

Ascarops/Physocephalus
(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 Spiruromorpha: an enigmatic clade linked by molecular characters, but all having indirect life-cycles involving one or more intermediate hosts, the first invariably being an arthropod. Most possess two trilobed lips (sometimes greatly reduced), a bipartite oesophagus (anterior muscular, posterior glandular) and non-bursate males with coiled tails and two dissimilar spicules. Several superfamilies are recognised: including spiroroids (with prominent lips) containing spiroceroids found in the stomach of pigs and transmitted by coprophagous beetles in which L3 develop. Amphibians and birds may act as paratenic hosts for L3. Infections by *Ascarops* and *Physocephalus* spp. have been associated with inappetence in pigs.

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: Spiruromorpha (enigmatic clade linked by molecular characters, indirect cycles with IHs)
Superfamily: Spiuroidea (two trilobed lips, oesophagus never with bulb, coiled tail in males, two unequal spicules)
Family: Spirocercidae (stout pink-red worm, well-developed buccal capsule, with six rudimentary lips)
Genus: *Ascarops* (parasitic in stomach of pigs)
Genus: *Physocephalus* (parasitic in stomach of pigs)
Species: various species cause inappetence in pigs

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)]
<i>Incertae sedis</i> 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.

Molecular phylogenetic studies have grouped a variety of superfamilies into the infraorder Spiruromorpha whose members are parasites of vertebrates with indirect life-cycles involving larval development within invertebrate intermediate hosts. Most members were previously classified within the order Spirurida: either within the suborder Camallanina (worms with conspicuous phasmids, uninucleate oesophageal glands, larvae without cephalic hooks, usually with copepodid intermediate hosts); or the suborder Spirurina (worms with inconspicuous phasmids, multinucleate oesophageal glands, larvae with cephalic hooks or spines, usually with non-copepodid intermediate hosts). Ten spirurid superfamilies are recognised: Gnathostomatoidea and Physalopteroidea (buccal cavity weakly cuticularized, 2 large lateral pseudolabia); Habronematoidea and Acuarioidea (buccal cavity well cuticularized, 2 large lateral pseudolabia); Filarioidea, Rictularioidea, Aprocotoidea and Diplotriaenoidea (buccal cavity well cuticularized, without pseudolabia); Thelazioidea (long cylindrical buccal cavity well cuticularized, body without caudal alae); and Spiruroidea (short buccal cavity well cuticularized, body with caudal alae).

The superfamily Spiruroidea comprises worms with simple non-ornamented heads infecting the stomach (sometimes oesophagus) of mammals and birds and using arthropods as intermediate hosts for the development of distinctive larvae with conspicuous buccal capsules with a left cephalic hook and a rasp of tiny spines. Four families are recognised: Gongylonematidae (body covered with large verruciform thickenings, pseudolabia absent, oral opening octagonal with median lobes, parasites of birds and mammals); Spiruridae (body without verruciform thickenings, reduced pseudolabia, oral opening elongated with lateral elevations, buccal cavity without teeth, parasites of mammals, rarely birds); Spirocercidae (body without verruciform thickenings, reduced pseudolabia, oral opening hexagonal, buccal cavity with teeth, parasites of mammals, rarely birds); and Hartertiidae (body without verruciform thickenings, large pseudolabia subdivided into lobes, parasites of birds). The family Spirocercidae contains 3 subfamilies: Spirocercinae (lips poorly developed, not prominently raised above oral opening, pharynx without rugose or annular thickenings, parasites of mammals and birds); Ascaropsinae (lips poorly developed, not prominently raised above oral opening, pharynx with rugose or annular thickenings, parasites of mammals); and Mastophorinae (lips highly-developed forming 6 denticulate labial lobes, separate over oral opening, parasites of rodents). The subfamily Ascaropsinae contains 10 genera (*Ascarops*

(syn. *Arduenna*), *Leiuris* (syn. *Spirocercella*), *Physocephalus* (syn. *Pereiraia*, *Physocephaloides*), *Pygarginema*, *Simondsia*, *Spirobakerus*, *Spirosprattus*, *Streptopharagus*, *Tejeria*, and *Texicospirura*) which are differentiated primarily on the basis of differences in adult morphology (cephalic, cuticular and genital structures), larval morphology (anatomy and ornamentation), host occurrence/specificity, geographic distribution and transmission patterns (predation, parateny). Genera of veterinary and medical significance are tabulated below:

Genus	No. spp.	Definitive Hosts	Location	Adult worms	Eggs	Transmission
Family: Spirocercidae (stout pink-red worm, well-developed buccal capsule, with 6 rudimentary lips)						
Subfamily: Ascaropsinae (buccal cavity with rugose or annular thickenings)						
<i>Ascarops</i> (thick stomach worm)	10	artiodactyls, rodents	stomach	10-25 mm long, oblique annuli in buccal capsule, 2 prominent trilobed lips, bipartite oesophagus	34-51 x 20-26 µm, oval, thick-shelled	indirect (L3 in insect IH) [sometimes amphibian or avian PH]
<i>Physocephalus</i> (thick stomach worm)	10	artiodactyls, rodents	stomach	6-22 mm long, transverse annuli in buccal capsule, 2 prominent trilobed lips, bipartite oesophagus	31-39 x 15-17 µm, ellipsoidal, thick-shelled	indirect (L3 in insect IH) [sometimes amphibian or avian PH]
Subfamily: Spirocercinae (weakly-developed lips)						
<i>Spirocerca</i>	5	carnivores	stomach, aorta	3-8 cm long, body pink-red, buccal capsule with thick wall, 2 prominent trilobed lips, bipartite oesophagus	22-38 x 8-15 µm, elongate, thick-shelled	indirect (L3 in insect IH) [sometimes rodent, bird, reptile PH]
<i>Cylicospirura</i> (red worm)	10	mammals	stomach	20-30 mm long, buccal capsule with 6 longitudinal ribs ending in bifid knobs, 6 teeth, bipartite oesophagus	30-40 x 15-25 µm, elongate, thick-shelled	indirect (L3 in insect IH)
<i>Cyathospirura</i> (red worm)	5	mammals	stomach	6-12 mm long, buccal capsule with 6 longitudinal ribs ending in single knob, 8 teeth, bipartite oesophagus	29-38 x 13-22 µm, ovoid, thick-shelled	indirect (L3 in insect IH)
Family: Gongylonematidae (anterior cuticle covered with large bosses or irregular scutes arranged in 8 rows)						
<i>Gongylonema</i>	46	mammals, birds	oesophagus, stomach	2-15 cm long, numerous anterior bosses, 2 prominent trilobed lips, bipartite oesophagus	40-70 x 22-35 µm, ovoid, thick-shelled	indirect (L3 in insect IH)

The genus *Ascarops* contains worms with poorly-developed flat lips, buccal cavities with 6 teeth or 6 groups of teeth, and a straight pharynx with spiral wall thickenings, while those of the genus *Physocephalus* have 6 large lips joined to form 2 lateral masses elevated above the anterior extremity, unarmed buccal cavities and elongated oesophagus. Some 18 species have been described from the stomachs of mammals, and the parasites have indirect life-cycles with larval development occurring in invertebrate intermediate hosts and sometimes being transported in small mammalian paratenic hosts. In particular, 2 species (*Ascarops strongylina* and *Physocephalus sexalatus*) commonly infect pigs around the world, sometimes causing catarrhal gastritis.

Parasite species	Definitive Hosts	Location [Clinical signs]	Intermediate Hosts [and Paratenic Hosts (PH)]	Distribution
<i>Ascarops</i>				
<i>A. africana</i> (syn. <i>Arduenna</i>)	Rodentia: murid (four-striped grass mouse), glirid (hazel dormouse); Serpentes: lamprophiid (striped house snake)			Africa
<i>A. dentata</i>	Artiodactyla: suid (pig, wild boar, Indian boar); Eulipotyphla: erinaceid (four-toed hedgehog)	stomach [inappetence]		Asia

<i>A. joliveti</i>	unknown		Coleoptera: tenebrionid (darkling beetle, <i>Hegeter tristis</i>)	Canary Islands
<i>A. kutassi</i>	Rodentia: sciurid (little ground squirrel, Asia Minor ground squirrel)			Eurasia
<i>A. minuta</i>	Chiroptera: vespertilionid (West European pond bat)			Europe
<i>A. mogera</i>	Eulipotyphla: talpid (Japanese mole, Kobe mole, Sado mole)			Asia
<i>A. scaptochiri</i>	Rodentia: cricetid (Chinese striped hamster)			China
<i>A. strongylina</i> (thick stomach worm)	Artiodactyla: suid (pig, wild boar, Sardinian wild boar, Indian boar, warthog), bovid (cattle), camelid (camel); Lagomorpha: leporid (rabbit); Rodentia: caviid (guinea pig), murid (black rat), spalacid (trans-Baikal zokor); Psittaciformes: cacatuid (sulphur-crested cockatoo)	stomach, small intestines [inappetence]	Coleoptera: scarabaeinid (dung beetle, <i>Caccobius</i> , <i>Canthon</i> , <i>Copris lunaris</i> , <i>Ceratophius</i> , <i>Cotinis</i> , <i>Dyscinetus</i> , <i>Oniticellus pallens</i> , <i>pallipes</i> , <i>Onitis philemon</i> , <i>ramellosus</i> , <i>Onthophagus catta</i> , <i>cervus</i> , <i>deflexicollis</i> , <i>falsus</i> , <i>gazella</i> , <i>gibbulus</i> , <i>mopsus</i> , <i>nuchicomis</i> , <i>quadridentatus</i> , <i>ramosellus</i> , <i>Phanaeus vindex</i> , <i>Phyllophaga</i> , <i>Potosia hungarica</i> , <i>Scarabaeus</i>), aphodiid (beetle, <i>Aphodius castaneus</i> , <i>granarius</i> , <i>moestus</i> , <i>rufus</i> , <i>sticticus</i>), geotrupid (dor beetle, <i>Anoplotrupes stercorosus</i> , <i>Geotrupes mutator</i> , <i>pyrenacius</i> , <i>stercorarius</i> , <i>vernalis</i> , <i>Gymnopleurus mopsus</i> , <i>pervus</i> , <i>Trypocopris vernalis</i>), histerid (clown beetle, <i>Hister corax</i> , <i>maindronii</i>), hybosorid (scavenger beetle, <i>Hybosorus orientalis</i>), passalid (leather beetle, <i>Passalus cornutus</i>), trogid (<i>Trox granulatus</i>); Odonata: aeshnid (dragonfly, <i>Anax parthenope</i>) [plus PH: Rodentia: murid (mouse, wood mouse), caviid (guinea pig), glirid (edible dormouse), sciurid (Indian palm squirrel, ground squirrel); Eulipotyphla: erinaceid (four-toed hedgehog, southern white-breasted hedgehog, northern white-breasted hedgehog), sorcid (common shrew, lesser white-toothed shrew, Eurasian pygmy shrew), talpid (European mole); Chiroptera: vespertilionid (common noctule, lesser noctule, common pipistrelle, western barbastelle, parti-coloured bat, serotine bat, Bechstein's bat, Daubenton's bat, Natterer's bat, lesser mouse-eared bat, greater mouse-eared bat, brown long-eared bat, whiskered bat, pond bat), rhinolophid (greater horseshoe bat, lesser horseshoe bat); Serpentes: colubrid (Asiatic water snake, pond snake, large whip snake, slender whip snake, smooth snake, grass snake, checkered keelback), lamprophiid (Montpellier snake), viperid (common European adder); Sauria: anguid (sheltopusik, slow worm, European glass lizard), gekkonid (Mediterranean	worldwide

			house gecko), lacertid (sand lizard, Macedonian lizard, common wall lizard, European green lizard, viviparous lizard); Anura: bufonid (European green toad), ranid (moor frog)]	
<i>A. talpa</i>	Eulipotyphla: talpid (Formosan mole)	small intestines		Taiwan
<i>A. tuvensis</i>	Rodentia: sciurid (suslik)			Eurasia
<i>Phyocephalus</i>				
<i>P. dromedarii</i>	Artiodactyla: camelid (dromedary)	abomasum	Coleoptera: scarabaeinid (rainbow scarab, <i>Phanaeus vindex</i> , dung beetle, <i>Scarabaeus cristatus</i>)	Middle-East
<i>P. ellobii</i> <i>sp. inq.</i>	Rodentia: heterocephalid (mole rat)		[PH: Coraciiformes: meropid (olive bee-eater)]	Africa
<i>P. gracilis</i>	Pilosa: bradypodid (pale-throated sloth)			South America
<i>P. lassancei</i>	Artiodactyla: cervid (brown brocket, red brocket deer)	abomasum		South America
<i>P. mediospiralis</i>	Rodentia: dasyproctid (agouti), cuniculid (paca)			South America
<i>P. meridionalis</i>	Perissodactyla: tapirid (South American tapir); Rodentia: cuniculid (lowland paca, lappe), dasyproctid (agouti, Azara's agouti)	stomach		South America
<i>P. nitidulans</i>	Perissodactyla: tapirid (South American tapir)	stomach		South America
<i>P. quadrialatus</i>	Rodentia: cricetid (grey dwarf hamster, Turkish hamster)			Eurasia
<i>P. raphiceri</i>	Artiodactyla: bovid (steenbuck)	abomasum		Africa
<i>P. sexalatus</i>	Artiodactyla: suid (pig, wild boar, Sardinian wild boar, warthog), tayassuid (white-lipped peccary, collared peccary), bovid (cattle), camelid (dromedary, Bactrian camel), cervid (roe deer, red brocket deer); Perissodactyla: tapirid (tapir), equid (horse, donkey); Lagomorpha: leporid (rabbit, hare); Diprotodontia: macropodid (Matschie's tree-kangaroo, rufous hare-wallaby, whiptail wallaby, allied rock wallaby, unadorned rock wallaby, red-legged pademelon)	stomach [inappetence]	Coleoptera: scarabaeid (dung beetle, <i>Amphimallon solstitialis</i> , <i>Aphodius</i> , <i>Ataenius cognatus</i> , <i>Ateuchus</i> , <i>Boreocanthon</i> , <i>Canthon laevis</i> , <i>Catharsuis</i> , <i>Ceratophius</i> , <i>Chironitis hungarica</i> , <i>Copris hispanus</i> , <i>lunaris</i> , <i>Deltochilum</i> , <i>Dichotomius</i> , <i>Gymnopleurus aciculatus</i> , <i>mopsus</i> , <i>parvus</i> , <i>sinnatus</i> , <i>sturmi</i> , <i>Melanocanthon</i> , <i>Oniticellus pallens</i> , <i>pallipes</i> , <i>Onthophagus bedeli</i> , <i>catta</i> , <i>centricornis</i> , <i>cervus</i> , <i>deflexicollis</i> , <i>gibbulus</i> , <i>hecate</i> , <i>nebulosus</i> , <i>quadridentatus</i> , <i>speculifer</i> , <i>Pentodon idiota</i> , <i>Phanaeus carnifex</i> , <i>vindex</i> , <i>Pinotus</i> , <i>Scarabaeus sacer</i> , <i>variolosus</i>), geotrupid (dung beetle, <i>Geotrupes douei</i> , <i>stercorarius</i> , <i>Trypocopris vernalis</i>), passalid (leather beetle, <i>Passalus cornutus</i>), silphid (carrion beetle, <i>Oiceoptoma</i>), tenebrionid (darkling beetle, <i>Pisterotarsa gigantea</i>), trogid (<i>Trox</i>); Blattodea: polyphagid (cockroach, <i>Polyphaga sausserae</i>); Dermaptera: labidurid (earwig, <i>Labidura riparia</i>); Diplopoda: glomerid (pill millipede, <i>Glomeris</i>); Decapoda:	worldwide

			<p>penaeid (white shrimp, <i>Litopenaeus setiferus</i>)</p> <p>[plus PH:</p> <p>Rodentia: murid (mouse, wood mouse, rat), cricetid (hispid cotton rat); Chiroptera: vespertilionid (little brown bat, common pipistrelle, Kuhl's pipistrelle, Nathusius's pipistrelle, barbastelle bat, northern bat, serotine bat, Bechstein's bat, Daubenton's bat, Natterer's bat, lesser mouse-eared bat, greater mouse-eared bat, brown long-eared bat, whiskered bat, pond bat, common noctule, lesser noctule), rhinolophid (greater horseshoe bat, lesser horseshoe bat); Cingulata: dasypodid (nine-banded armadillo), Eulipotyphla: erinaceid (four-toed hedgehog, European hedgehog, southern white-breasted hedgehog, northern white-breasted hedgehog, long-eared hedgehog), soricid (common shrew, lesser white-toothed shrew), talpid (European mole); Pilosa: bradypodid (three-toed sloth); Sauria: agamid (secret toadhead agama, steppe agama, Caucasian agama), anguid (slow worm, European glass lizard), gekkonid (Caspian bent-toed gecko, frog-eyed gecko), lacertid (sand lizard, Macedonian lizard, viviparous lizard), varanid (desert monitor); Serpentes: boid (dwarf sand boa), colubrid (cat snake, diadem snake, large whip snake, slender whip snake, spotted desert racer, smooth snake, steppe rat snake, grass snake, dice snake, Aesculapian snake), elapid (central Asian cobra), lamprophiid (arrow snake), viperid (common European viper), blunt-nosed viper; Anura: bufonid (European green toad); Accipitriformes: accipitrid (Eurasian sparrowhawk, red-tailed hawk); Charadriiformes: scolopacid (upland sandpiper, long-billed curlew); Cichliformes: cichlid (Pantano cichlid); Galliformes: numidid (helmeted guineafowl); Passeriformes: corvid (Eurasian magpie), laniid (loggerhead shrike); Strigiformes: strigid (eastern screech owl); Cichliformes: cichlid (Pantano cichlid); Siluriformes: heptapterid (pale catfish)]</p>	
<i>P. torresi</i>	Rodentia: dasyproctid (agouti)	stomach		South America

Parasite morphology: *Ascarops* and *Physocephalus* nematodes form 3 different type of morphological stages during their development: eggs; larvae (4 consecutive stages designated L1 to L4); and adult worms. The eggs are small, oval-elliptical in shape but slightly flattened at the poles, thick-shelled and embryonated when laid. *Ascarops* eggs range in size from 34-51 x 20-26 µm, while *Physocephalus* eggs are slightly smaller measuring 31-39 x 15-17 µm. First-stage larvae (L1) freed from eggs were elongate and cylindrical measuring around 150 µm in length, and they have rounded heads (sometimes with delicate spines), a prominent cephalic hook and tapering tails terminating in a conical knob (sometimes with tiny pointed processes). L2 are transient stages formed within intermediate hosts, while L3 are long-lasting stages often coiled up within membranous capsules. L3 freed from cysts range in length from 1.9-2.3 mm and have a cylindrical pharynx and tails terminating in a smooth knob-like process (*Ascarops*) or numerous digitiform processes (*Physocephalus*). L4 are transient parasitic stages that are beginning to develop adult mouthparts and genital primordia. Adults are small red-brown worms with cylindrical bodies measuring 6-25 mm in length. They often possess cervical, lateral and caudal alae, the former 2 being separated by an anterior cuticular inflation in the genus *Physocephalus* resulting in an arrowhead appearance. The anterior mouth has poorly-developed flat lips (*Ascarops*) or 2 trilobed lateral lips projecting upwards (*Physocephalus*). Both genera have well-developed thick-walled buccal capsules without median lobes but with prominent annuli (transverse in *Physocephalus*, oblique in *Ascarops*). The buccal capsule is unarmed (*Physocephalus*) or armed with 6 teeth or 6 groups of teeth (*Ascarops*). The oesophagus is bulbous and elongated (*Physocephalus*) or straight with spiral wall thickenings (*Ascarops*). Adult worms are sexually dimorphic, with females being larger than males (15-25 cf. 10-15 mm long for *Ascarops*, 13-22 cf. 6-13 mm long for *Physocephalus*). Mature females are didelphic with 2 ovaries and uteri connected to a midbody vulva and their tails have poorly-developed caudal alae. Mature males have curved twisted tails with well-developed caudal alae, characteristically asymmetrical (right side wider than left), 4 pairs of long pedunculate papillae (3 pairs precloacal, 1 pair adcloacal), and 2 unequal dissimilar spicules (long thin left spicule, short thick blunt right spicule).

Site of infection: Adult worms infect the stomachs (rarely the small intestines) of their definitive hosts, usually residing on top of the epithelium under a layer of mucus. Infective L3 develop in the body cavities of insect intermediate hosts, and they may also encapsulate in the mesenteries and viscera of small vertebrate paratenic hosts.

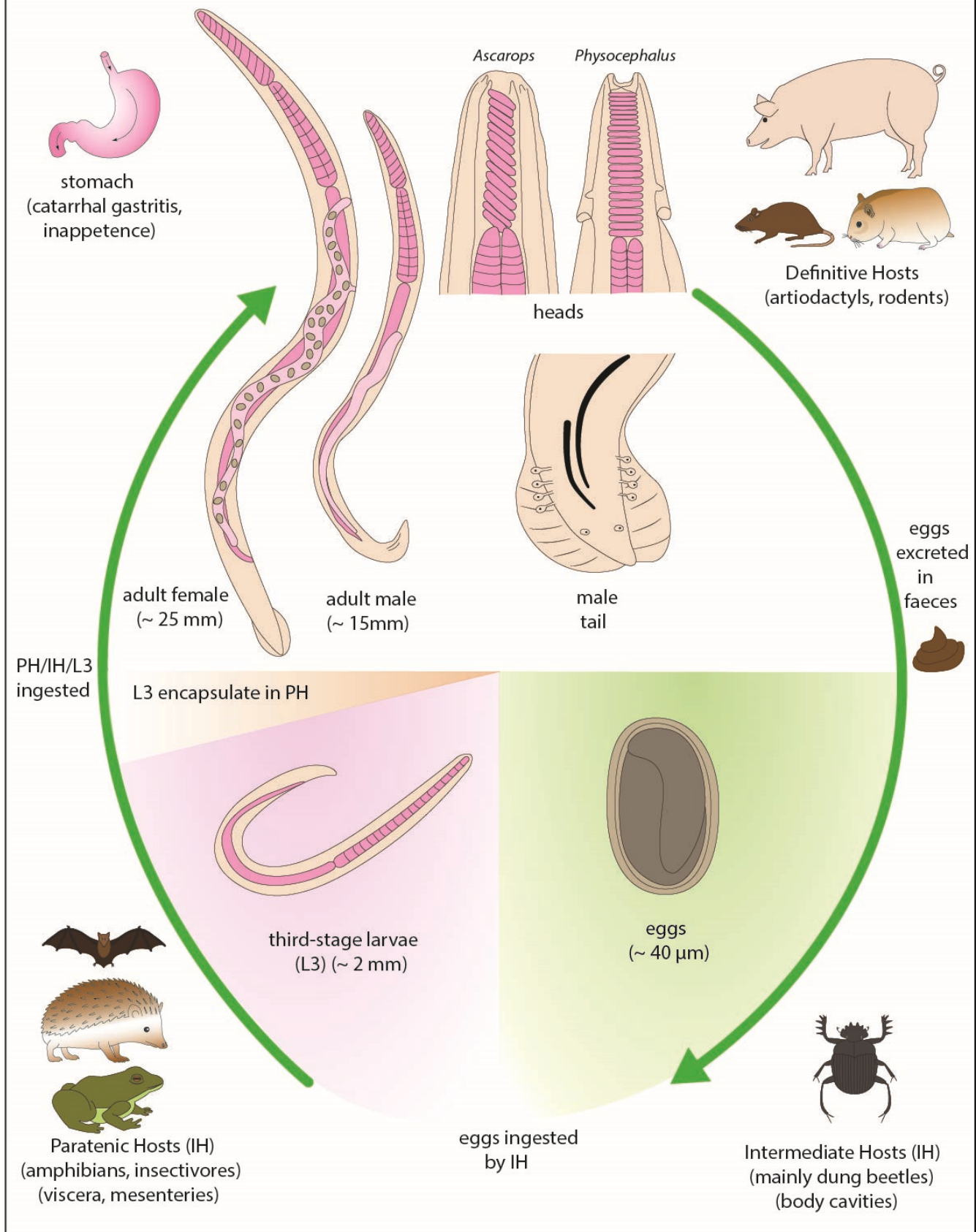
Pathogenesis: Infections by these stomach worms are relatively non-pathogenic as the parasites do not invade tissues but live in the lumen of the stomach. Heavy infections in young animals may cause a mild catarrhal gastritis with reddening and oedema of the mucosa but rarely resulting in clinical signs other than softening of the faeces and inappetence. Adult worms are found in animals over the age of 4 months, and the intensity of infection may increase with host age due to repeated exposure. Rare reports have been made where adult worms were detected in association with small haemorrhages and gastric ulcerations in pigs with anaemia, bloody diarrhoea and weight loss, but the animals were also infected with other nematodes considered to be more pathogenic (notably *Hyostromylus* and *Gnathostoma*).

Developmental cycle and mode of transmission: *Ascarops* and *Physocephalus* spp. have indirect heteroxenous life-cycles involving the development of adult worms in vertebrate definitive hosts, larval development in invertebrate intermediate hosts, and sometimes larval carriage in vertebrate paratenic hosts. Gravid females lay embryonated eggs in the stomach which are excreted with host faeces. The eggs survive well in the external environment, particularly in moist areas, and they have been shown to be dispersed in manure used to fertilise pastures and in wastewater used for irrigation. The eggs are ingested by variety of coprophagous insects (especially dung beetles, but also including other terrestrial beetles, cockroaches, earwigs, millipedes, dragonflies) which act as intermediate hosts supporting further larval development. Ingested eggs hatch in the gut within 1-3 days releasing L1 which migrate to the haemocoel, moult to L2 in 16-19 days and again to L3 in 25-31 days before encapsulating in host tissues. Infective L3 may be transferred to a range of insect-eating animals (rodents, bats, insectivores, birds, lizards, snakes, amphibians, fish, shrimp) which act as paratenic transport hosts because the larvae do not undergo any further development but re-encapsulate within host tissues. Final (definitive) hosts become infected by ingesting L3 contained within intermediate or paratenic hosts. Ingested L3 are released within the stomach and migrate to the pyloric region within 5-9 days (they do not undertake any somatic or extraintestinal migration). They moult to L4 in 4-5 days and then subadults (sometimes referred to as L5) within 20 days before maturing to adult worms by 25-31 days. The prepatent period (time from infection to first egg excretion) ranges from 42-50 days, and adult worms are thought to live for 10-11 months.

Differential diagnosis: Infections are diagnosed by the direct detection of parasites, either by the antemortem detection of worm eggs in faecal samples, or by the postmortem detection of adult worms on the stomach lining. The worm eggs are small, thick-shelled and contain active larvae, but they are not very buoyant so are best concentrated by floatation in heavy metal salt solutions with high specific gravities. Adult worms are usually visible due to their bright red colouration but they may be obscured by mucus. Molecular biological techniques have been used to examine parasite phylogenetic relationships and identify larvae following the polymerase chain reaction (PCR) amplification and sequencing of nuclear genes (ribosomal RNA and internal transcribed spacers).

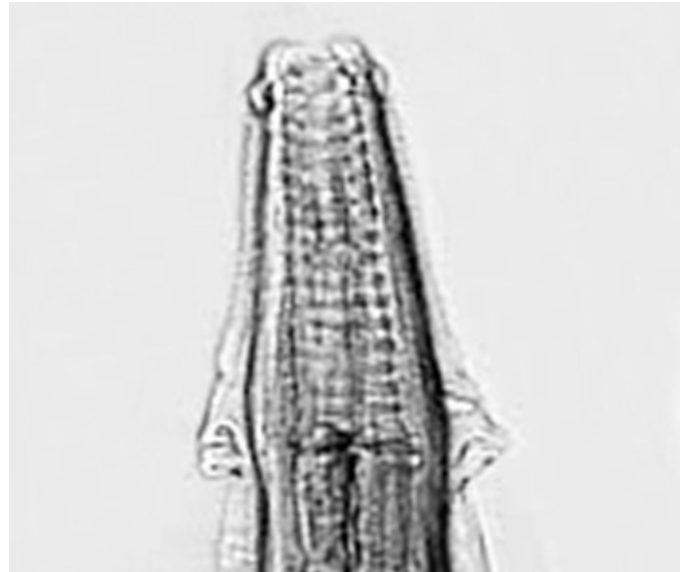
Treatment and control: There is little information on specific drug treatments for these stomach worms as they are not considered to be serious pathogens in livestock production. However, several broad spectrum anthelmintics regularly used for other helminth parasites are thought to be effective against adult stomach worms, including tetrahydropyrimidines (pyrantel), organophosphonates (dichlorvos) and macrocyclic lactones (ivermectin, doramectin). It has been recommended that regular chemoprophylaxis be used in intensive farming situations, with drenches give twice a year (around weaning in spring and confinement in autumn). Most infections are found in wild or feral pigs, or farmed pigs which are free-range or have some access to open pastures where they can contact potential intermediate and paratenic hosts. Various preventive strategies may be implemented in intensive farm situations to reduce pasture contamination and limit transmission, but such strategies are not practical in extensive farming situations or in natural systems involving wildlife. Where possible, sanitary practices should be used to remove and dispose of faeces. Animals should have access to clean food and water, and manure should not be used to fertilise pastures and wastewater should not be used for irrigation. Pasture rotation with other livestock or crops may be used but care should be taken that other parasites with broad host specificities do not become more widespread. Holding facilities should be regularly cleaned and disinfected, and coprophagous insects should be excluded (using chemicals and/or barriers). Livestock should be prevented from foraging in open areas and they should not be fed with offal or tissues from terrestrial or aquatic animals which may act as paratenic hosts.

Ascarops, Physocephalus





Ascarops adult worm, head



Physocephalus adult worm, head



Ascarops worm egg