Oxyuris
(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 *Oxyuris equi* causes perianal pruritus (itching) and restlessness in horses.

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:	*Oxyuris* (parasitic in large intestines of horses)
Species:	*O. equi* (causes perianal pruritus in horses)

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*); 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* 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: 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: Syphaciinae						
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
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
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 *Oxyuris* comprises pinworms whose buccal cavities have complex armature, non-pedunculate anterior amphids, oesophagi with posterior bulbs, males with irregular genital cones without sclerotized supporting structures, and females with long tapering pin-tails. Over 20 species have been described from the large intestines (caecum and colon) of vertebrates (mammals, birds, reptiles). They have direct monoxenous life-cycles whereby female worms migrate to the anus and attach eggs to the peri-anal skin which subsequently drop off to contaminate the environment. Few species have been associated with clinical disease, although *O. equi* commonly found in horses worldwide may cause intense peri-anal pruritus with loss of condition.

***Oxyuris* species**	**Definitive hosts**	**Location [Clinical signs]**	**Distribution**
O. acutissima	Rodentia: sciurid (red squirrel)		Eurasia
O. alata	Carnivora: mustelid (European badger)		Europe
O. ambiguus (= *Passalurus*)	Lagomorpha: leporid (rabbit)		worldwide
O. armata	Sauria: lacertid (common wall lizard)		Europe
O. bicristata (syn. *Trypanoxyuris*) (= *Rodentoxyuris*)	Rodentia: sciurid (fox squirrel, New World flying squirrel)		North America
O. caudata	Pterocliformes: pteroclid (Namaqua sandgrouse)		Africa
O. equi (syn. *O. curvula*) (equine pinworm)	Perissodactyla: equid (horse, Przewalski's horse, Polish konik horse, donkey, mule, onager, plains zebra, Grant's zebra), giraffid (Angolan giraffe); Primates: hominid (human)	caecum, colon [perianal pruritus]	worldwide
O. flagellum	Hyracoidea: procaviid (rock hyrax)		Europe
O. inflata	Testudines: testudinid (Greek tortoise); Pterocliformes: pteroclid (banded sand-grouse)		Europe

O. karamoja	Perissodactyla: rhinocerotid (white rhinoceros, black rhinoceros)		Africa
O. lobata	Testudines: testudinid (tent tortoise)		Africa
O. lunata	Testudines: testudinid (tent tortoise)		Africa
O. magnavulvaris (= *Thelandros*)	Urodela: plethodontid (green salamander, black salamander)	large intestines	North America
O. megaloon	Sauria: gekkonid (Leschenault's leaf gecko)		Asia
O. obvelata	Rodentia: murid (black rat)		
O. opisthogonima	Testudines: testudinid (tent tortoise)		Africa
O. paradoxa	Carnivora: mustelid (European polecat)		Europe
O. parallela (syn. *O. polyoon, Enterobius*) (now *Xeroxyuris*)	Rodentia: sciurid (Cape ground squirrel)		Africa
O. perarmata	Testudines: testudinid (tent tortoise)		Africa
O. praeputialis	Anura: bufonid (toad)		
O. pugio	Hyracoidea: procaviid (rock hyrax)		Europe
O. semilanceolata	Rodentia: murid (mouse)		
O. sumatrensis	Diplopoda: platyrhacid (millipede)		
O. tenuicauda	Perissodactyla: equid (Crawshay's zebra)		Africa

Parasite morphology: *Oxyuris* spp. form 3 different types of developmental stages: namely, eggs, larvae (4 consecutive stages encoded L1-L4); and adult worms. Eggs are ovoid but asymmetrical having one flattened side thus forming a D-shape. They range in size from 85-95 x 40-45 µm and have a white-yellow thin eggshell with a pseudo-operculum at one pole. When laid the eggs are partly embryonated containing a central gastrula stage. Larval development continues within the eggshell with the formation of first-stage larvae (L1) which moult twice to form infective L3. Following infection, eggs hatch releasing L3 which grow rapidly to 3-11 mm in length. L4 developing in host tissues measure from 5-10 mm long and have a large modified buccal capsule used to grasp mucosal tissue, an oesophagus with a well-developed posterior portion, and long tapering tails. Adults are large white-grey pinworms with stout cylindrical bodies (measuring from 1-16 cm in length) being thickened anteriorly and distinctly tapering posteriorly (pin-tailed). Worms are bound by a semi-transparent cuticle often with coarse transverse striations, and they have an anterior hexagonal mouth with 2 lateral lips, each with 2 sucker-like papillae. They also have non-pedunculate anterior amphids, a small buccal capsule armed with 3 bristle-like teeth at bottom, a short double bulbed oesophagus with a corpus, isthmus and posterior bulb with a valvular apparatus, and a subterminal anus/cloaca. Adult worms are sexually dimorphic, with males being much smaller than females (10-30 mm cf. 24-160 mm). Mature males have a truncated tail, often irregular in shape, with a pair of broad caudal alae supported by a pair of long narrow pedunculate papillae. The genital cone lacks sclerotized supporting structures and they do not have a gubernaculum but possess a single needle-shaped spicule 120-200 µm long. Mature females are didelphic with 2 ovaries and uteri connected to a common vulva opening anterior to the midbody. Females have thin tapering pointed pin-tails, either short (around a third of body length) or long (up to 3 times the body length in mature worms).

Site of infection: Adult worms live free within the large intestines of their hosts, with female worms often congregating in the rectum near the anus. Earlier larval stages undergo transient histotrophic development in the mucosa and crypts of the caecal and colon. There are no free-living larval stages, except for those that develop inside eggs in the external environment.

Pathogenesis: Most infections remain subclinical even though developing larvae feed on the gut mucosal lining and adult worms feed on gut content. Even in heavy infections, developing larvae only occasionally cause caecal and colonic inflammation, sometimes with mucosal erosion and ulceration leading to mild diarrhoea and secondary bacterial colonisation. Most of the pathogenesis associated with infections occurs when gravid female worms migrate out of the anus and deposit eggs on the perianal skin. Worm movement over mucosal surfaces may cause irritation resulting in catarrhal colitis and proctitis (becoming hyperplastic in chronic infections). In addition, the gelatinous cement-like substance used to attach eggs to the skin causes irritation and intense anal pruritus. Hosts become very restless and attempt to relieve the itch by rubbing their hindquarters and tails against solid substrates and objects (such as trees, fence posts and stable walls) often causing hair loss, bare patches of skin with erythematous and haemorrhagic dermatitis, and broken skin with scales and crusts (condition known as rat-tail in horses). Hosts are predisposed to secondary bacterial infections through wounds resulting in further irritation and restlessness. Hosts are distracted from feeding and may develop anorexia, dull coats and progressively lose body condition. Infections in horses occur in weaned foals, yearlings and adults, and there appears to be little immunity to re-infection, with heavy burdens sometimes developing with age. Most infections occur in stabled horses rather than those at pasture due to the heavier contamination of the local environment by worm eggs dropping from horses (rather than via faecal contamination).

Developmental cycle and mode of transmission: These pinworms have direct monoxenous life-cycles involving the shedding of worm eggs from the perianal skin of their hosts and their subsequent oral ingestion following embryonation and larval development.

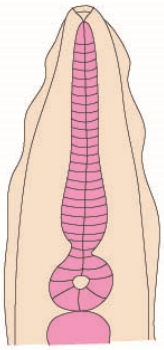
Gravid female worms migrate to the rectum and emerge headfirst through the anus laying eggs in clumps in a grey viscous/gelatinous sticky substance that hardens on contact with air to form white-yellow streaks or crusts. Females are prolific and may produce up to 50,000 eggs, but they shrink as they oviposit and eventually pass out of the anus and die. The worms and their secretions cause intense pruritus which the host attempts to relieve by rubbing against substrates which causes the eggs to dislodge from the skin to contaminate the surrounding environment. In suitable warm moist conditions, the eggs embryonate and moult twice to enclose infective L3 within 3-7 days. Worm eggs are susceptible to desiccation but can survive in moist conditions for periods ranging from 9-10 weeks up to 6 months. Hosts become infected when they ingest larvated eggs in contaminated feed and water. Ingested eggs hatch in the small intestines releasing L3 which move to the large intestines and invade mucosa and crypts in the caecum and colon. They do not undertake any somatic or hepato-pulmonary migration, but do undergo transient histotrophic development in the mucosa for 3-11 days. They then moult to L4 which re-enter the lumen and migrate to the dorsal colon intermittently attaching and feeding on the mucosa. L4 moult to subadults (sometimes designated L5) in 45-60 days and the developing adults feed on intestinal content as they mature over 2-3 months. Fertilised female worms congregate in the rectum where they may live for up to 6 months periodically emerging from the anus to deposit eggs before becoming exhausted and dying. The prepatent period (time from infection to first deposition of eggs) ranges from 120-156 days in horses.

Differential diagnosis: Clinical infections are strongly indicated in equids exhibiting clinical signs of perianal pruritus, dermatitis and hair loss (development of rat-tail). Visual examination of affected areas often reveals white-yellow-grey streaks or crusts, and large white long-tailed female worms may be found in or on faeces, having become dislodged during defaecation. Infections are best confirmed by the microscopic detection of the characteristic D-shaped worm eggs. However, the eggs are rarely passed in faeces so most coprological techniques are not appropriate. Instead, the eggs may be captured on transparent adhesive sticky-tape first applied to the perineum and then stuck onto a glass slide for microscopy. Adult worms may also be detected at post-mortem by dissection of the large intestines and examination of the contents. Molecular biological techniques have been used mostly to examine parasite phylogenetic relationships following the polymerase chain reaction (PCR) amplification of nuclear genes (ribosomal RNA and internal transcribed spacers) and the complete mitochondrial genome (but particularly cytochrome oxidase 1 and cytochrome b genes).

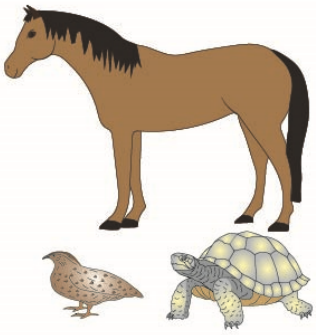
Treatment and control: A range of anthelmintic drugs have been used to treat clinical infections, including benzimidazoles (thiabendazole, cambendazole, parbendazole, oxibendazole, mebendazole, fenbendazole, albendazole, oxfendazole), macrocyclic lactones (ivermectin, moxidectin, abamectin), diethylenediamines (piperazine), tetrahydropyrimidines (pyrantel) and organophosphonates (dichlorvos, trichlorfon), with most being effective against adult or larval pinworms but not eggs. Few anthelmintics have any long-lasting residual activity so repeated treatments are required to prevent re-infections. Various strategies should also be adopted to reduce parasite transmission, primarily by improving hygienic practices. Given that worm eggs are adherent to the host perineum and are then dislodged, maintaining good body hygiene by regular grooming or washing affected areas helps reduce environmental contamination, particularly when soiled litter and bedding are removed and disposed of in nongrazing areas. Holding facilities should be regularly cleansed, not only floors but also potential rubbing spots (walls, doors, rails and posts). Clean food and water should be provided in elevated feed boxes and water troughs that cannot be easily contaminated. Several attempts at biological control have reported variable success using nematophagous fungi (*Pochonia, Duddingtonia, Manacrosporium*) whose mycelial masses entrap worm eggs in soiled litter.

Oxyuris

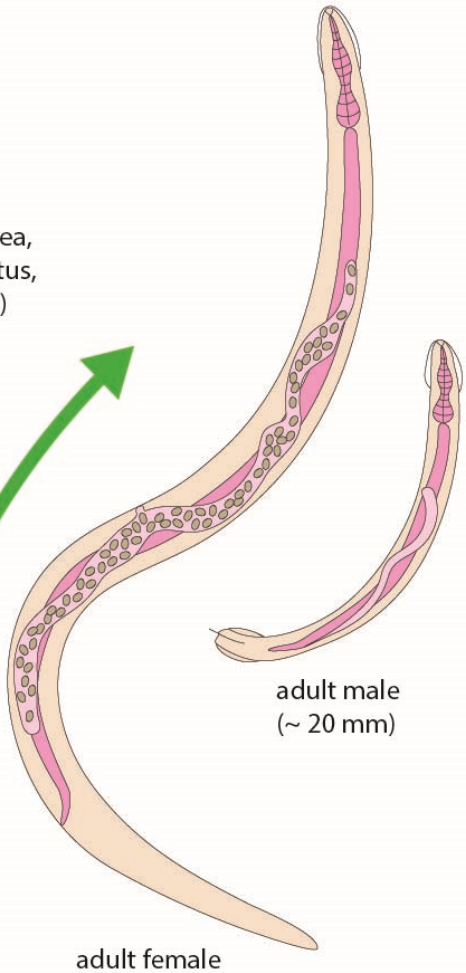
intestines
(colitis, diarrhoea,
perianal pruritus,
restlessness)



head

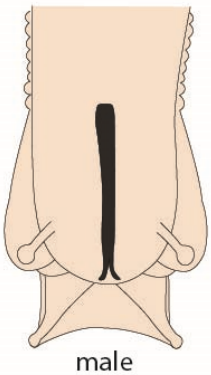


Definitive Hosts
(mammals,
birds, reptiles)



adult female
(~ 90 mm)

adult male
(~ 20 mm)



male
tail

eggs
ingested

L3 develop
within eggs

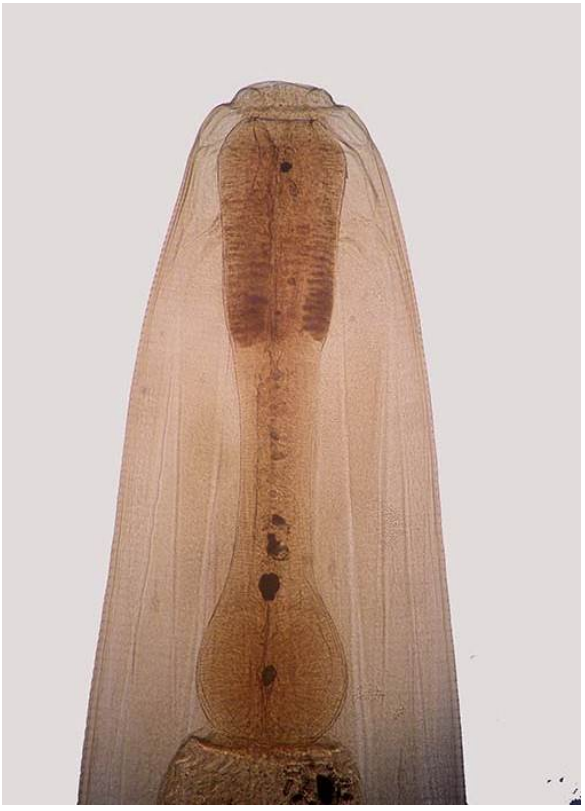
eggs
(~ 90 µm)

eggs
dislodged
into
environment

sticky
eggs
attached
around
anus

faecal-oral transmission

Oxyuris adult worm



Oxyuris adult worm, head