characters, indirect cycles with IHs)
Superfamily: Acuarioidea (small parasites mostly of birds, with cephalic cordons, ptilina or serrated shields)
Superfamily: Camallanoidea (conspicuous phasmids, L1 with dorsal tooth, ovoviviparous, L1-L3 in copepod)
Superfamily: Filarioidea (tissue-dwelling filarial parasites, lack lips, infect tissues/vessels, arthropod IH)
Superfamily: Habronematoidea (unique head structures with small pseudolabia and median lips)
Superfamily: Physalopteroidea (stomach worms in mammals, insect IH)
Superfamily: Spiruroidea (pseudolabia, bipartite oesophagus, infect birds (crop/gizzard), arthropod IHs
Superfamily: Thelazioidea (eye-worms of birds and mammals, transmitted by insects)
Suborder: Tylenchina (fungal, plant and animal parasites)[clade IV(10,11,12)]
Infraorder: Panagrolaimomorpha (free-living or parasitic (insects, reptiles, amphibians, mammals))
Superfamily: Strongyloidoidea (dauer stages, lip region without processes, striated cuticle)

*Contemporary genotypic classification schemes recognize strong monophyletic clades at the level of superfamily and infraorder, while previous phenotypic classification schemes had ranked many as separate orders.

The infraorder Oxyuridomorpha comprises the pinworms, unique microphagous nematodes with pointed tails, an oesophagus with a terminal bulb and the males having only a single spicule. Pinworms are conventionally classified in the order Oxyurida, the only major nematode group with adult representatives in either vertebrates or invertebrates. Two superfamilies are recognised: Oxyuroidea (parasites of the posterior gut of vertebrates (including mammals, birds and some reptiles) and Thelastomatoidea (parasites of invertebrates, especially herbivorous arthropods with a fermentation chamber (such as cockroaches, diplopods, orthopterans)). Members of the superfamily Oxyuroidea are distinguished by small nonbursate males with reduced numbers of caudal papillae and females with complex ovejectors producing thin-shelled eggs flattened on one side. The parasites have monoxenous transmission cycles whereby unembryonated eggs are passed into the environment with host faeces or gravid females migrate to the anus and deposit eggs in the perianal region. Three families are recognised: Oxyuridae (amphids non-pedunculate, genital cone without sclerotized supporting structure, male tail irregular, often bluntly truncate with or without dorsal point, sometimes with large digitiform papillae extending into caudal alae, parasitic in mammals and rarely birds); Pharyngodonidae (amphids pedunculate, genital cone supported by V-shaped sclerotized structure, parasitic in lower cold-blooded vertebrates, and a few in archaic mammals); and Heteroxynematidae (amphids non-pedunculate, genital cone without sclerotized supporting structure, male tail regular, conical or flattened dorsoventrally, parasitic in mammals and birds).

The family Oxyuridae contains 25 genera classified into 3 subfamilies: Oxyurinae (short oesophagus, male tail short with broad alae supported by long narrow papillae, single spicule, *Austroxyuris*, *Paraustroxyuris*, *Macropoxyuris* and *Potoroxyuris* in Australian marsupials, *Auchenacantha* in Dermoptera, *Citellina* in sciurids, *Hoplodontophorus* in hyracoids, *Oxyuris* in perissodactyls and *Skrjabinema* in artiodactyls); Syphaciinae (male gubernaculum with hook, area rugosa with parallel transverse grooves, well-developed caudal appendix, 5 tribes: Syphaciini (*Syphacia* (incl. subgenera *Syphacia*, *Seuratoxyuris*, *Cricetoxyuris*, *Segienamsyphacia, Rumbaisyphacia*), *Syphatineria* (incl. subgenera *Syphatineria*, *Africanoxys*, *Quentenora*, *Orientoxys*), *Sypharista* (incl. subgenera *Sypharista*, *Petauxyuris*, *Quentinema*), *Syphabulea* and *Lorentzicola*); Hilgertini (*Hilgertia*, *Heteromyoxyuris*, *Rauschtineria*); Passulurini (*Passalurus*); Acanthyoxyurini (*Acanthoxyurus*, *Idiuoxyuris*, *Petronema, Zenkoxyuris*); and

Protozoophagini (*Protozoophaga*, *Helminthoxys*, *Wellcomia*); parasitic in rodents and lagomorphs); and Enterobiinae (sexual dimorphism of lateral alae (single-crested in males, double-crested in females), uterine tube with dividing diaphragm, *Enterobius* (incl. subgenera *Enterobius*, *Colobenterobius*), *Trypanoxyuris* (incl. subgenera *Trypanoxyuris*, *Hapaloxyuris*, *Paraoxyuronema*, *Rodentoxyuris*), *Lemuricola* (incl. subgenera *Lemuricola*, *Protenterobius*, *Madoxyuris*), *Xeroxyuris,* parasitic in primates and sciurids). Representative pinworm genera of medical and veterinary significance are tabulated below:

Genus	No. spp.	Definitive Hosts	Location	Adult worms	Eggs	Transmission
Family: Oxyuridae						
Subfamily: Syphaciinae						
Syphacia	88	rodents	large intestines	1-6 mm long, small cervical alae, oesophagus with terminal globular bulb, eggs oviposited around anus	72-153 x 25-55 µm, reniform, thin-shelled	ingestion of larvated eggs
Passalurus (pinworm)	3	lagomorphs, rodents	large intestines	3-11 mm long, circular cuticular striations, oesophagus with terminal bulb, eggs passed in faeces	93-105 x 43-45 µm, D-shaped, thin-shelled	ingestion of larvated eggs
Subfamily: Oxyurinae						
Oxyuris (pinworm)	21	mammals, birds, reptiles	caecum, large intestines	1-16 cm long, oesophagus with terminal globular bulb, pin-tailed, eggs oviposited around anus	85-95 x 40-45 µm, D-shaped, thin-shelled	ingestion of larvated eggs
Subfamily: Enterobiinae						
Enterobius pinworms	27	primates, rodents	large intestines	1-15 mm long, lateral alae, oesophagus with terminal bulb, slender pointed tails, eggs oviposited around anus	50-60 x 20-30 µm, D-shaped, thin-shelled	ingestion of larvated eggs
Family: Heteroxynematidae						
Subfamily: Heteroxynematinae						
Aspiculuris	23	rodents	large intestines	2-5 mm long, prominent cervical alae, oesophagus with terminal oval bulb, eggs passed in faeces	70-98 x 29-50 µm, spindle-shaped, thin-shelled	ingestion of larvated eggs

The genus *Syphacia* contains pinworms with cuticularized cephalic plates around the mouth (round, quadrangular, oval, or laterally-elongated) in both sexes, lateral amphids, cephalic papillae not arranged in a square, cervical alae often present, ventral excretory pores and males with 2-4 ventral cuticular swellings. Over 80 species have been classified in 5 subgenera: *S.* (*Syphacia*) (oval cephalic plate, deirids not seen, accessory piece of gubernaculum without ornamentations); *S.* (*Seuratoxyuris*) (buccal ornamentation, deirids apparent, accessory piece of gubernaculum with ornamentations, short conical tail); *S.* (*Cricetoxyuris*) (quadrangular cephalic plate, well-developed lateral alae); *S.* (*Segienamsyphacia*) (oral aperture hexagonal in female); and *S.* (*Rumbaisyphacia*) (oral aperture not hexagonal, anterior margin of pharynx setiferous). *Syphacia* spp. are common pinworms found in the intestines of murid, cricetid and sciurid rodents and some lagomorphs throughout the world, often becoming nuisances in pet stores and laboratory animal colonies.

***Syphacia* species**	**Definitive hosts**	**Location [Clinical signs]**	**Distribution**
S. (*Syphacia*) *abertoni*	Rodentia: murid (common rock rat)	caecum	Australia
S. agraria	Rodentia: murid (striped field mouse, small Japanese field mouse, large Japanese field mouse, Himalayan field mouse, Korean field mouse), cricetid (tundra vole)		Asia
S. (*Syphacia*) *alata*	Rodentia: cricetid (hairy-tailed bolo mouse, Cana rice rat, black-footed pygmy rice rat)		South America
S. (*Syphacia*) *arctica*	Rodentia: cricetid (northern collared lemming)		Europe
S. arvicolae	Rodentia: cricetid (common vole, narrow-headed vole, tundra vole, European water vole)		Eurasia
S. (*Syphacia*) *australasiensis*	Rodentia: murid (Cape York rat)		Australasia
S. bonnei	Primates: atelid (Venezuelan red howler)		South America

S. (*Syphacia*) *boodjamullensis*	Rodentia: murid (common rock rat)	caecum	Australia
S. (*Cricetoxyuris*) *brachyuromyos*	Rodentia: nesomyid (Betsileo short-tailed rat)		Madagascar
S. (*Syphacia*) *brevicaudata*	Rodentia: murid (desert mouse)		Australasia
S. carlitosi	Rodentia: cricetid (Azara's grass mouse)		South America
S. caudibandata	Lagomorpha: leporid (common hare)		Asia
S. (*Syphacia*) *carnarvonensis*	Rodentia: murid (little native mouse)		Australia
S. cepapi	Rodentia: sciurid (Smith's bush squirrel)		Americas
S. citelli	Rodentia: sciurid (Wyoming ground squirrel, Richardson's ground squirrel, Townsend's ground squirrel)		North America
S. (*Syphacia*) *coccymyos*	Rodentia: murid (Rummler's brush mouse)		Asia
S. (*Syphacia*) *coli*	Rodentia: sciurid (Palawan flying squirrel), murid (Polynesian rat)		Asia
S. (*Seuratoxyuris*) *criteci*	Rodentia: cricetid (large vesper mouse, terraced rice rat, golden hamster), caviid (rock cavy)		Eurasia, Americas
S. (*Syphacia*) *critesi*	Rodentia: sciurid (Northern Palawan tree squirrel, Palawan flying squirrel)		Asia
S. (*Syphacia*) *darwini*	Rodentia: murid (Papua grassland mosaic-tailed rat)		Australia
S. (*Syphacia*) *emileromani*	Rodentia: murid (small Japanese field mouse, large Japanese field mouse, Korean field mouse, wood mouse)		Asia
S. eutamii	Rodentia: sciurid (yellow pine chipmunk, panamint chipmunk, Palmer's chipmunk)	caecum, large intestine	Americas
S. (Seuratoxyuris) evaginata	Rodentia: cricetid (marsh rice rat)		Asia
S. (*Syphacia*) *frederici*	Rodentia: murid (striped field mouse, small Japanese field mouse, large Japanese field mouse, Korean field mouse, wood mouse, yellow-necked mouse, herb field mouse, eastern broad-toothed field mouse), cricetid (tundra vole), dipodid (northern birch mouse)		Asia
S. funambuli	Rodentia: sciurid (northern palm squirrel)		Asia
S. guptae	Perciformes: trichiurid (smallhead hairtail)		Asia
S. (*Syphacia*) *helidonensis*	Rodentia: murid (eastern chestnut mouse)		Australia
S. hodarae	Rodentia: cricetid (small vesper mouse)	caecum, rectum	South America
S. (*Syphacia*) *insignis*	Rodentia: sciurid (three-striped ground squirrel)		Asia
S. (*Syphacia*) *kinsellai*	Rodentia: cricetid (black-footed pygmy rice rat)	caecum	Asia
S. (*Rumbaisyphacia*) *kumis*	Rodentia: murid (Sulawesi soft-furred rat)		Indonesia
S. laguri	Rodentia: cricetid (steppe lemming)		Eurasia
S. lahorea	Rodentia: sciurid (northern palm squirrel)		India
S. (*Syphacia*) *longaecauda*	Rodentia: murid (mountain mosaic-tailed rat)		New Guinea
S. (*Syphacia*) *lophuromyos*	Rodentia: murid (rusty-bellied brush-furred rat)		Africa
S. (*Syphacia*) *lorentzimyos*	Rodentia: murid (New Guinean jumping mouse)		New Guinea
S. (*Syphacia*) *magnispicula*	Rodentia: sciurid (Northern Palawan tree squirrel, Palawan flying squirrel)		Asia
S. (*Syphacia*) *mamelontenuis*	Rodentia: murid (New Guinean jumping mouse)		New Guinea
S. (*Syphacia*) *maxomyos*	Rodentia: murid (Whitehead's spiny rat, Musschenbroek's spiny rat)		Indonesia
S. (Seuratoxyuris) megadeiros	Rodentia: cricetid (Alfaria's rice rat, broad-footed climbing mouse)		South America
S. (*Syphacia*) *megaloon*	Rodentia: murid (mouse)		
S. (*Cricetoxyuris*) *mesocriceti*	Rodentia: cricetid (Chinese striped hamster, golden hamster, grey dwarf hamster)	caecum	Asia, North America
S. microtus	Rodentia: cricetid (common vole)		Eurasia

S. (*Syphacia*) *millardiae*	Rodentia: murid (soft-furred rat)		India
S. minuta	Rodentia: murid (eastern spiny mouse)		Asia
S. (*Syphacia*) *montana*	Rodentia: murid (yellow-necked mouse, Korean field mouse, wood mouse, Eurasian harvest mouse, yellow-spotted brush-furred rat), cricetid (muskrat, common vole, bank vole, field vole, reed vole, tundra vole, narrow-headed vole, Sikkim mountain vole, European pine vole, Hokkaido red-backed vole, Anderson's red-backed vole, grey red-backed vole, northern red-backed vole, Japanese grass vole, Smith's vole, Maximowicz's vole, wood lemming, Chinese striped hamster), dipodid (Mongolian five-toed jerboa, northern birch mouse), sciurid (red squirrel); Lagomorpha: ochotonid (Daurian pika); Carnivora: canid (red fox)		Eurasia
S. (*Syphacia*) *muris* (rat pinworm) (syn. *S. baylisi*, *ratti*)	Rodentia: murid (brown rat, black rat, white rat, yellow-tailed rat, rice field rat, lesser rice field rat, dusky field rat, pale field rat, bush rat, Polynesian rat, Alexandrine rat, Asian house rat, Indian house rat, African grass rat, Nile rat, small white-toothed rat, red spiny rat, Natal multimammate mouse, house mouse, lesser short-tailed gerbil); cricetid (northern red-backed vole, Maximowicz's vole): Eulipotyphla: soricid (giant musk shrew); Primates: hominid (human)	caecum, colon	worldwide
S. myopsi	Aulopiformes: synodontid (bluntnose lizardfish)		Atlantic
S. (*Syphacia*) *nigeriana*	Rodentia: cricetid (common vole, field vole, tundra vole, southwestern water vole, Mediterranean pine vole, Lusitanian pine vole, European water vole, European snow vole, Cabrera's vole, Gunther's vole), murid (Stella wood mouse		Eurasia, Africa
S. (*Syphacia*) *niobe*	Rodentia: murid (moss-forest rat)		Indonesia
S. (*Syphacia*) *obvelata* (mouse pinworm)	Rodentia: murid (house mouse, Ryukyu mouse, Cook's mouse, white mouse, striped field mouse, Korean field mouse, Eurasian harvest mouse, yellow-necked mouse, wood mouse, Algerian mouse, brown rat, black rat, white rat, Turkestan rat, Philippine black rat, Alexandrine rat, soft-furred rat, lesser bandicoot rat, midday jird, Shaw's jird, Tamarisk jird, Indian desert jird, Libyan jird, Mongolian gerbil, North African gerbil, lesser Egyptian gerbil, greater Egyptian gerbil, great gerbil, fat-tailed gerbil, Indian gerbil, lesser Egyptian jerboa, greater Egyptian jerboa, jerboa), sciurid (squirrel, ground squirrel, long-tailed ground squirrel, Daurian ground squirrel, flying squirrel, Siberian chipmunk), caviid (guinea pig), cricetid (muskrat, big-eared rat, common vole, bank vole, reed vole, Muisk vole, meadow vole, field vole, tundra vole, narrow-headed vole, grey red-backed vole, northern red-backed vole, large-eared vole, Mediterranean pine vole, Mogollon vole, Maximowicz's vole, Brandt's vole, wood lemming, Arctic lemming, Siberian brown lemming, Chinese striped hamster, winter white dwarf hamster); Eulipotyphla: soricid (common shrew, lesser white-toothed shrew, greater white-toothed shrew, Eurasian water shrew, Eurasian pygmy shrew, alpine shrew); Primates: hominid (human)	caecum, colon	worldwide
S. oceanica (syn. *Syphatineria*)	Rodentia: sciurid (Northern Palawan tree squirrel)		Asia
S. (*Syphacia*) *odilbainae*	Rodentia: murid (short-tailed cane mouse)		Asia
S. (*Syphacia*) *ohtaorum*	Rodentia: murid (Ryukyu mouse, Taiwan field mouse)		Asia
S. (*Cricetoxyuris*) *okuensis*	Rodentia: murid (Mount Oku rat)		Asia
S. oryzomyos	Rodentia: cricetid (marsh rice rat)		Americas
S. oschanensis	Rodentia: murid (Turkestan rat)	caecum	Russia
S. (Seuratoxyuris) pahangi	Rodentia: murid (Indo-Malayan pencil-tailed tree mouse, Chinese white-bellied rat)		Asia

S. pallaryi (syn. *Syphatineria*)	Rodentia: sciurid (Barbary ground squirrel)		Africa
S. (*Syphacia*) *paruromyos*	Rodentia: murid (Sulawesi giant rat)		Indonesia
S. paraxeri	Rodentia: sciurid (red bush squirrel)		Africa
S. pearsei (= *Syphatineria* (*Africanoxys*))	Rodentia: sciurid (red-legged sun squirrel, Gambian sun squirrel)	caecum	Africa
S. pennanti	Rodentia: sciurid (northern palm squirrel)		Asia
S. (Seuratoxyuris) peromysci (syn. *S. samorodini*)	Rodentia: cricetid (cotton mouse, white-footed mouse, deer mouse, Oldfield mouse, Florida mouse)		North America
S. (Seuratoxyuris) petrusewiczi	Rodentia: cricetid (common vole, bank vole, grey red-backed vole, northern red-backed vole, Japanese red-backed vole, Chinese striped hamster), murid (Eurasian harvest mouse)		Eurasia
S. (Seuratoxyuris) phyllotios	Rodentia: cricetid (Darwin's leaf-eared mouse)		South America
S. (*Syphacia*) *pseudomyos*	Rodentia: murid (sandy inland mouse)		Australia
S. quentini	Rodentia: cricetid (dusky rice rat)	caecum	South America
S. (*Cricetoxyuris*) *ramirohitra*	Rodentia: murid (gregarious short-tailed rat)		Asia
S. (Seuratoxyuris) rauschi	Rodentia: cricetid (northern red-backed vole)		Eurasia
S. (*Syphacia*) *rifaii*	Rodentia: murid (hill rat)		Indonesia
S. sarawakensis	Rodentia: sciurid (gray-cheeked flying squirrel)		Indonesia
S. sciuri	Rodentia: sciurid (Indian palm squirrel)		Asia
S. (*Syphacia*) *semiadii*	Rodentia: murid (spiny Boki Mekot rat)		Indonesia
S. sigmodoni (*sigmodontis*?)	Rodentia: cricetid (hispid cotton rat)		Americas
S. srtolana	Rodentia: cricetid (grey-red-backed vole)		Eurasia
S. srivastavi	Artiodactyla: suid (pig)	stomach	India
S. (*Syphacia*) *stroma*	Rodentia: murid (mouse, striped field mouse, alpine field mouse, Ural field mouse, eastern broad-toothed field mouse, wood mouse, yellow-necked mouse, Eurasian harvest mouse, yellow-spotted brush-furred rat, gerbil), cricetid (bank vole, field vole, reed vole, tundra vole, Maximowicz's vole, grey red-backed vole, northern red-backed vole, European water vole); Passeriformes: sturnid (common starling)		Eurasia
S. (Syphacia) sulawesiensis	Rodentia: murid (yellow-tailed rat)		Asia
S. (*Syphacia*) *taeromyos*	Rodentia: murid (Celebes rat)		Indonesia
S. thompsoni	Rodentia: sciurid (northern flying squirrel, southern flying squirrel, fox squirrel, red squirrel, American red squirrel, Caucasian squirrel)		North America
S. tineri	Rodentia: murid (brown rat)		India
S. toschevi	Rodentia: sciurid (red squirrel)		Eurasia
S. transafricana (= *Syphatineria*)	Rodentia: sciurid (striped ground squirrel, unstriped ground squirrel)		Africa
S. ungula	Rodentia: sciurid (red squirrel)		Europe
S. vandenbrueli	Rodentia: murid (Eurasian harvest mouse)		Eurasia
S. (*Syphacia*) *venteli*	Rodentia: cricetid (scaly-footed water rat), murid (Costa Rican dusky rat		South America
S. (*Segienamsyphacia*) *yuniae*	Rodentia: murid (Sulawesi soft-furred rat)		Indonesia

Parasite morphology: *Syphacia* spp. form 3 different types of morphological developmental stages: eggs; larvae (4 consecutive stages designated L1-L4); and adult worms. The eggs are asymmetrically ellipsoidal being flattened on one side and convex on the other (variously described as reniform, crescentic, banana- or D-shaped). Collectively, the eggs range in size from 72-153 x 25-55 µm, with considerable variation between species (e.g. *S. muris* eggs measure 72-82 x 25-36 µm while *S. obvelata* eggs measure 118-153 x 33-55 µm). They are bound by thin double-walled eggshells with a small opercular cap near one end and they generally contain a developed larva (some *S. muris* eggs may contain a central morula). Little information is available on larval morphology as development from L1 to L3 occurs within the egg and L4 are transient endoparasitic stages in the host. L3 mechanically freed from eggs measured 140-220 µm in length. Adults are small white cylindrical pinworms measuring 1.1-6.0 mm long with narrow tapering tails containing irregular ridges. They are bound by a tough cuticle with transverse annulations (sometimes with interspersed longitudinal ridges), small cervical alae (prominent in male *S. obvelata* but inconspicuous in females, present in *S. muris* females but absent in males) and long lateral alae (absent on *S. obvelata* males) annulated in continuity with the body cuticle. The head is bulb-like and often inflated forming cephalic vesicles (absent in *S. muris*). The anterior end contains a cuticularized cephalic plate or cap (usually round but sometimes oval, square or laterally elongated) with a central mouth surrounded by 3 fleshy lips (without labial papillae), 4 cephalic papillae (not arranged in a square) and 2 lateral amphids. They have a small buccal cavity and a tripartite oesophagus with a prominent posterior globular/subglobular bulb with a triradiate valve-like apparatus. Adult worms are sexually dimorphic, with females being larger than males (e.g. 2.8-4.0 cf. 1.2-1.3 mm for *S. muris*, 3.4-6.0 cf. 1.1-1.6 mm for *S. obvelata*). Mature females have large uteri filled with eggs (often obscuring internal anatomy), a muscular ovejector and an anterior vulva that is either slit-like and guarded by 2 fleshy lips or tetraradiate and guarded by 4 lips. Mature males have a single testis connected to the posterior intestines and opening into a common cloaca. They have long pointed curved tails (without caudal alae), a gubernaculum (sometimes with an accessory hook) and a single long prominent spicule (absent in *Aspiculuris*). Males also have 2-4 conspicuous ventral cuticular protuberances (called mamelons) which are not regularly spaced between species (more posterior in *S. muris* than *S. obvelata*) and have different numbers of transverse striae (8-9 in *S. muris*, 10-12 in *S. obvelata*).

Site of infection: Endoparasitic stages (developing larvae and adult worms) mainly infect the caecum, and sometimes the colon, of their rodent hosts. Infective larvae develop within worm eggs contaminating the external environment.

Pathogenesis: Most infections remain asymptomatic as the parasites do not invade host tissues but feed in the lumen on intestinal content. Heavy infections have sometimes been associated with various inflammatory conditions (perianal irritation, mucoid enteritis) or intestinal perturbations (intestinal impaction, intussusception, rectal prolapse) contributing to unthriftiness (dull coat, depressed growth, loss of condition). The highest worm burdens are found in weaning animals, especially males. Mice develop an age resistance to infection around 4-9 weeks of age with immune expulsion of worms and the acquisition of protection against re-infection (apparently involving strong Th2 cellular responses). Some immunocompromised strains of mice are unable to clear parasites and develop chronic infections, but often without causing disease.

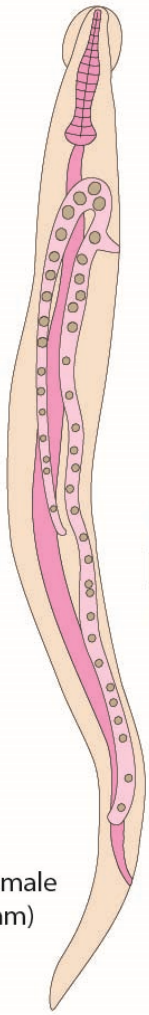
Developmental cycle and mode of transmission: *Syphacia* spp. have direct monoxenous life-cycles involving the ingestion of worm eggs containing infective larvae. Gravid females migrate from the caecum through the colon to the rectum and anus to deposit some 250-550 eggs in small groups or clumps on the perianal area before dying. Migrating adult worms are sometimes found in mucus covering faecal pellets. Eggs develop infective larvae within 5-20 hours of deposition and those dislodged into the external environment may survive for weeks in moderate conditions of temperature and humidity. Some parasite species also demonstrate distinct daily patterns of egg deposition: e.g. most *S. muris* eggs are laid during the daytime (circadian rhythm) when their nocturnally-active hosts are resting and grooming in burrows or nests. Rodents become infected when they ingest infective eggs either directly from the perianal region whilst grooming or less directly when they contaminate bedding, food or water. There are also some reports of auto-infection occurring by retro-infection when hatched larvae migrate through the anus into the colon. Ingested eggs hatch in small intestine releasing L3 which migrate to the caecum and develop within the lumen (larvae do not undergo local histotrophic development nor any somatic or extra-intestinal migration). L3 moult twice over 2-4 days to subadults (often called L5) which then mature over several days to adults. Fertilized females have been found as early as 5 days after infection, and migrating gravid females as early as 6-9 days. The prepatent period (time from infection to first egg deposition) ranges from 8-11 days for *S. muris* and 11-15 days form *S. obvelata.*

Differential diagnosis: Infections rarely produce any clinical signs although perianal irritation may be indicative. Worm eggs are usually detected by microscopic examination of sticky-tape impression smears collected from perianal regions. The eggs are characteristic in size and shape, having a distinctive asymmetrical D-shape (rather than being spindle-shaped like *Aspiculuris* eggs). Worm eggs have also been detected occasionally in anal swabs and faecal floats. Infections may also be diagnosed at post-mortem by the microscopic detection of adult worms in samples of caecal content placed in saline (pinworms usually migrate out of contents into saline over a short period) or by examination of fixed and stained histological sections. *Syphacia* spp. are more commonly found in the caecum while *Aspiculuris* spp. generally occur in the colon. A range of molecular biological techniques have been applied to the characterization of pinworm species by restriction fragment length polymorphism (RFLP) analyses, random amplified polymorphic DNA (RAPD) analyses and the polymerase chain reaction (PCR) amplification and sequencing of nuclear genes (ribosomal RNA and internal transcribed spacers) and mitochondrial genes (cytochrome c oxidase subunit 1).

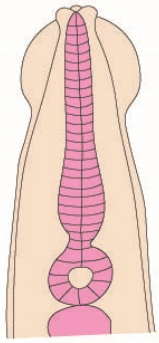
Treatment and control: A wide range of chemicals have been used to treat pinworm infections in laboratory rodents, most as oral medications administered via food or water. Conventional anthelmintics, such as benzimidazoles (thiabendazole, fenbendazole), diethylenediamines (piperazine), organophosphonates (dichlorvos, trichlorfon, haloxon) and heterocyclic thiazines (phenothiazine), were effective against adult worms and larval stages but not eggs. Earlier studies reported some anthelmintic effects using cyanine dyes (pyrvinium), triarylmethane dyes (gentian violet, crystal violet), fluorides (sodium fluoride), iodides (stilbazium iodide), substituted dihydroxybenzene (hexylresorcinol) and halogenated hydrocarbons (carbon tetrachloride, tetrachloroethylene), while more recent studies showed that several antibiotics (terramycin, aureomycin, bacitracin, puromycin) reduced worm burdens. Regular or sustained treatments were required to prevent rapid re-infection in addition to thorough cleaning of animal holding facilities. Worm eggs have been found on cages, equipment, ventilation ducts and even dust in laboratory animal colonies, and the eggs are highly resistant to cold, desiccation and many disinfectants, but are susceptible to heat. Preventive strategies should therefore not only include the removal and disposal of host faeces and soiled bedding, but also the sterilization of cages and rooms preferably using steam-cleaning devices. Care should be taken to prevent the contamination of food and water supplies, and routine surveillance, quarantine and isolation procedures should also be implemented to detect and manage infections in rodent colonies, as they can be difficult to eradicate once entrenched.

Syphacia

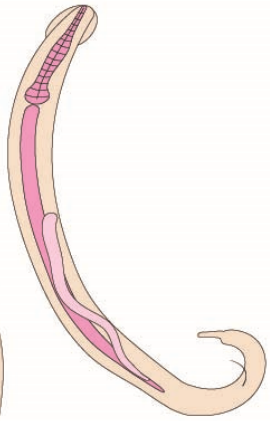
intestines
(mild enteritis, illthrift)



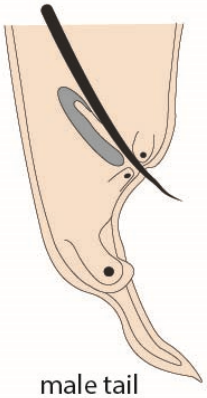
adult female
(~ 4 mm)



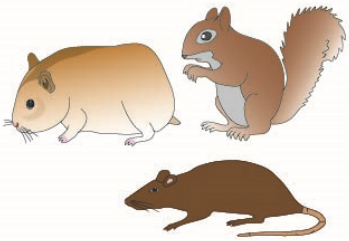
head



adult male
(~ 1.5 mm)



male tail
(lateral)



Definitive Hosts
(rodents,
lagomorphs)

eggs ingested
via grooming or
with food/water
(possiblly some
L3 retro-infection)

L3 develop
within eggs

eggs
(~ 100 µm)

eggs may be dislodged
to contaminate
environment

sticky
eggs
attached
around
anus

contaminative transmission

Syphacia adult worm

Syphacia worm eggs

Syphacia adult worm, male tail

Syphacia adult worm, head