Enterobius
(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 *Enterobius vermicularis* cause perianal pruritus (itching), insomnia and irritability in humans, especially children.

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:	*Enterobius* (parasitic in large intestines of mammals)
Species:	*E. vermicularis* (causes perianal pruritus (enterobiasis) in humans)

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: 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
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
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

Pinworms belonging to the subfamily Enterobiinae have buccal apertures surrounded by 3 prominent lips, each partly covering a corresponding oesophageal tooth (triangular with a small sharp denticle). Adults worms have symmetrical lateral alae (longitudinal expansions of the cuticle running the length of the body) which exhibit sexual dimorphism (single-crested in males, double-crested in females). Some 50 pinworm species have been described from primates around the world, including several *Enterobius* spp. The genus *Enterobius* contains worms with simple buccal cavities and simple cephalic vesicles, cuticular thickenings (corresponding to cuticularized rings) not extending laterally, caudal appendix atrophied or absent, area rugosa without ventral crest, and a cuticular vagina directed posteriorly. Two subgenera are recognised: *E.* (*Enterobius*) (oesophageal teeth without superstructures, cuticularized rings joined with a small square sheet bearing 2 leaf-shaped ventral extensions, lateral alae arise immediately behind cephalic vesicle, female lateral alae with 2 longitudinal parallel crests, males with a short spicule) parasitic in cercopithecid, pongid and hominid primates; and *E.* (*Colobenterobius*) (oesophageal teeth with projections, cuticularized rings connected with a small square without leaf-shaped ventral extensions, lateral alae start behind level of oesophageal bulb, female lateral alae with single crest, males with a long spicule) parasitic in colobid primates. The species *E. vermicularis* is the most common worm found in humans worldwide, particularly in temperate regions. They are commonly found as group infections in children, in families and in institutions (where contact between individuals is high and hygiene may be low). They are estimated to infect from 400-1,000 million people worldwide, but few countries consider them to be of public health significance due to their low pathogenicity. Infections are more irritating than debilitating, causing embarrassment, low morbidity and rarely mortality. However, individual families often spend considerable time and money trying to rid themselves of infections. The species *E. gregorii* is generally indistinguishable from *E. vermicularis* and is considered by some to be a junior synonym, although male worms have smaller spicules. Numerous pinworm species have been described from a range of mammals, birds, reptiles, amphibians, insects and millipedes, but they appear to be highly host-specific. Curiously, dogs and cats do not become infected with pinworms so companion animals should never be considered as sources of human infection. Whilst *Enterobius* spp. are commonly known as pinworms (or seatworms), in some countries they are paradoxically called threadworms (a common name generally applied to *Strongyloides* spp.). This may cause great confusion when considering treatment options because the drugs used to treat these worms are different.

***Enterobius* species**	**Definitive hosts**	**Location [Clinical signs]**	**Distribution**
Subgenus *Enterobius*			
E. (*E.*) *anthropopitheci* (chimpanzee pinworm)	Primates: hominid (chimpanzee, bonobo)	large intestines [diarrhoea?]	Japan, Africa
E. atelis (= *Trypanoxyuris*)	Primates: atelid (black-handed spider monkey)		Asia
E. (*E.*) *bipapillatus*	Primates: cercopithecid (African green monkey, grivet, rhesus macaque)		
E. (*E.*) *brevicauda*	Primates: cercopithecid (chacma baboon)		Africa
E. (*E.*) *buckleyi*	Primates: hominid (Bornean orangutan, Sumatran orangutan)	large intestines [diarrhoea?]	Asia
E. callithricis (= *Trypanoxyuris*)	Primates: callitrichid (common marmoset)		South America
E. (*E.*) *chabaudi*	Primates: cercopithecid (northern plains gray langur)		India
E. duplicidens (= *Paraoxyuronema*)	Primates: atelid (gray woolly monkey)		South America
E. (*E.*) *foecundus sp. inq.*	Primates: hominid (orangutan)		Asia
E. (*E.*) *gregorii* (now considered to be a synonym of *E. vermicularis*)	Primates: hominid (human, chimpanzee)	large intestines [perianal pruritus, insomnia, irritability, occasionally diarrhoea]	Europe, Africa, Asia
E. interlabiata	Primates: aotid (northern night monkey)		South America
E. lagothricis (= *Trypanoxyuris*)	Primates: atelid (gray woolly monkey)		South America
E. lemuris (= *Lemuricola*)	Primates: lemurid (black lemur, white-headed lemur)		Madagascar
E. (*E.*) *lerouxi*	Primates: hominid (western gorilla)		Africa
E. (*E.*) *macaci*	Primates: cercopithecid (rhesus macaque, Japanese macaque, Assam macaque, Taiwan rock macaque, crab-eating macaque, southern pig-tail macaque)	large intestines	Asia, North America
E. microon (= *Trypanoxyuris*)	Primates: aotid (three-striped night monkey)		South America
E. nycticebi (syn. *Lemuricola*)	Primates: cercopithecid (stump-tailed macaque), lorisid (pygmy slow loris)		Asia
E. parallela (syn. *E. polyoon*, *Oxyuris*) (now *Xeroxyuris*)	Rodentia: sciurid (Cape ground squirrel)		Africa
E. sciuri	Rodentia: sciurid (red squirrel, Abert's squirrel)		North America
E. (*E.*) *shriveri*	Primates: cercopithecid (rhesus macaque, southern pig-tail macaque, crab-eating macaque, African green monkey)	large intestines	Asia, North America
E. (*E.*) *simiae sp. inq.*	Primates: hominid (Sumatran orangutan)		Asia
E. (*E.*) *vermicularis* (human pinworm or seatworm) (syn. *Oxyuris*)	Primates: hominid (human, chimpanzee, orangutan), atelid (white-bellied spider monkey), cercopithecid (Arabian sacred baboon, mantled guereza, chacma baboon, crab-eating macaque?); [PH?: Diptera: muscid (house fly, *Musca domestica*)]	large intestines [perianal pruritus, insomnia, irritability, occasionally diarrhoea]	worldwide, esp. temperate zones
E. (*E.*) *yagoi*	Rodentia: murid (gray leaf-eared mouse)		South America
Subgenus *Colobenterobius*			
E. (*C.*) *colobis*	Primates: cercopithecid (ashy red colobus, Thollon's red colobus)	large intestine	Africa
E. (*C.*) *emodensis*	Primates: cercopithecid (Himalayan langur)		Asia
E. (*C.*) *entellus*	Primates: cercopithecid (northern plains gray langur)		Asia
E. (*C.*) *guerezae*	Primates: cercopithecid (mantled guereza)		Africa
E. (*C.*) *inglisi*	Primates: cercopithecid (*Colobus* sp.)		Africa

E. (*C.*) *longispiculum*	Primates: cercopithecid (dusky leaf monkey)		Asia
E. (*C.*) *paraguerezae*	Primates: cercopithecid (mantled guereza)		Africa
E. (*C.*) *pesteri*	Primates: cercopithecid (*Colobus* sp.)		Africa
E. (*C.*) *pitheci*	Primates: cercopithecid (capped langur)		Asia
E. (*C.*) *presbytis*	Primates: cercopithecid (Phayre's leaf monkey)		Asia
E. (*C.*) *pygatrichus*	Primates: cercopithecid (golden snub-nosed monkey)		Asia
E. (*C.*) *serratus*	Primates: cercopithecid (proboscis monkey)		Asia
E. (*C.*) *zakiri*	Primates: cercopithecid (northern plains gray langur)		Asia

Parasite morphology: These worms form three developmental stages: eggs, larvae and adults. The eggs are translucent, elongate-oval in shape, measure 50-60 µm in length by 20-30 µm in width, and are characteristically asymmetric about the long axis being distinctly flattened on one side (forming a D-shape). The eggs are bound by three distinct membranes (inner lipoidal embryonic membrane, middle hyaline chitinous layer and outer albuminous layer) and larvae develop rapidly within the eggs. Mature larvae freed from eggs are long and thin (measuring up to 140-150 µm in length) and are presumed to be third-stage larvae (L3) as they are infective. Adult worms appear as small white elongate spindle-shaped tubes with pointed tails (hence the name, pinworm). They have three lips surrounding the anterior mouth, a large oesophageal bulb, and a conspicuous anterior cuticular inflation (swollen head). Male worms are 1-5 x 0.2-0.6 mm in size, have a single spicule (100-140 µm long in *E. vermicularis*, 68-80 µm in *E. gregorii*), and their posterior ends are strongly curved ventrally and have 4 pairs of caudal papillae (1st and 4th pairs pedunculated and surrounded by cuticular thickenings). Female worms measure 8-15 x 0.3-0.6 mm in size, have a single-crested lateral ala (double-crested in *E. anthropopitheci*), pronounced slender pointed tails and bifurcate reproductive tracts with numerous characteristic eggs developing within the uteri. Adult worms of *E. anthropopitheci* are somewhat smaller (males 1-2 mm, females 3-5 mm).

Site of infection: Adult worms tend to congregate in the ileocaecal region of the gut where they attach to the mucosa, but they may wander throughout the intestines from the stomach to the rectum. Fertilised female worms migrate out through the anus and deposit eggs of the perianal skin.

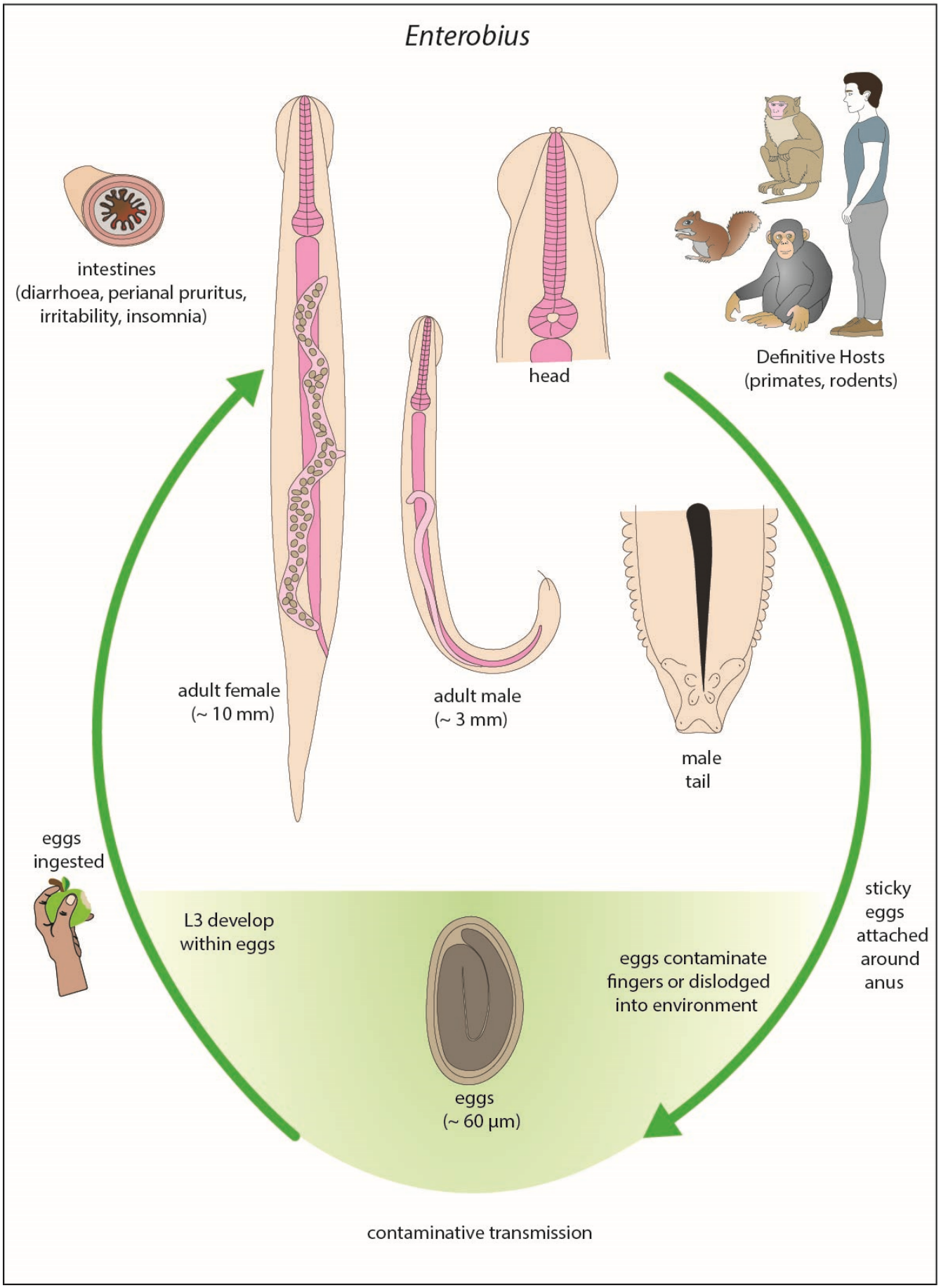
Pathogenesis: While many infections remain asymptomatic, worm burdens may increase with time resulting in damage to the intestines by adult worms and/or damage to the perineum resulting from egg deposition. Adult worms attach to the mucosa and feed on intestinal content, bacteria and possibly epithelial cells, causing minute ulcerations which may lead to mild catarrhal inflammation with diarrhoea, eosinophilia and bacterial infection. More commonly, however, infections are characterised by intense perianal itching (*pruritus ani*) caused by host sensations and reactions to female worms depositing sticky eggs on the skin (particularly overnight). Patients vigorously scratch themselves attempting to relieve the itching, but in doing so, often cause skin damage, excoriation, eczema, bleeding, bacterial dermatitis and folliculitis. Heavy infections in children may cause restlessness, irritability, hyperactivity, anorexia, weight loss, insomnia, nightmares, tooth grinding, incontinence (bed-wetting), perianal pain, nausea and vomiting. Occasionally, wandering worms have been associated with appendicitis, vaginitis, and rarely, extra-intestinal granulomas in ectopic sites. Risk factors for pinworm infection include finger sucking and poor hygiene often prominent in crowded group situations (such as nurseries, day-care centres, orphanages, hospitals and other institutionalized healthcare facilities). Infected families may suffer much shame and embarrassment (sometimes exaggerated into a syndrome known as pinworm neurosis) and they make huge efforts to rid themselves of infections.

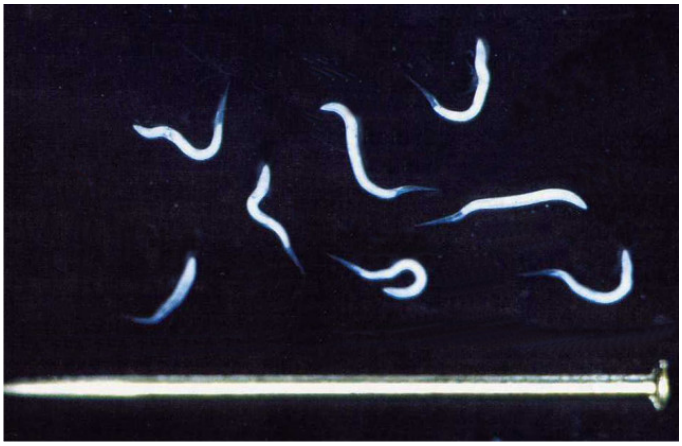
Developmental cycle and mode of transmission: Pinworms have direct life-cycles involving the oral ingestion of eggs containing infective larvae. The eggs, however, are usually not excreted with faecal material, but are attached to the perianal skin. Such transmission is therefore not strictly faecal-oral, but rather contaminative, involving the transfer of eggs to the mouth via host behaviours or inanimate objects. Infections are most prevalent in children, people in institutionalized settings and homosexuals. Gravid females migrate out through the anus onto the perineum, particularly during the night, and leave trails of eggs (up to 10,000) as they crawl about (up to 12 cm per hour). The female worms die after oviposition, whereas the males die soon after copulation. Freshly laid eggs are non-infectious but they rapidly embryonate to contain infective larvae (presumably L3) within 6 hours upon exposure to atmospheric oxygen at body temperature. The eggs are dislodged by host scratching and contaminate hands, bedding, clothing, toys, and furniture. They are very light and easily disseminated with house dust by the slightest of air currents. The embryonated eggs are resistant to putrefaction and disinfectants and may remain viable in cool moist conditions for up to 20 days but will succumb to desiccation in dry conditions within one day. Eggs may also be spread by passive carriage by flies, cockroaches and on the fur of pets. Following ingestion by human hosts (sometimes following inhalation), the eggs hatch in the small intestine and the larvae migrate to the large intestine and mature to adults over 2-6 weeks. Studies have shown worm development to involve haplodiploidy, whereby female worms are diploid and develop from fertilised eggs, whereas male worms are haploid and develop parthenogenetically (in this case, involving a unique process called arrhenotoky as the progeny are male rather than female). After copulation, gravid females migrate down the intestines and emerge from the anus to begin egg laying. Occasionally, eggs trapped in perianal folds may hatch and the larvae may enter the intestines directly via the anus (process called retro-infection). Infrequently, larvae may enter the vulva and infect the vagina of women. The prepatent period (time from infection to first production of eggs)

ranges from 15-35 days and the parasite may complete its whole life-cycle in 2-13 weeks, with infections often becoming progressively heavier due to continual parasite uptake through auto-infection (both re-infection and retro-infection).

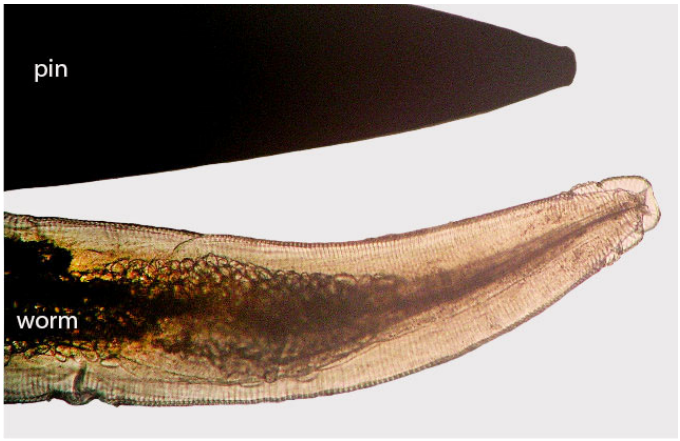
Differential diagnosis: Worm eggs are rarely found in faeces so conventional coprological examination techniques are not used. Instead, infections are best diagnosed by the macroscopic detection of adult worms or the microscopic detection of eggs on the perineum. Motile worms may be seen on perianal skin glistening under bright light when close visual examinations are conducted during the night or early in the morning. Adult worms may sometimes be observed on the surface of fresh stool samples. Alternatively, sticky-tape may be quickly applied to the perianal skin first thing in the morning and then stuck onto a glass slide for microscopic examination of adherent eggs (aptly-named perianal sticky-tape test). Parents of infected children should be trained to collect appropriate samples to respect patient rights and privacy (especially involving minors) and alleviate any shame or embarrassment. Endoscopy (colonoscopy) has been used to detect infections by adult worms in large bowel compartments. More recently, molecular biological techniques using polymerase chain reactions (PCR) to amplify specific parasite gene sequences (mitochondrial cytochrome oxidase gene and nuclear ribosomal RNA genes) have been applied to the genetic characterization of various isolates from humans and chimpanzees from different geographic locations (the studies have confirmed their separate identities).

Treatment and control: Anthelmintic treatment for pinworm infections is readily available from most pharmacies. The drug of choice is mebendazole, although albendazole, levamisole, pyrantel and ivermectin are also effective. Piperazine has been used for many years but requires a longer course of treatment. Treatment should be repeated after about 10 days to kill any newly-acquired worms. It is advisable to institute whole group treatment where appropriate, so that other group, cohort or family members do not continue to act as sources of infection. To avoid constant re-infection, it is imperative that strict personal hygienic precautions are introduced, particularly frequent hand-washing and keeping fingernails clipped short. Household decontamination is difficult as infective eggs can survive for many days in cool moist house dust and for a few days on toys or furniture. Nonetheless, clothes, bed linen and towels should be laundered in hot water, dusty areas should be well vacuumed and potentially contaminated surfaces should be cleaned. While the eggs are very resistant to many disinfectants, they are susceptible to desiccation in dry sunny conditions. Infections are more prevalent in regions with temperate and cooler climates where there is reduced sun exposure and people wear heavier clothing which is laundered infrequently.

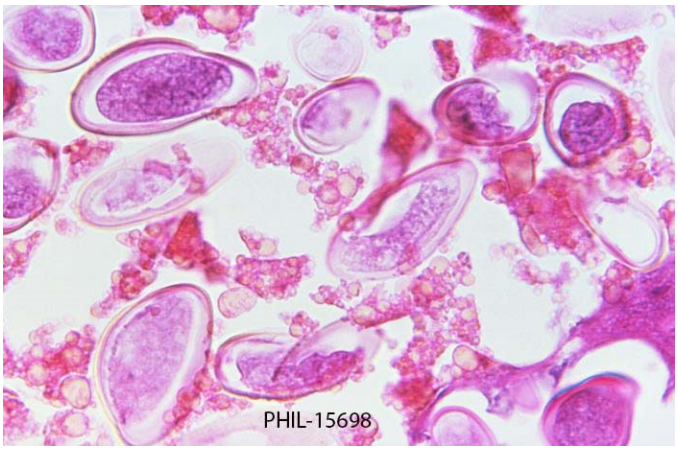

Enterobius
intestines
(diarrhoea, perianal pruritus, irritability, insomnia)
head
Definitive Hosts
(primates, rodents)
adult female
(~ 10 mm)
adult male
(~ 3 mm)
male
tail
eggs
ingested
L3 develop
within eggs
eggs
(~ 60 µm)
eggs contaminate
fingers or dislodged
into environment
sticky
eggs
attached
around
anus
contaminative transmission



Enterobius adult worms



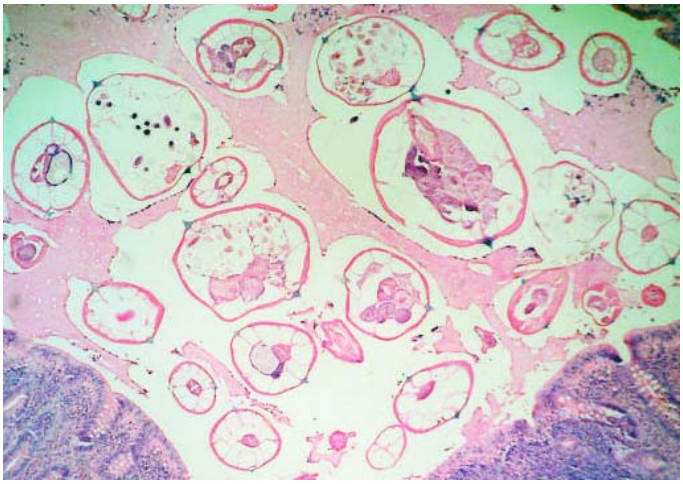
Enterobius adult worm



Enterobius worm eggs

Enterobius worm egg

Enterobius larva



Enterobius sections of worms in caecum