Ascaridia
(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 Ascaridomorpha which includes ascaridoid nematodes (roundworms) characterised by their large size, three prominent anterior lips and the absence of a bursa. They occur in the small intestines of many animals (including humans) and most have simple direct life-cycles involving faecal-oral transmission. Female worms produce numerous eggs which are excreted with host faeces and undergo embryonation to contain infective larvae. When ingested, larvae hatch from the eggs and develop into adult worms in the gut. The larvae of ascaridoid species undergo hepato-pulmonary migration before forming adults, whereas those of heterakoid species do not. Heterakoid worms have a large sucker anterior to the cloaca in males, and two major families are recognised: heterakids having an oesophagus with a rounded terminal bulb, and ascaridiids having one without. Ascaridiid eggs/L3 may be transported by earthworms (paratenic hosts) to birds, and several *Ascaridia* spp. may cause anaemia and/or diarrhoea in poultry.

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:	Ascaridomorpha (large roundworms, mouth surrounded by three large lips, numerous caudal papillae)
Superfamily:	Heterakoidea (preanal sucker anterior to cloaca in males, direct cycle, infection by ingestion of eggs)
Family:	Ascaridiidae (slender club-shaped oesophagus without rounded terminal bulb)
Genus:	*Ascaridia* (parasitic in small intestines of birds)
Species:	various species cause anaemia/diarrhoea in poultry

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 Ascaridomorpha is characterised by large roundworms with poorly developed buccal cavity with 3 large lips, an undivided oesophagus, numerous caudal papillae, nonbursate males often with pre-anal suckers, and females with complex ovejectors. Five superfamilies (conventionally assigned to the order Ascaridida) are recognised as parasites in vertebrates: Ascaridoidea (cylindrical oesophagus often terminated by swelling without bulb, coelomyarian, eggs thick-shelled); Heterakoidea (oesophagus cylindrical or with claviform corpus, short isthmus and valved bulb, coelomyarian, pre-anal sucker, eggs thick-shelled); Cosmocercoidea (oesophagus with cylindrical corpus, elongate isthmus and valved bulb, platymyarian, eggs with delicate shells or hatch *in utero*); Seuratoidea (lips absent, oesophagus short, platymyarian, eggs with delicate shells or hatch *in utero*); and Subuluroidea (well-developed buccal capsule without lips, coelomyarian, pre-anal sucker, eggs thick-shelled).

The superfamily Heterakoidea contains worms with prominent pre-anal suckers surrounded by cuticularized rings. Adult worms are parasitic in the gastrointestinal tracts of vertebrates (birds, reptiles, amphibians, mammals) and have direct monoxenous life-cycles where hosts become infected by ingesting larvated eggs and the released larvae do not undertake hepatopulmonary migration. The superfamily contains 4 families: Ascaridiidae (large stout lips, slender club-shaped oesophagus without posterior bulb, anterior cuticular flange absent); Heterakidae (rounded lips not connected by lateral lobes, short stout oesophagus with rounded trivalved terminal bulb, lateral alae present); Aspidoderidae (square lips connected by lateral lobes, long narrow oesophagus with small trivalved terminal bulb, anterior cuticle thickened to form cephalic cap); and Kiwinematidae (shallow rounded lips without distinct margins, oesophagus with trivalved terminal bulb, lateral alae present). Representative genera of significance to animal health and production are tabulated below.

Genus	No. spp.	Definitive Hosts	Location	Adult worms	Eggs	Transmission
Ascaridiidae (slender club-shaped oesophagus without rounded terminal bulb)						
Ascaridia	45	birds (esp. galliform), reptiles, fish	intestines	15-120 mm long, poorly developed cuticular alae, 3 large trilobed anterior lips, no oesophageal bulb, abursate males with precloacal sucker, larvae do not undertake hepato-pulmonary migration,	55-99 x 40-57 µm, ovoid, thick-shelled	direct (faecal-oral) (sometimes eggs/L3 in earthworm PH)
Heterakidae (worms with lateral alae, oesophagus with rounded terminal bulb)						
Heterakis (caecal worm)	51	birds (esp. galliform), rodents	intestines	4-23 mm long, lateral alae, fine longitudinal striations, 3 anterior lips, oesophageal bulb, abursate males with precloacal sucker, larvae do not undertake hepato-pulmonary migration	63-80 x 35-50 µm, ellipsoidal, thick-shelled	direct (faecal-oral) (sometimes eggs/L3 in earthworm PH)

The family Ascaridiidae is monotypic containing a single genus *Ascaridia* (syn. *Cotylascaris*) of large roundworms which are commonly found in the intestines of birds, especially Galliformes. Around 40 species have been described, some in association with significant diseases in domestic poultry and aviary birds. The parasites have direct monoxenous life-cycles involving faecal-oral transmission of eggs shed into the environment. Infections are more prevalent in tropical and subtropical regions than in temperate regions as eggs are unable to develop to the infectious stage at temperatures under 15°C. Several species are also thought to utilize invertebrates (earthworms) as paratenic (transport) hosts containing larvae hatched from ingested eggs (the larvae do not undergo further development in these hosts).

***Ascaridia* species**	**Definitive Hosts [plus Paratenic Hosts (PH)]**	**Location [Clinical signs]**	**Distribution**
Avian hosts			
A. aegyptiaca	Pelecaniformes: ardeid (little egret)		Europe
A. alectoris	Galliformes: phasianid (chicken, rock partridge)		Europe
A. bonasae	Galliformes: phasianid (ruffed grouse)		North America
A. calcarata	Galliformes: numidid (helmeted guineafowl)		Africa
A. centropusi	Cuculiformes: cuculid (greater coucal)		India
A. columbae	Columbiformes: columbid (domestic pigeon, thick-billed green pigeon, pin-tailed green pigeon, hill pigeon, rock dove, mourning dove, white-winged dove, Eurasian collared dove, Oriental turtle dove, Barbary dove); Galliformes: phasianid (chicken, Caucasian chukar partridge, common pheasant); Anseriformes: anatid (goose); Phoenicopteriformes: phoenicopterid (flamingo); Accipitriformes: accipitrid (cinereous vulture); Dasyuromorphia: thylacinid (Tasmanian tiger, extinct)	small intestines	worldwide
A. cristata	Gruiformes: gruid (grey-crowned crane, black-crowned crane, Sarus crane)		Africa, Asia
A. cuculina	Cuculiformes: cuculid (common cuckoo)		Russia
A. cylindrica	Galliformes: phasianid (black grouse, hazel grouse, western capercaillie, willow ptarmigan)		Russia
A. dissimilis	Galliformes: phasianid (chicken, wild turkey, domestic turkey, chukar, Caucasian chukar); Anseriformes: anatid (goose)	small intestines	worldwide
A. dolichocerca	Accipitriformes: accipitrid (Papuan harrier)		New Guinea
A. fasciata	Columbiformes: columbid (African green pigeon, coastal green-tailed pigeon)		Africa
A. francolina	Galliformes: phasianid (double-spurred spurfowl, Ahanta spurfowl)		Africa

A. galli (syn. *A. anseris, brasiliensis, compar, compressa, granulosa, hamia, lineata, magalhaesi, perspicillum, sinensis, styphlocerca*)	Galliformes: phasianid (chicken, red junglefowl, Indian peafowl, green peafowl, greater prairie chicken, domestic turkey, wild turkey, ocellated turkey, common pheasant, blood pheasant, silver pheasant, grey peacock-pheasant, grey partridge, red-legged partridge, rock partridge, eastern rock partridge, central rock partridge, chukar partridge, Caucasian chukar, Barbary partridge, Daurian partridge, hazel grouse, black grouse, Caucasian black grouse, ruffed grouse, sharp-tailed grouse, Siberian grouse, Caucasian grouse, common quail, northern bobwhite quail, Japanese quail, willow ptarmigan, rock ptarmigan, black-billed capercaillie, western capercaillie, black francolin, Himalayan snowcock, Temminck's tragopan), numidid (helmeted guineafowl); Anseriformes: anatid (domestic goose, greylag goose, domestic duck, mallard, muscovy, mottled duck, muscovy duck, common pochard, northern pintail, common scoter); Columbiformes: columbid (pigeon, rock dove, spotted dove, Eurasian collared-dove, ruddy quail-dove, Luzon bleeding-heart dove); Cuculiformes: cuculid (lesser coucal); Passeriformes: emberizid (yellowhammer), passerid (house sparrow), turdid (varied thrush, American robin); Pelecaniformes: ardeid (eastern cattle egret, Indian pond heron); Psittaciformes: psittacid (Alexandrine parrot); Accipitriformes: accipitrid (common buzzard); Strigiformes: strigid (Eurasian eagle-owl); Carnivora: felid (cat) [PH: Clitellata: lumbricid (earthworms, *Allolobophora calliginosa, chlorotica, Eisenia foetida, Nicodrilus calliginosus, roseus*)]	small intestines, sometimes large intestines, stomach [anaemia, diarrhoea]	worldwide
A. geei	Galliformes: phasianid (chicken); Columbiformes: columbid (Oriental turtle dove)		Asia
A. hermaphrodita (syn. *A. pseudohermaphrodita, truncata*)	Psittaciformes: psittacid (white-eyed parakeet, white-eared parakeet, sun parakeet, scaly-headed parrot, yellow-crowned amazon, vinaceous-breasted amazon, hyacinth macaw), psittaculid (budgerigar); Columbiformes: columbid (Inca dove)		Americas, Australia
A. magnipapilla	Galliformes: phasianid (black grouse, western capercaillie)	small intestines	Russia
A. nepalensis	Galliformes: phasianid (Himalayan monal)		Asia
A. nicobarensis	Psittaciformes: psittacid (long-tailed parakeet)		Africa
A. numidae	Galliformes: numidid (vulturine guineafowl, helmeted guineafowl, crested guineafowl, plumed guineafowl); phasianid (rock partridge)	small intestines	Africa
A. ornata	Psittaciformes: psittacid (orange-winged amazon)		South America
A. orthocerca	Rheiformes: rheid (greater rhea)		South America
A. pagoti	Columbiformes: columbid (Madagascan green pigeon)		Madagascar
A. petrensa	Galliformes: phasianid (chukar partridge)		Eurasia
A. pintoi	Tinamiformes: tinamid (red-winged tinamou)		South America
A. platycerci	Psittaciformes: psittaculid (yellow-collared lovebird, rosy-faced lovebird, Fischer's lovebird, scarlet-chested parrot, red-rumped parrot, princess parrot, Australian king parrot, Australian ringneck parrot, rose-ringed parakeet, eastern rosella, budgerigar), cacatuid (yellow-crested cockatoo)		Australia
A. pterophora	Gruiformes: gruid (whooping crane)		North America
A. razia	Columbiformes: columbid (pigeon)		India
A. sergiomeirai	Psittaciformes: psittacid (white-eyed parakeet, scaly-breasted parrot); Galliformes: cracid (black-fronted piping guan)		South America
A. serrata	Galliformes: cracid (black-fronted piping guan, Trinidad piping guan)		South America
A. skrjabini	Galliformes: phasianid (Himalayan snowcock, Tibetan snowcock)		Asia
A. sprenti	Psittaciformes: psittaculid (eastern bluebonnet, red-winged parrot, red-rumped parrot, elegant parrot, turquoise parrot, scarlet-chested parrot, princess parrot, regent parrot, Australian ringneck parrot, Bourke's parrot)	small intestines	Australia

A. stroma	Gruiformes: gruid (common crane, blue crane, Demoiselle crane, Eurasian crane, Sarus crane)		Africa, Eurasia
A. struthionis	Struthioniformes: struthionid (common ostrich)		Africa
A. subequalis	Cuculiformes: cuculid (cuckoo)		Europe
A. trilabium	Cuculiformes: cuculid (greater coucal)		Asia
A. triloba	Pelecaniformes: threskiornithid (Madagascan ibis)		Madagascar
A. zelandica	Cuculiformes: cuculid (shining cuckoo)		New Zealand
Reptilian hosts			
A. francolina	Sauria: agamid (Oriental garden lizard)		Asia
A. frenatusi	Sauria: gekkonid (common house gecko)		Asia
A. japalurae	Sauria: agamid (Swinhoe's japalura)		Asia
Piscine hosts			
A. alatae	Siluriformes: clariid (walking catfish)		Asia
A. barbi	Cypriniformes: cyprinid (Niger barb)		Africa
A. ganpatii	Synbranchiformes: mastacembelid (zigzag eel)		Asia
A. seenghali	Siluriformes: bagrid (Gangetic mystus)		India

Parasite morphology: *Ascaridia* spp. form 3 morphologically-different stages during their development: eggs; larvae (4 sequential stages designated L1-L4); and adult worms. The ovoid-ellipsoidal eggs measuring 55-99 x 40-57 μm have convex sides and thick albuminous smooth eggshells. They are laid unembryonated containing a central single-celled morula. Excreted eggs embryonate to form first stage larvae (L1) which moult within the eggshell to form infective larvae. It is unsure as to how many moults occur within the egg, with many studies reporting one moult to form infective L2, and other studies reporting 2 moults to form infective L3. Newly hatched larvae measured 0.3-1.0 mm long and had simple mouths without lips, intestines with granular contents and tapering tails. Larvae recovered from the intestinal mucosa of their hosts (probably L3, and sometimes referred to as static or arrested larvae) were similar in morphology and considered small measuring up to 1mm in length. Larvae recovered later from the host gut content (probably L4, as sexual differentiation had begun) were larger measuring 1.6-3.0 mm long but growing rapidly to 6 mm over 1-2 weeks. These larvae had mouths with developing lips, a conspicuous nerve ring and oesophagus, and developing males had preanal swellings (the beginnings of the preanal sucker) on their sickle-shaped tails. Adults are large stout worms measuring 15-120 mm in length with cylindrical semitransparent creamy-white bodies tapering at both ends. They are bound by a tough cuticle with transverse striations and 2 small poorly-developed lateral alae (absent in a few species) but lack an anterior cuticular flange. They have an anterior triangular mouth surrounded by 3 large stout denticulate lips without interlabia, but with 2 conspicuous papillae (sensory organs) on the dorsal lip and one on each of the subventral lips. The oesophagus is slender and club-shaped but lacks a posterior bulb and the tail is conically pointed. Adult worms exhibit distinct sexual dimorphism, with female worms being considerably longer and more robust than males (20-120 mm cf. 15-80 mm). Mature females are didelphic with 2 ovaries and 2 uteri in an amphidelphic configuration (opposed) connected to a short vagina terminating in a midbody vulva. Females have a subterminal anus and straight blunt tails, sometimes ending in a caudal spine. Mature males have a conspicuous round-oval preanal sucker (0.2-0.3 x 0.15-0.2 mm) with a chitinous rim. They have curved pointed tails with 2 narrow smooth membranous caudal alae supported by 9-10 pairs of relatively large caudal papillae arranged longitudinally in various configurations (usually comprising 2-3 pairs pre-anal, 1-2 pairs adanal, 3-5 pairs postanal and 3 pairs subterminal). Males lack a gubernaculum but have 2 equal or subequal spicules ranging in length from 1-4 mm and usually expanded proximally.

Site of infection: Adult worms are found mainly in the small intestines (duodenum, jejunum) of their avian hosts, although adults of several species may occasionally migrate erratically up to the oesophagus, crop, or gizzard, out to the body cavity or liver, or down through the large intestines and cloaca (sometimes passed in host faeces) and entering the oviduct (sometimes infecting host eggs). Earlier larval stages develop within the intestinal mucosa but do not undertake any extra-intestinal migrations. Larvated eggs and freed larvae have also been detected in the intestines of invertebrate paratenic (transport) hosts (earthworms).

Pathogenesis: Most infections are light and remain subclinical, but heavy infections by *A. galli* in poultry are a major cause of ill-thrift with poor growth, weight depression and reduced egg production. Clinical disease (ascaridiosis) is more common in young birds (< 3 months old) as older animals acquire protective immune responses, but nonetheless may still act as asymptomatic carriers (larvae may sequester in mucosal tissues). Disease usually begins during the prepatent period when larvae invade the intestinal mucosa causing traumatic damage with petechial haemorrhages and provoking catarrhal (sometimes haemorrhagic) enteritis. The subsequent development of large adult worms in the lumen may cause pressure atrophy of villi with epithelial necrosis and villous adhesions. Aggregates or tangles of worms may cause intestinal blockages and aberrant migrations may cause lesions higher or lower in the alimentary tract and sometimes in the liver (fatty degeneration, coagulation necrosis, cellular infiltrations) and lungs (haemorrhages, haemosiderosis). Adult worms consume intestinal content and rob their hosts of proteins, carbohydrates, minerals (calcium, phosphorus) and vitamins (A, B1) contributing to hypoglycaemia, malnutrition, delayed growth and even rickets. It is also thought that parasite secretions/excretions may act as toxins causing metabolic disturbances and thymus atrophy. Clinical signs include intermittent diarrhoea, dehydration, enteritis, anaemia, anorexia, unthriftiness, stunted growth, loss of condition, weight loss, cachexia, emaciation, pica, adynamia, lethargy, listlessness, drooping wings, ruffled feathers, paresis and sudden death. In heavy

infections, adult worms infect the oviducts of hens resulting in the production of misshapen eggs with thin soft shells, sometimes containing worms. Disease is worse in birds subject to stress, such as overcrowding, malnourishment (mineral and protein deficiencies), thirst, thermal discomfort, and some concomitant infections by other pathogens (including viruses, bacteria, protozoa and helminths).

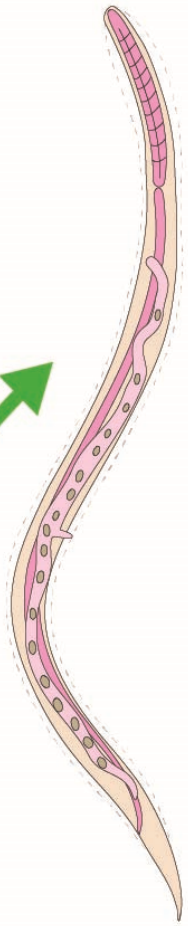
Developmental cycle and mode of transmission: *Ascaridia* spp. have direct monoxenous life-cycles involving the faecal-oral transmission of eggs containing infective larvae, sometimes transported in invertebrate paratenic hosts. Female worms in the intestines of their hosts lay unembryonated eggs which are excreted with faeces into the external environment. The eggs embryonate forming L1 which then moult inside the egg to form infective larvae (some reports state that 1 moult occurs to produce L2, while others say 2 moults occur to form L3). The time taken for larval development depends on prevailing conditions, generally taking 7-20 days in warm moist conditions, but longer in cooler conditions with little development occurring at temperatures under 15°C. The larvated eggs are highly resistant to desiccation and can persist in soil for months. Earthworms may also act as paratenic (transport) hosts carrying larvated eggs or released larvae in their intestines (but not in extraintestinal tissues). New final hosts become infected when they ingest eggs with infective larvae in contaminated food or water or by consuming infected earthworms. Ingested eggs hatch in the proventriculus or duodenum releasing infective larvae which do not undergo extensive somatic or hepato-pulmonary migration (while larvae may sometimes be found in the liver or lungs, experimental studies indicate they fail to develop further). Instead, many infective larvae undergo local transient histotrophic development (sometimes called tissue-phase or mucosa-phase) when they penetrate the mucosal lining. This phase is terminated when the larvae moult to the next stage (L3 or L4 depending on what stage was infective). It generally lasts for 3-16 days, but has been found to be extended up to 54 days or longer in heavily-infected or resistant hosts. It has been suggested that some larvae may arrest their development within the mucosa in response to developing host immune responses (explaining why older birds may carry latent infections). Eventually, the larvae emerge into the lumen of the small intestines where they complete their development to adults in 30-50 days. Other experimental studies have also demonstrated that some infective larvae may develop into adults without leaving the lumen, moulting to L4 in 6-9 days and to subadults (often referred to as L5) in 14-19 days. The prepatent period (time from infection to first egg excretion) is therefore quire variable, ranging from 28-70 days depending on the age of the birds and the site of adult development. Female worms are prolific egg layers and they have been found to live for over 1 year. Infections are more prevalent in poultry enterprises where birds are free-ranging or kept on deep litter, rather than confined to battery cages.

Differential diagnosis: Clinical infections may be indicated in susceptible birds exhibiting vague signs of illthrift, but other causative agents cannot be excluded. Occasionally, large worms may be excreted in host faeces or be found within thin-walled misshapen eggs. Infections are generally diagnosed, however, by the microscopic detection of worm eggs in faecal samples, either in wet mounts or smears but usually following their concentration by sedimentation in water and floatation in saturated sugar or heavy metal salt solutions (with high specific gravities). *Ascaridia* eggs are remarkably similar in appearance to those of *Heterakis,* both being thick-shelled and ellipsoidal, but those of *Ascaridia* are slightly larger and have convex sides rather than nearly parallel sides. Infections may also be detected at post-mortem by the detection of parasites (larvae and adult worms) in the intestinal contents, mucosal scrapings, squash preparations or tissue digests, particularly in areas with acute enteritis and sometimes chronic distention. Molecular biological techniques have been applied to the characterization of parasite species following the polymerase chain reaction (PCR) amplification of random amplified polymorphic DNA (RAPD) or restriction fragment length polymorphism (RFLP) analyses or sequencing of mitochondrial genes (particularly cytochrome c oxidase subunit 3, NADH dehydrogenase subunits 1 and 4).

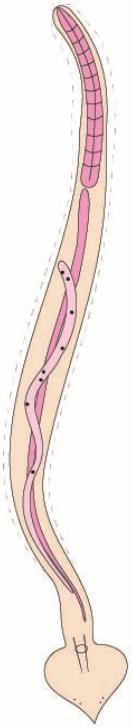
Treatment and control: Clinical infections in poultry have been treated using a range of anthelmintic drugs, including tetrahydropyrimidines (pyrantel), benzimidazoles (mebendazole, flubendazole, albendazole, fenbendazole), imidazothiazoles (levamisole, tetramisole), diethylenediamines (piperazine) and macrocyclic lactones (ivermectin), with most drugs being effective against both immature and mature stages. Continuous in-feed medication with the aminoglycoside antibiotic hygromycin B has also been widely used to suppress infections in poultry. Most anthelmintics have little residual activity and are not long-lasting so birds require regular treatment as they may be readily re-infected. Control programmes must therefore also adopt preventive strategies designed to reduce parasite transmission, either by reducing contamination of the environment by infective stages or limiting their uptake by new susceptible hosts. Appropriate sanitary and hygienic practices include frequent litter removal, not using faeces as fertiliser in grazing areas, providing clean food and water, preventing the faecal contamination of feeding and watering devices (raising them off the ground), improving drainage, using insecticides to reduce potential paratenic host populations, raising birds on elevated platforms or hard surfaces, and regular cleaning of holding facilities and runs. While worm eggs are resistant to desiccation, they are susceptible to detergents and various plant extracts (such as bishkatali, neem, or papaya extracts impregnated into the litter). Bird management practices should avoid overcrowding and other stressors, use quarantine and isolation procedures particularly for new stock, separate cohorts especially young chickens from adults, exclude wild and feral birds from poultry facilities, and regularly rotate poultry runs, yards, pastures and sheds.

Ascaridia

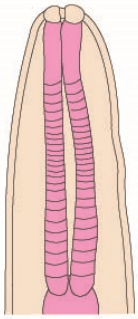
intestines
(anaemia, enteritis,
diarrhoea, illthrift)



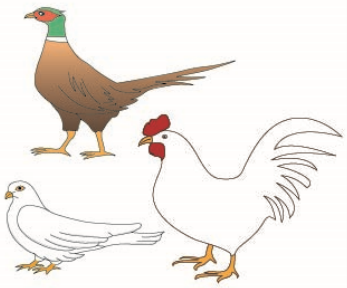
adult female
(~ 100 mm)



adult male
(~ 60 mm)

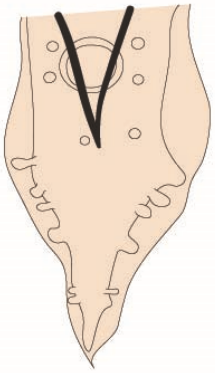


head



Definitive Hosts
(birds, esp. poultry)

local larval
migration in
mucosa



male
tail

eggs
excreted
in faeces

eggs/L2/PH
ingested

L2 also carried in PH

second-stage larva
(L2) (~ 1 mm)

external
environment

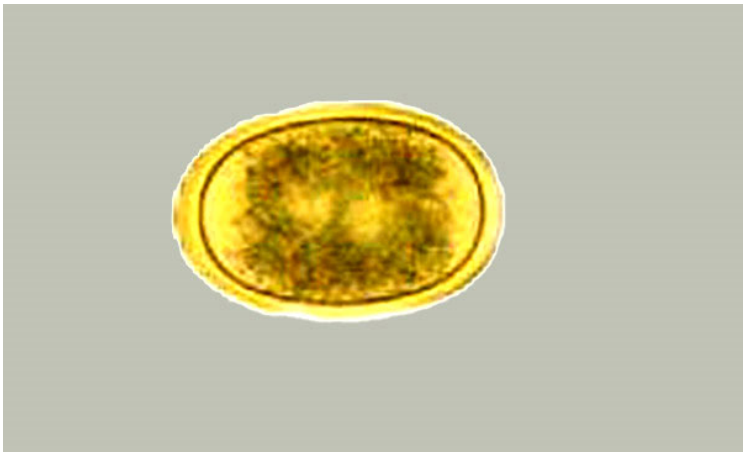
eggs
(~ 70 µm)

L2 develop
in eggs

Paratenic Hosts (PH)
(earthworms)
(body cavity, viscera)

Ascaridia adult worms

Ascaridia adult worms



Ascaridia worm egg

Ascaridia larva