

CHAPTER 1

Veterinary helminthology

PRINCIPLES OF CLASSIFICATION

When examined, living organisms can be seen to form natural groups with features in common. These similarities may be morphological, but increasingly may be based on DNA analysis. Groups of organisms are combined into biologically meaningful groups, usually attempting to represent evolutionary pathways. A group of this sort is called a **taxon**, and the study of this aspect of biology is called **taxonomy**. The study of the complex systems of interrelationship between living organisms is called **systematics**.

The taxa into which organisms may be placed are recognised by international agreement; the primary ones are **kingdom, phylum, class, order, family, genus** and **species**. The intervals between these are large, and some organisms cannot be allocated to them precisely, so intermediate taxa, prefixed appropriately, have been formed; examples of these are the **suborder** and the **superfamily**. As an example, the taxonomic status of one of the common abomasal parasites of ruminants may be expressed as shown below.

Kingdom	Animalia
Phylum	Nematoda
Class	Secernentea
Order	Strongylida
Suborder	Strongylina
Superfamily	Trichostrongyloidea
Family	Trichostrongylidae
Subfamily	Haemonchinae
Genus	<i>Haemonchus</i>
Species	<i>contortus</i>

The names of taxa must follow a set of internationally agreed rules, but it is permissible to anglicise the endings, so that members of the superfamily Trichostrongyloidea in the example above may also be termed trichostrongylids.

The names of the genus and species are expressed in Latin form, the generic name having a capital letter, and they must be in grammatical agreement. It is customary to print Latin names in italics. Accents are not permitted. If an organism is named after a person, amendment may be necessary; the name of Müller, for example, has been altered in the genus *Muellerius*.

HELMINTHOLOGY

Parasitic helminths can affect humans, animals and plants, with estimated numbers of between 75,000 and 300,000 species. The higher taxa containing helminths of veterinary importance are:

Major

- Nematoda (roundworms)
- Platyhelminthes (flatworms)
 - Trematoda (Flukes)
 - Cestoda (Tapeworms)

Minor

- Acanthocephala (thorny-headed worms)

PHYLUM NEMATODA

The nematodes (Nematoda) are commonly called **roundworms** from their appearance in cross-section, and are parasitic or free-living. In the majority of nematodes the sexes are separate.

CLASS SECERNENTEA

The system of classification of nematodes of veterinary importance, which is based on current taxonomic literature, is given in Table 1.1. In this system, nematode genera and species in the class Secernentea are grouped into 16 **superfamilies** in which nematodes of veterinary importance occur. The superfamilies can be conveniently divided into **bursate** and **non-bursate** groups, the most typical features of which are summarised in Table 1.2.

STRUCTURE AND FUNCTION

Most nematodes have a cylindrical unsegmented form, tapering at either end, and the body is covered by a colourless, somewhat translucent, layer: the cuticle.

The tough cuticle is secreted by the underlying hypodermis, which projects into the body cavity forming two lateral cords, which carry the excretory canals, and a dorsal and ventral cord carrying the nerves (Fig. 1.1). The muscle cells, arranged longitudinally, lie between the hypodermis and the body cavity. The latter contains fluid at a high pressure, which maintains the turgidity and shape of the body (pseudocoelom). Locomotion is effected by undulating waves of muscle contraction and relaxation that alternate on the dorsal and ventral aspects of the worm. A circular muscle layer is absent in nematodes. Most of the internal organs are filamentous and suspended in the fluid-filled body cavity (Fig. 1.1).

The **digestive system** is tubular (Fig. 1.2a). The mouth, or stoma, of many nematodes is a simple opening, which may be surrounded by two or three lips, and leads directly into the oesophagus. Where

Table 1.1 Classification of parasitic nematodes of veterinary importance.

Kingdom	Phylum	Class	Order	Superfamily	Family (Subfamily) Genus
Animalia	Nematoda	Secernentea	Strongylida	Trichostrongyloidea	Trichostrongylidae
					<i>Trichostrongylus</i>
					<i>Marshallagia</i>
					<i>Hyostrogylus</i>
					<i>Mecistocirrus</i>
					<i>Graphidium</i>
					<i>Obeliscoides</i>
					<i>Libyostrongylus</i>
					<i>Graphinema</i>
					<i>Impalaia</i>
					(Ostertaginae)
					<i>Ostertagia</i>
					<i>Teladorsagia</i>
					<i>Spiculopteragia</i>
					<i>Apteragia</i>
				<i>Camelostrongylus</i>	
				(Haemonchinae)	
				<i>Haemonchus</i>	
				Cooperidae	
				<i>Cooperia</i>	
				Ornithostrongylidae	
<i>Ornithostrongylus</i>					
Amidostomidae					
<i>Amidostomum</i>					
<i>Epomidiostomum</i>					
Molineidae					
<i>Nematodirus</i>					
<i>Nematodirella</i>					
<i>Lamanema</i>					
<i>Molineus</i>					
<i>Ollulanus</i>					
<i>Tupaiostrongylus</i>					
Heligmonellidae					
<i>Nippostrongylus</i>					
<i>Nematospiroides</i>					
Dictyocaulidae					
<i>Dictyocaulus</i>					
				Strongyloidea	Strongylidae
					(Strongylinae)
					<i>Strongylus</i>
					<i>Triodontophorus</i>
					<i>Chabertia</i>
					<i>Oesophagostomum</i>
					<i>Poteriostomum</i>
					<i>Craterostomum</i>
					<i>Oesophagodontus</i>
					<i>Codiostomum</i>
					(Cyathostominae)
					<i>Cyathostomum</i>
					<i>Cyclicocyclus</i>
					<i>Cylicodontophorus</i>
					<i>Cylicostephanus</i>
					Syngamidae
					<i>Syngamus</i>
					<i>Cyathostoma</i>
					<i>Mammomonogamus</i>
					<i>Stephanurus</i>
					Deletrocephalidae
					<i>Deletrocephalus</i>
					<i>Paradeletrocephalus</i>
				Ancylostomatoidea	Ancylostomatidae
					<i>Ancylostoma</i>
					<i>Uncinaria</i>
					<i>Bunostomum</i>
					<i>Gaigeria</i>
					<i>Necator</i>
					<i>Globocephalus</i>
					<i>Agriostomum</i>
				Diaphanocephaloidea	Diaphanocephalidae
					<i>Kalicephalus</i>

Kingdom	Phylum	Class	Order	Superfamily	Family (Subfamily) Genus		
Animalia	Nematoda	Secernentea		Metastrongyloidea	Metastrongylidae <i>Metastrongylus</i>		
					Protostrongylidae <i>Muellerius</i> <i>Protostrongylus</i> <i>Cystocaulus</i> <i>Spiculocaulus</i> <i>Neostongylus</i> <i>Varestrongylus</i> <i>Parelaphostongylus</i> <i>Elaphostongylus</i>		
					Filaroididae <i>Oslerus</i> <i>Filaroides</i>		
					Angiostrongylidae <i>Angiostrongylus</i>		
					Crenosomidae <i>Crenosoma</i>		
					Rhabditida	Rhabditoidea	Strongyloidae <i>Strongyloides</i>
							Panagrolaimidae <i>Halicephalobus</i>
							Rhabditidae <i>Rhabditis</i>
							Rhabdiasidae <i>Rhabdias</i>
					Ascaridida	Ascaridoidea	Ascaridae <i>Ascaris</i> <i>Toxocara</i> <i>Toxascaris</i> <i>Parascaris</i> <i>Ascaridia</i> <i>Heterakis</i> <i>Porrocaecum</i> <i>Bayliascaris</i> <i>Polydelphus</i> <i>Ophidascaris</i> <i>Angusticaecum</i>
Anisakidae <i>Anisakis</i> <i>Contraecum</i> <i>Hysterothylacium</i> <i>Pseudoterranova</i> <i>Sulcasaris</i>							
Diectophymatoidea	Diectophymatidae <i>Diectophyma</i> <i>Hystrichis</i> <i>Eustrongylides</i>						
	Oxyurida	Oxyuroidea	Oxyuridae <i>Oxyuris</i> <i>Skrjabinema</i> <i>Aspicularis</i> <i>Syphacia</i> <i>Passalurus</i> <i>Dermatoxys</i> <i>Enterobius</i>				
Cosmocercidae <i>Probstmayria</i>							
Aspidoderidae <i>Paraspidodera</i>							
Pharyngodonidae <i>Tachygonetria</i>							
Spirurida			Spiruroidea	Spirocercidae <i>Spirocerca</i> <i>Ascarops</i> <i>Physocephalus</i> <i>Simondsia</i> <i>Streptoparagus</i>			
				Habronematidae <i>Habronema</i> <i>Draschia</i> <i>Parabronema</i> <i>Histiocephalus</i>			

Continued

Table 1.1 Continued

Kingdom	Phylum	Class	Order	Superfamily	Family (Subfamily) Genus	
Animalia	Nematoda	Secernentea			Thelazidae <i>Thelazia</i> <i>Oxyspirura</i>	
					Gnathostomatidae <i>Gnathostoma</i>	
					Gongylonematidae <i>Gongylonema</i>	
					Physalopteridae <i>Physaloptera</i>	
					Spiruridae <i>Spirura</i> <i>Odontospirura</i> <i>Protospirura</i> <i>Pterygodermatities</i>	
					Tetrameridae <i>Tetrameres</i>	
					Hartertiidae <i>Hartertia</i>	
					Pneumospiridae <i>Metathelazia</i> <i>Vogeloides</i>	
					Subuluroidea	Subuluridae <i>Subulura</i>
					Dracunculoidea	Dracunculidae <i>Dracunculus</i> <i>Avioseperis</i>
					Acuarioidea	Acuaridae <i>Echinuria</i> <i>Dispharynx</i> <i>Cheilospirura</i> <i>Streptocara</i>
					Filarioidea	Filariidae <i>Parafilaria</i> <i>Stephanofilaria</i> <i>Loa</i> <i>Suifilaria</i>
						Onchocercidae <i>Dirofilaria</i> <i>Acanthocheilonema</i> <i>Dipetalonema</i> <i>Onchocerca</i> <i>Pelecitus</i> <i>Chanderella</i> <i>Setaria</i> <i>Elaeophora</i> <i>Splendidofilaria</i> <i>Brugia</i> spp. <i>Wuchereria</i> <i>Mansonella</i> <i>Paranchocerca</i>
					Adenophorea	Enoplida
				Capillaridae <i>Capillaria</i> <i>Eucoleus</i>		
			Trichinelloidea	Trichinellidae <i>Trichinella</i>		

the mouth opening is large and well developed it is often surrounded by a leaf crown. In others, such as the strongyloids, it is large, and opens into a **buccal capsule**, which may contain blades or teeth. Such parasites, when feeding, draw a plug of mucosa into the buccal capsule, where it is broken down by the action of enzymes, which are secreted into the capsule from adjacent glands. Some of these worms may also secrete anticoagulant, and small vessels, ruptured in the digestion of the mucosal plug, may continue to bleed for some minutes after the worm has moved to a fresh site.

Those nematodes with very small buccal capsules, like the trichostrongyloids, or simple oral openings, like the ascaridoids, generally feed on mucosal fluid, products of host digestion and cell debris, while others, such as the oxyuroids, appear to scavenge on the contents of the lower gut. Worms living in the bloodstream or tissue spaces, such as the filarioids, feed exclusively on body fluids.

The **oesophagus** is usually muscular and pumps food into the intestine. It is of variable form (Fig. 1.3), and is a useful preliminary identification character for groups of worms. It may be **filariform**,

Table 1.2 Characteristic features of parasitic nematodes of veterinary importance.

Superfamily	Typical features
Bursate nematodes	
Trichostrongyloidea <i>Trichostrongylus, Ostertagia, Dictyoacaulus, Haemonchus, etc.</i>	Buccal capsule small. Life cycle direct ; infection by L ₃
Strongyloidea <i>Strongylus, Syngamus, etc.</i>	Buccal capsule well developed; leaf crowns and teeth usually present. Life cycle direct ; infection by L ₃
Ancylostomatoidea <i>Ancylostoma, Uncinaria, etc.</i>	Buccal capsule well developed; leaf crowns and teeth usually present. Life cycle direct ; infection by L ₃
Metastrongyloidea <i>Metastrongylus, Muellerius, Protostrongylus, etc.</i>	Buccal capsule small. Life cycle indirect ; infection by L ₃ in intermediate host
Non-bursate nematodes	
Rhabditoidea <i>Strongyloides, Rhabditis, etc.</i>	Very small worms; buccal capsule small. Free-living and parasitic generations. Life cycle direct ; infection by L ₃
Ascaridoidea <i>Ascaris, Toxocara, Parascaris, etc.</i>	Large white worms. Life cycle direct ; infection by L ₂ in egg
Diectophymatoidea <i>Diectophyma, etc.</i>	Very large worms. Life cycle indirect ; infection by L ₃ in aquatic annelids
Oxyuroidea <i>Oxyuris, Skrjabinema, etc.</i>	Female has long pointed tail. Life cycle direct ; infection by L ₃ in egg
Spiuroidea <i>Spirocerca, Habronema, Thelazia, etc.</i>	Spiral tail in male. Life cycle indirect ; infection by L ₃ from insects
Filarioidea <i>Dirofilaria, Onchocerca, Parafilaria, etc.</i>	Long thin worms. Life cycle indirect ; infection by L ₃ from insects
Trichuroidea <i>Trichuris, Capillaria</i>	Whip-like or hair-like worms. Life cycle direct or indirect ; infection by L ₁
Trichinelloidea <i>Trichinella, etc.</i>	

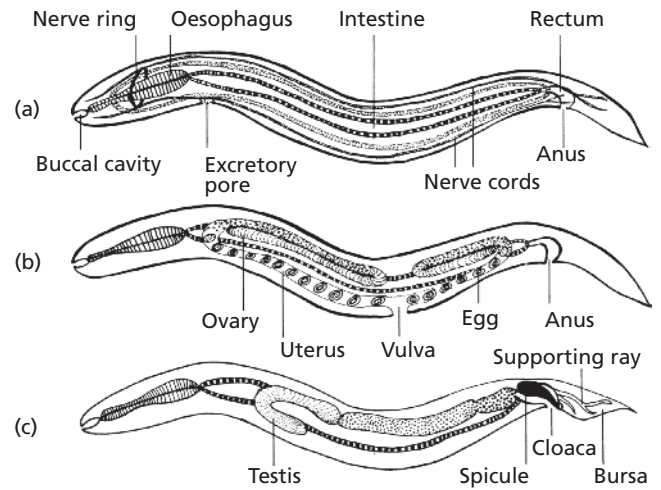


Fig. 1.2 Longitudinal sections of a generalised nematode. (a) Digestive, excretory and nervous system. (b) Reproductive system of a female nematode. (c) Reproductive system of a male nematode.

The **intestine** is a simple tube descending from the oesophagus whose lumen is enclosed by a single layer of epithelial cells or by a syncytium. The luminal surfaces possess microvilli, which increase the absorptive capacity of the cells. In female worms the intestine terminates in an anus, while in males there is a cloaca which functions as an anus, and into which opens the vas deferens and through which the copulatory spicules may be extruded.

simple and slightly thickened posteriorly, as in the bursate nematodes; **bulb-shaped**, with a large posterior swelling, as in the ascarioids; or **double bulb-shaped**, as in the oxyuroids. In some groups this wholly muscular form does not occur: the filarioids and spirooids have a **muscular-glandular** oesophagus which is muscular anteriorly, the posterior part being glandular; the **trichuroid** oesophagus has a capillary form, passing through a single column of cells, the whole being known as a stichosome. A **rhabditiform** oesophagus, with slight anterior and posterior swellings, is present in the preparasitic larvae of many nematodes, and in adult free-living nematodes.

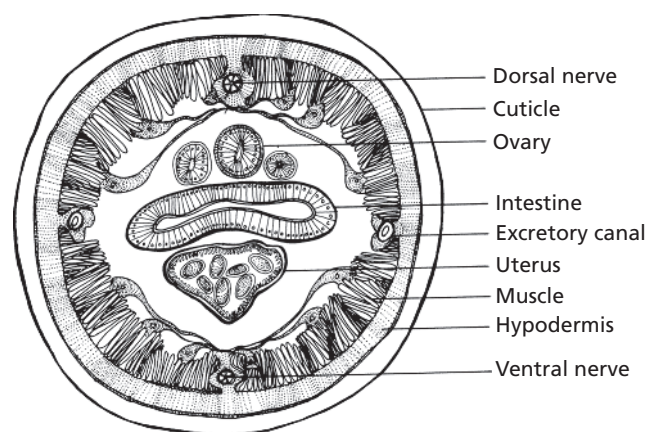


Fig. 1.1 Transverse section of a generalised female nematode.

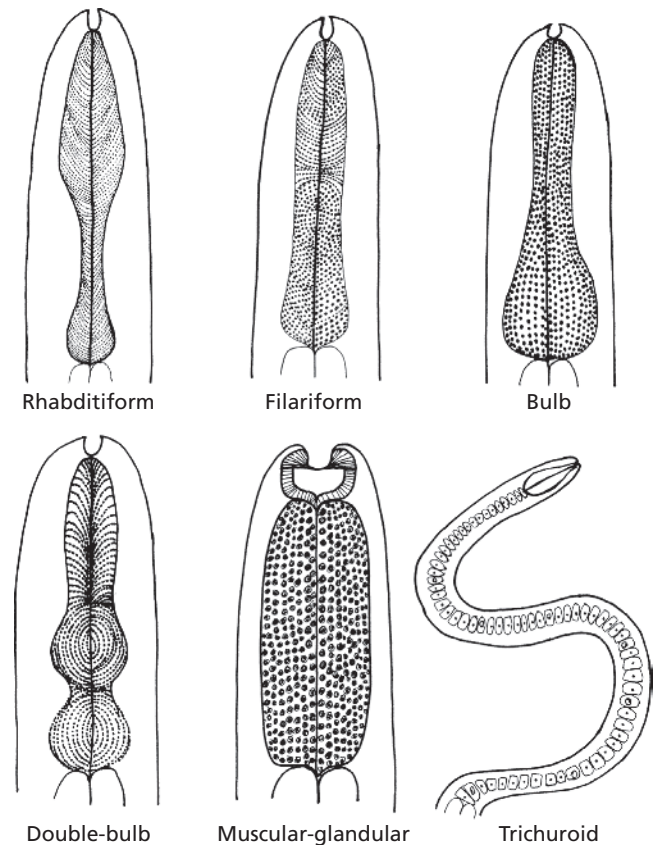


Fig. 1.3 The basic forms of oesophagus found in nematodes.

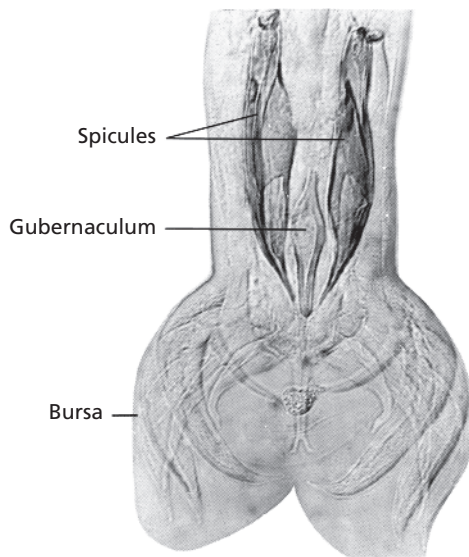


Fig. 1.4 Male trichostrongylid nematode bursa showing spicules and bursa.

The so-called ‘**excretory system**’ is very primitive, consisting of a canal within each lateral cord joining at the excretory pore in the oesophageal region.

The **reproductive systems** consist of filamentous tubes, which float in the body cavity. The **female organs** comprise ovary, oviduct and uterus, which may be paired (didelphic) or sometimes single (monodelphic), ending in a common short vagina, which opens at the vulva (Fig. 1.2b). The location of the vulva can be a useful aid in diagnosis, being at the anterior end (opisthodelphic), middle (amphidelphic) or the posterior end (prodelphic). At the junction of uterus and vagina in some species there is a short muscular organ, the ovejector, which regulates and assists in egg laying. A vulval flap may also be present. Nematodes can be oviparous, ovoviviparous or viviparous.

The **male organs** consist of a single continuous testis and a vas deferens terminating in a muscular ejaculatory duct into the cloaca (Fig. 1.2c). Accessory male organs are sometimes important in identification, especially of the trichostrongyloids, the two most important being the spicules and gubernaculum (Fig. 1.4). The **spicules** are chitinous organs, usually paired, which are inserted in the female genital opening during copulation. In some species they are absent (e.g. *Trichinella*) or only one spicule is present (e.g. *Trichuris*). The **gubernaculum**, also chitinous, is a small structure located in the dorsal wall, which acts as a guide for the spicules. When the guide is located in the ventral wall it is referred to as a **telamon**. With the two sexes in close apposition the amoeboid sperm are transferred from the cloaca of the male into the uterus of the female.

The **cuticle** may be modified to form various structures (Fig. 1.5), the more important of which include the following.

- **Leaf crowns** consisting of rows of papillae occurring as fringes round the rim of the buccal capsule (external leaf crowns) or just inside the rim (internal leaf crowns). They are especially prominent in certain nematodes of horses. Their function is not known, but it is suggested that they may be used to pin a patch of mucosa in position during feeding, or that they may prevent the entry of foreign matter into the buccal capsule when the worm has detached from the mucosa.

- **Cervical papillae** occur anteriorly in the oesophageal region, and **caudal papillae** posteriorly at the tail. They are spine-like or finger-like processes, and are usually diametrically placed. Their function may be sensory or supportive.
- **Cervical** and **caudal alae** are flattened wing-like expansions of the cuticle in the oesophageal and tail regions respectively.
- **Cephalic** and **cervical vesicles** are inflations of the cuticle around the mouth opening and in the oesophageal region.
- The **copulatory bursa**, which embraces the female during copulation, is important in the identification of certain male nematodes and is derived from much expanded caudal alae, which are supported by elongated caudal papillae called **bursal rays**. It consists of two lateral lobes and a single small dorsal lobe. It is particularly well developed in the strongylids.
- **Plaques** and **cordons** are plate-like and cord-like ornamentations present on the cuticle of many nematodes of the superfamily Spiruroidea.

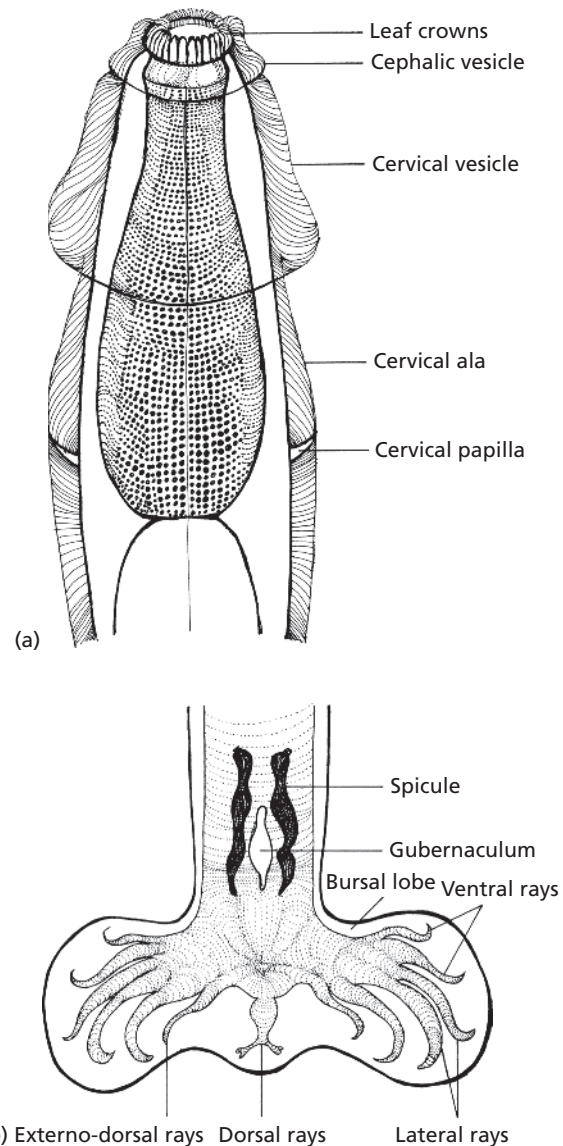


Fig. 1.5 Cuticular modifications of a generalised nematode: (a) anterior region; (b) posterior region of a male.

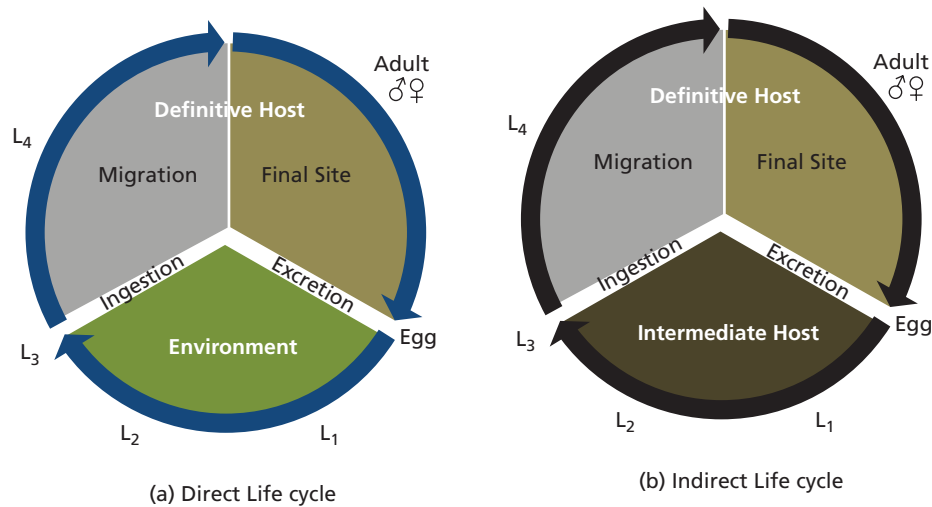


Fig. 1.6 Generalised nematode life cycles: (a) direct; (b) indirect.

BASIC NEMATODE LIFE CYCLE

In the Nematoda, the sexes are separate and the males are generally smaller than the females, which lay eggs or larvae. During development, a nematode moults at intervals, shedding its cuticle. In the complete life cycle there are four moults, the successive larval stages being designated L₁, L₂, L₃, L₄ and finally L₅, which is the immature adult.

One feature of the basic nematode life cycle is that immediate transfer of infection from one **final host** to another rarely occurs. Some development usually takes place either in the faecal pat or in a different species of animal, the **intermediate host**, before infection can take place.

In the common form of **direct** life cycle (Fig. 1.6a), the free-living larvae undergo two moults after hatching and infection is by ingestion of the free L₃ stage. There are some important exceptions however, infection sometimes being by larval penetration of the skin or by ingestion of the egg containing a larva.

In **indirect** life cycles (Fig. 1.6b), the first two moults usually take place in an intermediate host and infection of the final host is either by ingestion of the intermediate host or by inoculation of the L₃ when the intermediate host, such as a blood-sucking insect, feeds.

After infection, two further moults take place to produce the L₅ or immature adult parasite. Following copulation a further life cycle is initiated.

In the case of gastrointestinal parasites, development may take place entirely in the gut lumen or with only limited movement into the mucosa.

However, in many species, the larvae travel considerable distances through the body before settling in their final (predilection) site and this is the migratory form of life cycle. One of the most common routes is the **hepatic-tracheal**. This takes developing stages from the **gut** via the portal system to the **liver** then via the hepatic vein and posterior vena cava to the **heart** and from there via the pulmonary artery to the **lungs**. Larvae then travel via the bronchi, trachea and oesophagus to the **gut**. It should be emphasised that the above is a basic description of nematode life cycles and that there are many variations.

DEVELOPMENT OF THE PARASITE

Egg

Nematode eggs differ greatly in size and shape, and the shell is of variable thickness, usually consisting of three layers.

The inner membrane, which is thin, has lipid characteristics and is impermeable. A middle layer, which is tough and chitinous, gives rigidity and, when thick, imparts a yellowish colour to the egg. In many species this layer is interrupted at one or both ends with an operculum (lid) or plug. The third outer layer consists of protein, which is very thick and sticky in the ascaridoids and is important in the epidemiology of this superfamily.

In contrast, in some species the eggshell is very thin and may be merely present as a sheath around the larva.

The survival potential of the egg outside the body varies, but appears to be connected with the thickness of the shell, which protects the larva from desiccation. Thus parasites whose infective form is the larvated egg usually have very thick-shelled eggs which can survive for years on the ground.

Hatching

Depending on the species, eggs may hatch outside the body or after ingestion.

Outside the body, hatching is controlled partly by factors such as temperature and moisture and partly by the larva itself. In the process of hatching, the inner impermeable shell membrane is broken down by enzymes secreted by the larva and by its own movement. The larva is then able to take up water from the environment and enlarges to rupture the remaining layers and escape.

When the larvated egg is the infective form, the host initiates hatching after ingestion by providing stimuli for the larva, which then completes the process. It is important for each nematode species that hatching should occur in appropriate regions of the gut and hence the stimuli will differ, although it appears that dissolved carbon dioxide is a constant essential.

Larval development and survival

Three of the important superfamilies, the trichostrongyloids, the strongyloids and the rhabditoids, have a completely free-living pre-parasitic phase. The first two larval stages usually feed on bacteria, but the L₃, sealed off from the environment by the retained cuticle of the L₂, cannot feed and must survive on the stored nutrients acquired in the early stages. Growth of the larva is interrupted during moulting by periods of lethargus in which it neither feeds nor moves.

The cuticle of the L₂ is retained as a sheath around the L₃; this is important in larval survival with a protective role analogous to that of the eggshell in egg-infective groups.

The two most important components of the external environment are temperature and humidity. The optimal temperature for the development of the maximum number of larvae in the shortest feasible time is generally in the range 18–26°C. At higher temperatures, development is faster and the larvae are hyperactive, thus depleting their lipid reserves. The mortality rate then rises, so that few will survive to L₃. As the temperature falls the process slows, and below 10°C the development from egg to L₃ usually cannot take place. Below 5°C movement and metabolism of L₃ is minimal, which in many species favours survival.

The optimal humidity is 100%, although some development can occur down to 80% relative humidity. It should be noted that even in dry weather where the ambient humidity is low, the microclimate in faeces or at the soil surface may be sufficiently humid to permit continuing larval development.

In the trichostrongyloids and strongyloids, the embryonated egg and the ensheathed L₃ are best equipped to survive in adverse conditions such as freezing or desiccation; in contrast, the L₁ and L₂ are particularly vulnerable. Although desiccation is generally considered to be the most lethal influence in larval survival, there is increasing evidence that by entering a state of anhydrobiosis, certain larvae can survive severe desiccation.

On the ground most larvae are active, although they require a film of water for movement and are stimulated by light and temperature. It is now thought that larval movement is mostly random and encounter with grass blades accidental.

Infection

As noted previously, infection may be by ingestion of the free-living L₃, and this occurs in the majority of trichostrongyloid and strongyloid nematodes. In these, the L₃ sheds the retained sheath of the L₂ within the alimentary tract of the host, the stimulus for exsheathment being provided by the host in a manner similar to the hatching stimulus required by egg-infective nematodes. In response to this stimulus the larva releases its own exsheathing fluid, containing an enzyme, leucine aminopeptidase, which dissolves the sheath from within, either at a narrow collar anteriorly so that a cap detaches, or by splitting the sheath longitudinally. The larva can then wriggle free of the sheath.

As in the pre-parasitic stage, growth of the larva during parasitic development is interrupted by two moults, each of these occurring during a short period of lethargus.

The time taken for development from infection until mature adult parasites are producing eggs or larvae is known as the **pre-patent period** and this is of known duration for each nematode species.

METABOLISM

The main food reserve of pre-parasitic nematode larvae, whether inside the eggshell or free-living, is lipid, which may be seen as droplets in the lumen of the intestine. The infectivity of these stages is often related to the amount of lipid present; larvae which have depleted their reserves are not as infective as those which still retain quantities of lipid.

Apart from these reserves, the free-living first- and second-stage larvae of most nematodes feed on bacteria. However, once they reach the infective third stage, they are sealed in the retained cuticle of the second stage, cannot feed and are completely dependent on their stored reserves.

In contrast, the adult parasite stores its energy as glycogen, mainly in the lateral cords and muscles, and this may constitute 20% of the dry weight of the worm.

Free-living and developing stages of nematodes usually have an aerobic metabolism, whereas adult nematodes can metabolise carbohydrate by both glycolysis (anaerobic) and oxidative decarboxylation (aerobic). However, in the latter, pathways may operate which are not present in the host and it is at this level that some antiparasitic drugs operate.

The oxidation of carbohydrates requires the presence of an electron transport system, which in most nematodes can operate aerobically down to oxygen tensions of 5.0 mmHg or less. Since the oxygen tension at the mucosal surface of the intestine is around 20 mmHg, nematodes in close proximity to the mucosa normally have sufficient oxygen for aerobic metabolism. Otherwise, if the nematode is temporarily or permanently some distance from the mucosal surface, energy metabolism is probably largely anaerobic.

As well as the conventional cytochrome and flavoprotein electron transport system, many nematodes have 'haemoglobin' in their body fluids which gives them a red pigmentation. This nematode haemoglobin is chemically similar to myoglobin and has the highest affinity for oxygen of any known animal haemoglobin. The main function of nematode haemoglobin is thought to be to transport oxygen, acquired by diffusion through the cuticle or gut, into the tissues; blood-sucking worms presumably ingest a considerable amount of oxygenated nutrients in their diet.

The end products of the metabolism of carbohydrates, fats or proteins are excreted through the anus or cloaca, or by diffusion through the body wall. Ammonia, the terminal product of protein metabolism, must be excreted rapidly and diluted to non-toxic levels in the surrounding fluids. During periods of anaerobic carbohydrate metabolism, the worms may also excrete pyruvic acid rather than retaining it for future oxidation when aerobic metabolism is possible.

The 'excretory system' terminating in the excretory pore is almost certainly not concerned with excretion, but rather with osmoregulation and salt balance.

Two phenomena which affect the normal parasitic life cycle of nematodes and which are of considerable biological and epidemiological importance are **arrested larval development** and the **periparturient rise** in faecal egg counts.

ARRESTED LARVAL DEVELOPMENT

(Synonyms: inhibited larval development, hypobiosis)

This phenomenon may be defined as the temporary cessation in development of a nematode at a precise point in its parasitic development. It is usually a facultative characteristic and affects only a

proportion of the worm population. Some strains of nematodes have a high propensity for arrested development while in others this is low. The stage at which larvae become arrested varies between species of nematodes; for example, L₃ stage in *Trichostrongylus*, Cyathostominae, and *Ancylostoma*, L₄ stage in *Ostertagia*, *Teladorsagia*, *Haemonchus*, and *Obeliscoides*, or immature adults as in *Dictyocaulus*.

Conclusive evidence for the occurrence of arrested larval development can only be obtained by examination of the worm population in the host. It is usually recognised by the presence of large numbers of larvae at the same stage of development in animals withheld from infection for a period longer than that required to reach that particular larval stage.

The nature of the stimulus for arrested development and for the subsequent maturation of the larvae is still a matter of debate. Although there are apparently different circumstances which initiate arrested larval development, most commonly the stimulus is an environmental one received by the free-living infective stages prior to ingestion by the host. It may be seen as a ruse by the parasite to avoid adverse climatic conditions for its progeny by remaining sexually immature in the host until more favourable conditions return. The name commonly applied to this seasonal arrestment is **hypobiosis**. Thus the accumulation of arrested larvae often coincides with the onset of cold autumn/winter conditions in the northern hemisphere, or very dry conditions in the subtropics or tropics. In contrast, the maturation of these larvae coincides with the return of environmental conditions suitable to their free-living development, although it is not clear what triggers the signal to mature and how it is transmitted.

The degree of adaptation to these seasonal stimuli and therefore the proportion of larvae which do become arrested seem to be a heritable trait and is affected by various factors, including grazing systems and the degree of adversity in the environment. For example, in Canada where the winters are severe, most trichostrongyloid larvae ingested in late autumn or winter become arrested, whereas in southern Britain with moderate winters, about 50–60% are arrested. In the humid tropics where free-living larval development is possible all the year round, relatively few larvae become arrested.

However, arrested development may also occur as a result of both acquired and age immunity in the host and, although the proportions of larvae arrested are not usually so high as in hypobiosis, they can play an important part in the epidemiology of nematode infections. Maturation of these arrested larvae seems to be linked with the breeding cycle of the host and occurs at or around parturition.

The epidemiological importance of arrested larval development from whatever cause is that, first, it ensures the survival of the nematode during periods of adversity and, second, the subsequent maturation of arrested larvae increases the contamination of the environment and can sometimes result in clinical disease.

PERIPARTURIENT RISE IN FAECAL EGG COUNTS

(Synonyms: postparturient rise, spring rise)

Periparturient rise (PPR) refers to an increase in the numbers of nematode eggs in the faeces of animals around parturition. This phenomenon is most marked in ewes, goats and sows and recent data support the hypothesis that there is competition for nutrients between the immune system, the rapidly growing fetus in late pregnancy and the udder during lactation, particularly metabolisable

protein. This relaxation of immunity can be largely restored by supplementation with rumen-undegradable protein and is also influenced by the body protein status of the ewe.

The source of the PPR is threefold:

- 1 Maturation of larvae arrested due to host immunity.
- 2 An increased establishment of infections acquired from the pastures and a reduced turnover of existing adult infections.
- 3 An increased fecundity of existing adult worm populations.

Contemporaneously, but not associated with the relaxation of host immunity, the PPR may be augmented by the maturation of hypobiotic larvae.

The importance of the PPR is that it occurs at a time when the numbers of new susceptible hosts are increasing and so ensures the survival and propagation of the worm species. Depending on the magnitude of infection, it may also cause a loss of production in lactating animals and, by contamination of the environment, lead to clinical disease in susceptible young stock.

NEMATODE SUPERFAMILIES

SUPERFAMILY TRICHOSTRONGYLOIDEA

The trichostrongyloids are small, often hair-like, worms in the bursate group, which, with the exception of the lungworm *Dictyocaulus*, parasitise the alimentary tract of animals and birds. Structurally they have few cuticular appendages and the buccal capsule is vestigial and possesses no leaf crowns. Teeth are usually absent. The males have a well developed bursa with large lateral lobes and two spicules, the configuration of which is used for species differentiation. The life cycle is direct and usually non-migratory and the ensheathed L₃ is the infective stage.

The trichostrongylids are responsible for considerable mortality and widespread morbidity, especially in ruminants. The most important alimentary genera are *Ostertagia* (and other members of the subfamily Ostertaginae, *Teladorsagia*, *Spiculoptera*, *Apteria*, *Camelostrongylus*), *Haemonchus*, *Trichostrongylus*, *Cooperia*, *Nematodirus*, *Hyostrongylus*, *Marshallagia* and *Mecistocirrus*. *Dictyocaulus* is an important genus affecting the respiratory tract of ruminants and horses.

Other genera of lesser importance are *Graphidium*, *Obeliscoides*, *Ollulanus*, *Libyostrongylus*, *Graphinema*, *Impalaia*, *Ornithostrongylus*, *Amidostomum*, *Epomidiostomum*, *Nematodirella*, *Lamanema*, *Nippostrongylus* and *Nematospiroides*.

FAMILY TRICHOSTRONGYLIDAE

Trichostrongylus

Adult worms are small, slightly reddish/brown in colour, slender and hair-like, usually less than 7.0 mm long (Fig 1.7) and difficult to see with the naked eye. The worms have no obvious buccal capsule and cephalic inflations are absent. A most useful generic character is the distinct excretory notch in the oesophageal region (Fig. 1.8). The male bursa has long lateral lobes, while the dorsal lobe is not well defined with a slender dorsal ray, which is cleft near its tip into two branches. The ventro-ventral ray is well separated from the other rays. The spicules are thick and unbranched and a gubernaculum is present. Species identification is based on the shape and size of the spicules (Table 1.3). In the female, the tail is bluntly tapered

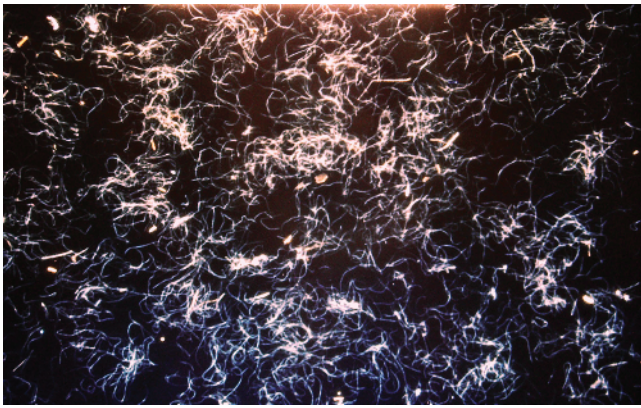


Fig. 1.7 Adult *Trichostrongylus* worms.



Fig. 1.8 Characteristic excretory notch in the oesophageal region of *Trichostrongylus*.

Table 1.3 Identification of *Trichostrongylus* spp. based on male spicule morphology.

Species	Spicules: description	Spicules: morphology
<i>T. axei</i>	Spicules are dissimilar and unequal in length (the right being shorter than the left)	(a)
<i>T. colubriformis</i>	Thick, brown, unbranched, of equal length and terminate in a barb-like tip	(b)
<i>T. vitrinus</i>	Thick, unbranched, of equal length and end in a point	(c)
<i>T. longispicularis</i>	The spicules are stout, brown, unbranched, slightly unequal in length and terminate in a tapering blunt tip that has a small semi-transparent protrusion	(d)
<i>T. rugatus</i>	Spicules are unequal and dissimilar, bearing transverse ridges near the tip	(e)
<i>T. falculatus</i>	Spicules sub-equal – 100 µm long	(f)
<i>T. capricola</i>	Spicules are equal in length. Thinner distally than anteriorly and terminate in a rounded tip	(g)
<i>T. retortaeformis</i>	Spicules are stout, unequal in length and terminate in a barb-like tip	(h)



Fig. 1.9 Tail of adult female *Trichostrongylus*.

(Fig. 1.9) and there is no vulval flap and the vulva opens a short distance from the middle of the body. The females possess double ovejectors.

Life cycle: This is direct and the preparasitic phase is typically trichostrongyloid, eggs developing to the infective L₃ in about 7–10 days under optimal conditions. Following ingestion and exsheathment, larvae penetrate the mucosa of the small intestine (Fig. 1.10) and after two moults the fifth-stage worms are present under the intestinal epithelium around 2 weeks after initial infection. The prepatent period is generally 2–3 weeks.

Trichostrongylus species

Species	Hosts	Site
<i>Trichostrongylus axei</i> (syn. <i>Trichostrongylus extenuatus</i>)	Cattle, sheep, goat, deer, horse, pig	Abomasum or stomach
<i>Trichostrongylus colubriformis</i>	Cattle, sheep, goat, camel, rabbit, pig, dog, human	Duodenum, anterior small intestine
<i>Trichostrongylus vitrinus</i>	Sheep, goat, camel, deer, rabbit	Duodenum, small intestine
<i>Trichostrongylus capricola</i>	Sheep, goat	Small intestine
<i>Trichostrongylus falculatus</i>	Sheep, goat, antelope	Small intestine
<i>Trichostrongylus longispicularis</i>	Sheep, cattle, goat, camel, deer, llama	Small intestine
<i>Trichostrongylus probolurus</i>	Sheep, goat, camel, occasionally human	Stomach, small intestine
<i>Trichostrongylus rugatus</i>	Sheep, goat	Small intestine
<i>Trichostrongylus retortaeformis</i>	Rabbit, hare	Small intestine
<i>Trichostrongylus calcaratus</i>	Rabbit, hare	Small intestine
<i>Trichostrongylus affinis</i>	Rabbit, sheep, occasionally human	Small intestine
<i>Trichostrongylus tenuis</i>	Gamebirds (grouse, partridge, pheasant), chicken, duck, goose, turkey, emu	Small intestine, caecae

Trichostrongylus axei

Synonym: *Trichostrongylus extenuatus*

Common name: Stomach hairworm

Description, gross: Males measure around 3–6 mm and females 4–8 mm in length. The male spicules are dissimilar and unequal

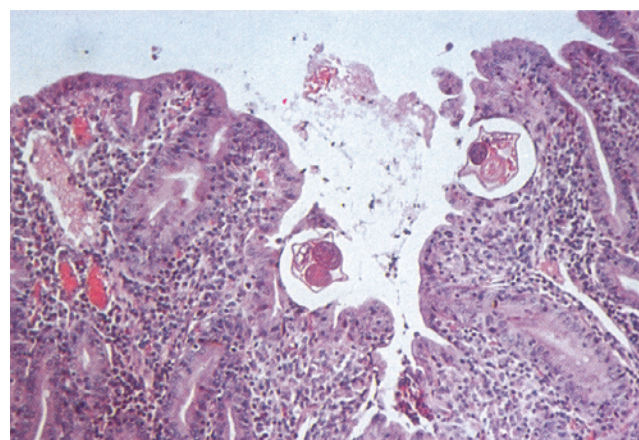


Fig. 1.10 Developing *Trichostrongylus vitrinus* in the small intestinal mucosa.

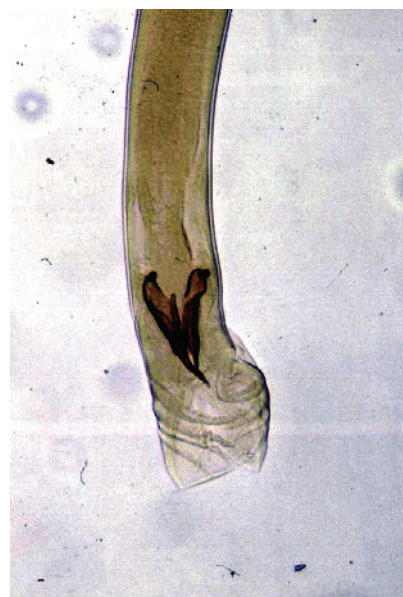


Fig. 1.11 Copulatory bursa and spicule of *Trichostrongylus axei*.

in length, the right being shorter than the left (Table 1.3a and Fig. 1.11).

Trichostrongylus colubriformis

Synonym: *Trichostrongylus instabilis*

Common name: Black scour or bankrupt worm

Description: Males measure around 4.0–5.5 mm and females 5.5–7.5 mm in length. The spicules are thick, brown, unbranched, of equal length and terminate in a barb-like tip (Table 1.3b and Fig. 1.12). The female has double ovejectors.



Fig. 1.12 Copulatory bursa and spicule of *Trichostrongylus colubriformis*.

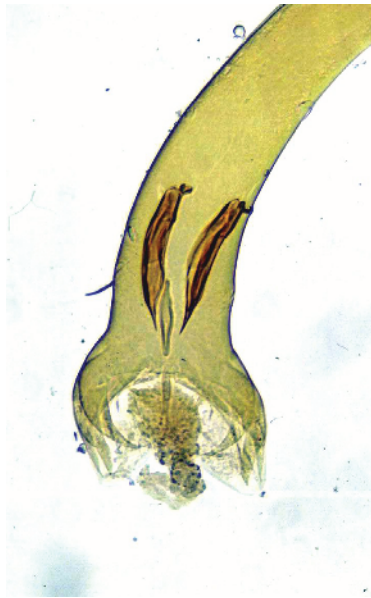


Fig. 1.13 Copulatory bursa and spicule of *Trichostrongylus vitrinus*.

Trichostrongylus vitrinus

Common name: Black scour worm

Description: Males measure around 4–6 mm and females 5–8 mm in length. The spicules are thick, unbranched, of equal length and end in a point (Table 1.3c and Fig. 1.13).

Trichostrongylus capricola

Description: Males measure around 4–5 mm and females 6–7 mm in length. The male spicules are of equal length, thicker anteriorly than distally and end in a rounded tip (Table 1.3g).

Trichostrongylus falculatus

Description: Males measure around 4.5–5.5 mm. The spicules are thick, brown, of almost equal length with a sickle-shaped offshoot (Table 1.3f). The gubernaculum is bent anteriorly at right angles.

Trichostrongylus longispicularis

Description: Males are around 5.5 mm in length. The spicules are stout, brown, unbranched, and slightly unequal in length terminating in a tapering blunt tip that has a small semi-transparent membranous protrusion (Table 1.3d).

Trichostrongylus probolurus

Description: Males are 4.5–6.5 mm and females 6–7.5 mm in length. The spicules are large and of equal size with two triangular projections.

Trichostrongylus rugatus

Description: Males are 4.5–5.5 mm and females 4.5–7.0 mm in length. The spicules differ in size and dimensions and have a complex form with transverse ridges near the tip of the spicule (Table 1.3e).

Trichostrongylus retortaeformis

Description: Males measure around 5.5–7 mm and females 7–9 mm in length. The spicules are short, large and curved with two thin offshoots (Table 1.3h).

Trichostrongylus calcaratus

Description: The adults are small, white and hair-like, usually less than 7.0 mm long. Male worms have an asymmetrical dorsal ray and two short nearly equal spicules.

Trichostrongylus affinus

Description: Males measure 5–7.5 mm and females 8.5–9 mm in length. The male spicules are short, broad, and equal in length, bent ventrally and taper distally into two blunt hooks.

Trichostrongylus tenuis

Description: Males measure around 5.0–6.5 mm and females 7–9 mm in length. The spicules are curved distally and possess an auricular offshoot anteriorly.

Life cycle: The prepatent period is short (7–10 days).

Marshallagia

Similar to *Ostertagia* spp. and can be differentiated by its greater length (males 10–13 mm; females 15–20 mm).

Life cycle: The life cycle is similar to *Ostertagia* except that L₂ can hatch from the egg. Following ingestion, larvae burrow into the abomasal mucosa and form small greyish white nodules, which may contain several developing parasites. The young L₅ emerge from the nodules around day 16 post infection and egg-laying is usually apparent by 3 weeks. Arrested development of larvae can occur.

Marshallagia species

Species	Hosts	Site
<i>Marshallagia marshalli</i>	Sheep, goat, deer, camel	Abomasum

Marshallagia marshalli

Synonym: *Ostertagia tricuspis*, *Ostertagia marshalli*

Description: The male bursa has a long thin dorsal ray, which bifurcates near the posterior extremity (Fig. 1.14). The end of the yellowish-brown spicule is divided into three small processes (Fig. 1.15). The ellipsoidal eggs are much larger than other trichostrongyloid species (>150 µm) and resemble those of *Nematodirus battus* (see Fig. 4.3).

Hyostrogylus

Slender reddish worms when fresh, with males measuring around 5–7 mm and females 6–10 mm in length (Fig. 1.16). The body cuticle is both transversely and longitudinally striated with 40–45 longitudinal striations.

Life cycle: The free-living and parasitic stages are similar to those of *Ostertagia* in cattle; infection is through oral ingestion of L₃. The pre-patent period is about 3 weeks. Hypobiosis of L₄ may occur following repeated infection, or be induced by seasonal changes, and is often seen in older animals. In sows these hypobiotic larvae may resume their development during the periparturient relaxation of immunity and/or early lactation, leading to an increase in the faecal egg count.

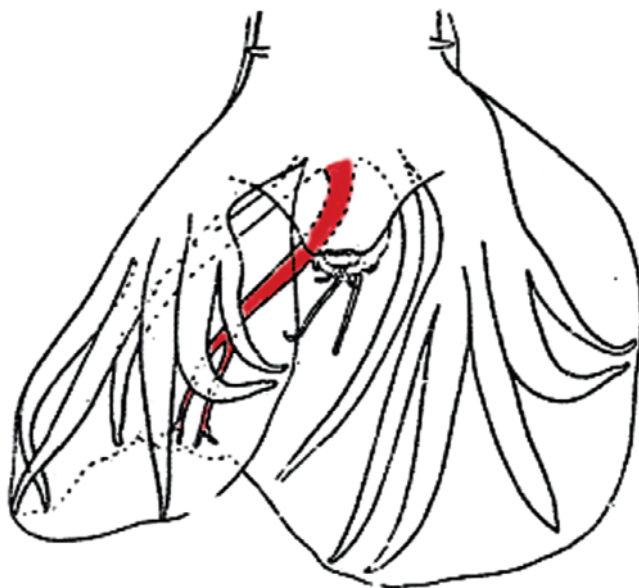


Fig. 1.14 Copulatory bursa of *Marshallagia marshalli* highlighting long thin bifurcating dorsal ray. (Redrawn from Ransom, 1907.)

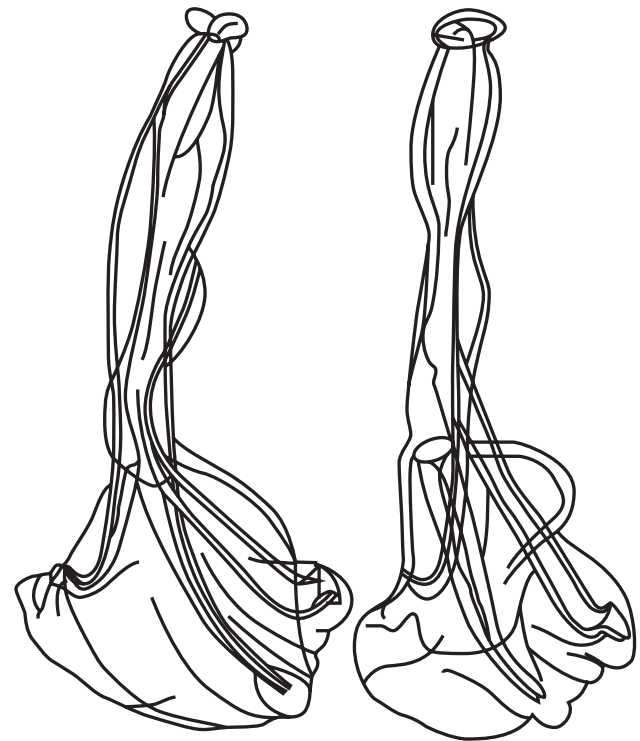


Fig. 1.15 Spicules of *Marshallagia marshalli*. (Redrawn from Ransom, 1907.)

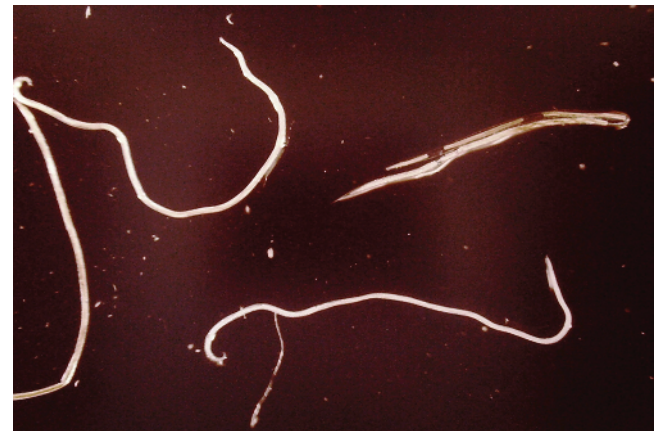


Fig. 1.16 Adult worms of *Hyostrogylus rubidus*.

Hyostrogylus species

Species	Hosts	Site
<i>Hyostrogylus rubidus</i>	Pig	Stomach

Hyostrogylus rubidus

Description: A small cephalic vesicle is present. The bursa of the male is well developed and the dorsal lobe is small. There is a well-developed narrow telamen and the spicules are equal, short, thinning distally and bifurcate into two branches. It is usually the only bursate nematode located in the pig stomach.

Mecistocirrus

Worms of this genus are similar in appearance to *Haemonchus contortus*, except that in the female the slit-shaped flapless vulva is located close to the anus. The males measure up to around 30 mm and the females 42 mm in length. The cuticle contains many longitudinal ridges and the paired cervical papillae are readily apparent. The small buccal capsule is armed with a small lancet. In the female the ovaries are spirally coiled round the intestine, similar to *Haemonchus*. The male spicules are thin and long and in the bursa the dorsal ray is located symmetrically.

Life cycle: This is direct and similar to that of *Haemonchus*. The prepatent period is longer than in *Haemonchus*, being 60–80 days, partly the result of the longer duration of the fourth stage in the abomasal mucosa.

Mecistocirrus species

Species	Hosts	Site
<i>Mecistocirrus digitatus</i>	Cattle, buffalo, sheep, goat, pig	Abomasum

Mecistocirrus digitatus

Description: The spicules are long and narrow and fused together for the majority of their length and the tips are surrounded by a spindle-shaped tube. In the female the vulva is positioned near the tip of the tail and there is no vulval flap.

Graphidium

Stomach worms of lagomorphs found throughout Europe.

Life cycle: The life cycle is direct. Infection is by ingestion of infective larvae, which develop to the adult stage in the stomach in about 12 days.

Graphidium species

Species	Hosts	Site
<i>Graphidium strigosum</i>	Rabbit, hare	Stomach, small intestine

Graphidium strigosum

Description: Adults are reddish worms when fresh. The male is 8–16 mm and the female 11–20 mm in length. The cuticle possesses 40–60 longitudinal lines and thin transverse striations. The lateral lobes of the bursa are large and the dorsal lobe small. The long slender spicules terminate in several branched points.

Obeliscoides

This genus contains several species of worms found in a number of rabbit species in the USA.

Life cycle: The life cycle is direct. Infection is by ingestion of infective larvae, which develop to the adult stage in the stomach in about 19 days.

Obeliscoides species

Species	Hosts	Site
<i>Obeliscoides cuniculi</i>	Rabbit, hare. Occasionally white-tailed deer	Stomach

Obeliscoides cuniculi

Description: Adults are red-brownish in colour and males measure 10–16 mm and the females 15–18 mm in length. The brown spicules are bifurcated at their distal tips and terminate in a hook. The female worm tapers in the distal 20% of the body.

Libyostrongylus

Parasites of ratites (ostrich) commonly referred to as 'wireworms' found in the proventriculus and gizzard.

Life cycle: The life cycle is typically strongyle. Following ingestion, infective larvae burrow into the proventricular glands and under the kaolin layer of both the proventriculus and gizzard where they develop into adult worms 4–5 weeks later. Eggs which contain fully developed larvae are very resistant to desiccation and can survive a couple of years.

Libyostrongylus species

Species	Hosts	Site
<i>Libyostrongylus douglassi</i>	Ostrich	Proventriculus, gizzard
<i>Libyostrongylus dentatus</i>	Ostrich	Proventriculus, gizzard

Libyostrongylus douglassi

Description: Small yellowish-red nematodes, males 4–6 mm and females 5–6 mm in length. The male bursa is well developed; the dorsal ray is long and split in its distal half forming three small branches either side. The spicules each terminate in a large and small spine.

Libyostrongylus dentatus

Description: Males worms are 6–8 mm and females 10–12 mm in length. There is a prominent dorsal, oesophageal tooth. The male has a large bursa; the dorsal ray is long and bifurcated extending into a rounded lobe of the bursal membrane. The spicules have a dorsal process arising two-thirds from the anterior and the main shaft ending in a rounded point capped by a hyaline sheath.

Graphinema

Graphinema species

Species	Hosts	Site
<i>Graphinema aucheniae</i>	Llama, vicuna	Abomasum

Graphinema aucheniae

Description: Male worms measure 5.5–8.0 mm and females 9–12 mm in length. These worms have a small buccal capsule, a

claviform oesophagus and cervical papillae. The male bursa has a small antero-ventral ray and a widely divergent posteroventral ray. The dorsal ray bifurcates near the distal tip, with each branch dividing distally. The spicules are long and pointed.

Life cycle: Similar to that of other trichostrongyles.

Impalaia

Impalaia species

Species	Hosts	Site
<i>Impalaia tuberculata</i>	Camel	Abomasum
<i>Impalaia nudicollis</i>	Camel	Abomasum

Impalaia tuberculata

Description: Males are 7–9 mm and females 14–18 mm long. The cervical cuticle is studded with papillae. Spicules are equal in length, slender and with a fine pointed end.

Impalaia nudicollis

Description: Males are 7.5–8.2 mm and females 14.8–16.7 mm long. Males have long spicules and a long gubernaculum.

SUBFAMILY OSTERTAGINAE

Species within the subfamily Ostertaginae are considered together as they form a large and complex group, the taxonomy of which has not been fully elucidated. Some species names are considered synonymous and species polymorphism is commonly reported. The adults are slender reddish-brown worms up to 1.0 cm long, occurring on the surface of the abomasal mucosa and are only visible on close inspection (Fig. 1.17). They possess a short buccal cavity and a very small pair of cervical papillae. The short spicules are brown in colour and terminate in two or three processes, depending on the species. In the female the vulva can be covered with a flap or this may be absent and the tip of the tail is annulated. The larval stages



Fig. 1.17 *Ostertagia ostertagi* on the abomasal mucosa.

occur in the gastric glands and can only be seen microscopically following processing of the gastric mucosa. Species differentiation is generally based on the structure of the male spicules. These worms occur in cattle, sheep and other ruminants.

Life cycle: Eggs are passed in the faeces and, under optimal conditions, develop within the faecal pat to the infective third stage within 2 weeks. When moist conditions prevail, the L₃ migrate from the faeces on to the herbage. After ingestion, the L₃ exsheaths in the rumen and further development takes place in the lumen of an abomasal gland. Two parasitic moults occur before the L₅ emerges from the gland around 18 days after infection to become sexually mature on the mucosal surface. The entire parasitic life cycle usually takes 3 weeks, but under certain circumstances many of the ingested L₃ become arrested in development at the early fourth larval stage (EL₄) for periods of up to 6 months (also referred to as hypobiosis).

Ostertagia ostertagi

Morph species: *Ostertagia* (syn. *Skrjabinagia*) *lyrata*


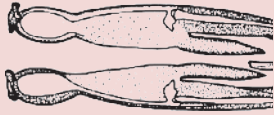






Description: Adults are slender reddish-brown worms with a short buccal cavity. Males measure 6–8 mm and females 8–11 mm in length. The cuticle in the anterior region is striated transversely whereas the rest of the body is unstriated and bears around 30 longitudinal ridges.

- *Ostertagia ostertagi*. The spicules are divided in the posterior region where two thin lateral branches arise from the main stem (Table 1.4a). The bursa is small and the accessory bursal membrane is supported by two divergent rays (Fig. 1.18). In the female, the vulva is sited about 1.5 mm from the posterior and is covered with a flap (Fig. 1.19).
- *Ostertagia lyrata*. The spicules are stout and divided into three branches posteriorly. The main branch is solid and ends in a shoe-like expansion. One lateral branch is thick and massive, terminating in a hat-like expansion; the other is small and pointed (Table 1.4b and Fig. 1.20). The gubernaculum is spindle-shaped.

Ostertagia species (subfamily Ostertaginae)

Species	Hosts	Site
<i>Ostertagia ostertagi</i> <i>Ostertagia</i> (syn. <i>Skrjabinagia</i>) <i>lyrata</i>	Cattle, deer, rarely goat	Abomasum
<i>Ostertagia leptospicularis</i> (syn. <i>Ostertagia crimensis</i>) <i>Skrjabinagia</i> (<i>Ostertagia</i>) <i>kolchida</i> (syn. <i>Grosspiculagia podjapolskyi</i>)	Deer, cattle, sheep and goat	Abomasum
<i>Teladorsagia circumcincta</i> <i>Ostertagia trifurcata</i> <i>Teladorsagia davtianii</i>	Sheep, goat, deer, camel, llama	Abomasum
<i>Spiculoptera spiculoptera</i> (syn. <i>Apteragia spiculoptera</i> , <i>Rinadia spiculoptera</i> , <i>Mazamostrongylus spiculoptera</i>)	Deer (red deer, fallow deer, roe deer), cattle, sheep, goat	Abomasum
<i>Spiculoptera asymmetrica</i> (syn. <i>Ostertagia asymmetrica</i> , <i>Apteragia asymmetrica</i> , <i>Rinadia asymmetrica</i> , <i>Mazamostrongylus asymmetrica</i>)	Deer (roe deer, sika deer, fallow deer)	Abomasum
<i>Apteragia quadrispiculata</i>	Deer (roe deer, sika deer, fallow deer)	Abomasum
<i>Spiculoptera</i> (<i>Apteragia</i>) <i>bohmi</i> <i>Spiculoptera</i> (<i>Rinadia</i>) <i>mathevossiani</i>	Mouflon, deer (fallow deer, roe deer)	Abomasum
<i>Spiculoptera peruvianus</i>	Llama, vicuna	Abomasum

Table 1.4 Identification of Ostertaginae based on male spicule morphology.

Species	Spicules: description	Spicules: morphology
<i>Ostertagia ostertagi</i>	The spicules are of equal length and shape, tapering towards the distal end into three processes	(a) 
<i>Ostertagia lyrata</i>	The spicules are stout and divided into three branches posteriorly. The main branch is solid and ends in a shoe-like expansion. One lateral branch is thick and massive terminating in a hat-like expansion; the other is small and pointed	(b) 
<i>Ostertagia leptospicularis</i>	The spicules are slender, of equal length and shape tapering towards the distal end into three processes, with the two lateral branches extremely fine and pointed	(c) 
<i>Skjabinagia kolchida</i>	The spicules are of equal length and shape tapering towards the distal end into three branches terminating in an 'ice-skate' like structure. The medial branch is the shortest and truncated	(d) 
<i>Teladorsagia circumcincta</i>	Spicules are variable in length but normally long and thin. The posterior end is split into two branches of equal length. A third short offshoot, not readily seen, arises in front of the bifurcation	(e) 
<i>Ostertagia trifurcata</i>	Spicules are short and broad; the posterior end is divided into three processes, one long and thick with a truncated end, and two short slender branches each tapering to a point	(f) 
<i>Spiculoptera spiculoptera</i>	The spicules are of equal length, bifurcating distally where it contains a cavity and distally ending in a fan-shaped expansion	(g) 
<i>Spiculoptera bohmi</i>	Spicules of equal size but asymmetrical. The right spicule divides into into three branches and the left spicule into two branches	(h) 

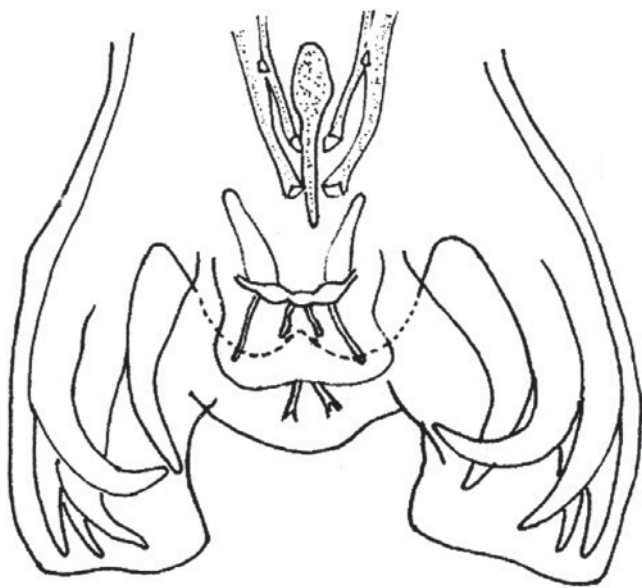


Fig. 1.18 Male bursa and spicules of *Ostertagia ostertagi*.

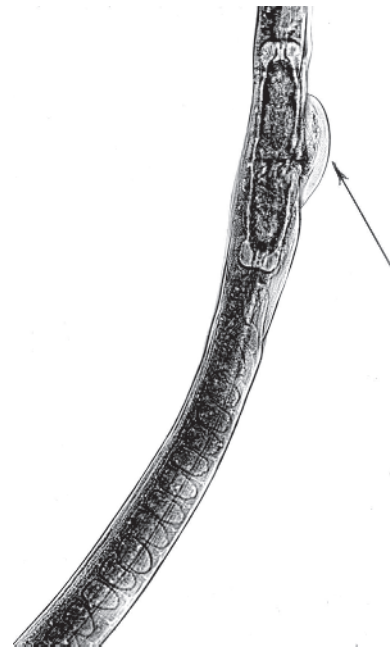


Fig. 1.19 Female vulva and flap (arrowed) of *Ostertagia ostertagi*.

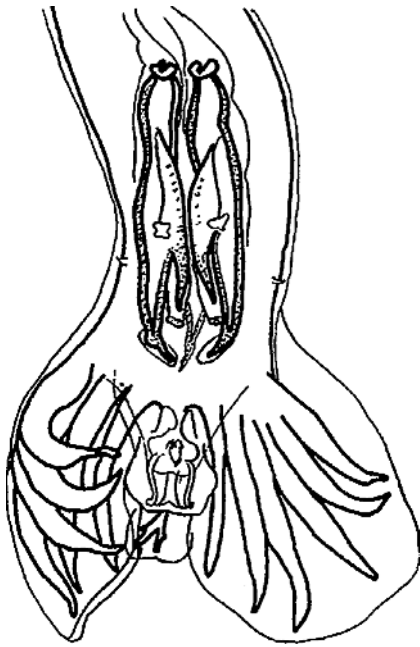


Fig. 1.20 Male bursa and spicules of *Ostertagia lyrata*.

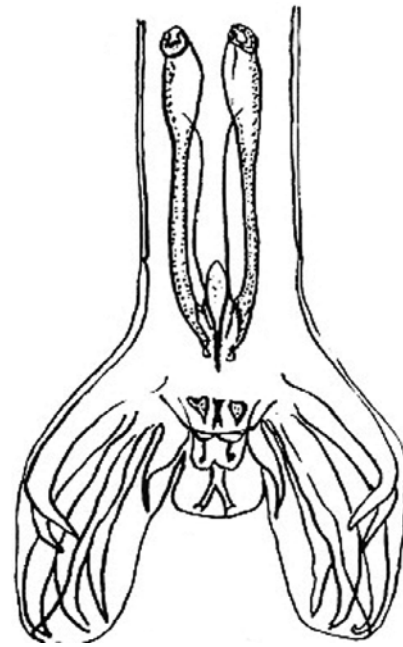


Fig. 1.21 Male bursa and spicules of *Ostertagia leptospicularis*.

Ostertagia leptospicularis

Synonym: *Ostertagia crimensis*

Morph species: *Skrjabinagia (Ostertagia) kolchida* (syn. *Grosspiculagia podjapolskyi*)

Description: Adults are slender reddish-brown worms with a short buccal cavity. Males measure 6–8 mm and females 8–9 mm in length. Distinguished from other ostertagian species by the length of the oesophagus, which is longer (0.7 mm compared with approximately 0.6 mm in other species). In cattle, the worms are thinner than *O. ostertagi* and male worms are differentiated on spicule morphology.

- *Ostertagia leptospicularis*. The spicules are of equal length and shape, tapering towards the distal end into three processes (Table 1.4c and Fig. 1.21). The gubernaculum is racket-shaped.
- *Skrjabinagia kolchida*. The spicules are of equal length and shape, tapering towards the distal end into three branches terminating in a shoe-like structure (Table 1.4d and Fig. 1.22). The medial branch is the shortest and truncated. The gubernaculum is longer than in *O. leptospicularis* and twisted.

Teladorsagia circumcincta

Synonym: *Ostertagia circumcincta*

Morph species: *Ostertagia trifurcata*, *Teladorsagia davtiani*

Description: Adults are slender reddish-brown worms with a short buccal cavity. Males measure 6–8 mm and females 8–10 mm.

- *Teladorsagia circumcincta*. The lateral lobes of the bursa are well developed but the dorsal lobe is small; a telamon is present in the genital cone; the accessory bursal membrane is small, and supported by two divergent rays (Fig. 1.23). Spicules are variable in length but normally long and thin (Table 1.4e and Fig. 1.24a). The posterior end is split into two branches of equal length. A third short offshoot,

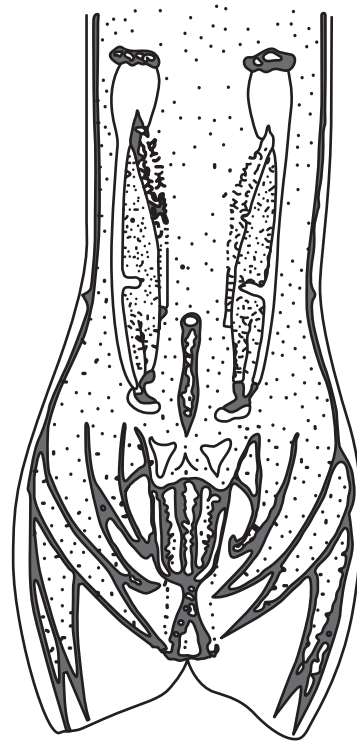


Fig. 1.22 Male bursa and spicules of *Skrjabinagia kolchida*.

not readily seen, arises in front of the bifurcation. The gubernaculum is racket-shaped. In the female, the vulva is usually covered with a large flap and opens near the posterior of the body.

- *Ostertagia trifurcata*. The bursa is longer than in *T. circumcincta*. The lateral lobes of the bursa are well developed, and the dorsal lobe is small (Fig. 1.25). A well-developed telamon is present in the genital cone. The accessory bursal membrane is modified to form Sjöberg's organ supported by two rays. The spicules are

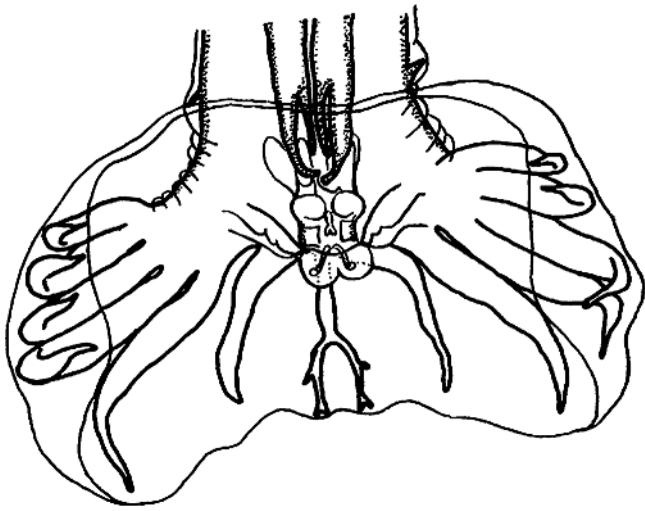


Fig. 1.23 Male bursa and spicules of *Teladorsagia circumcincta*.

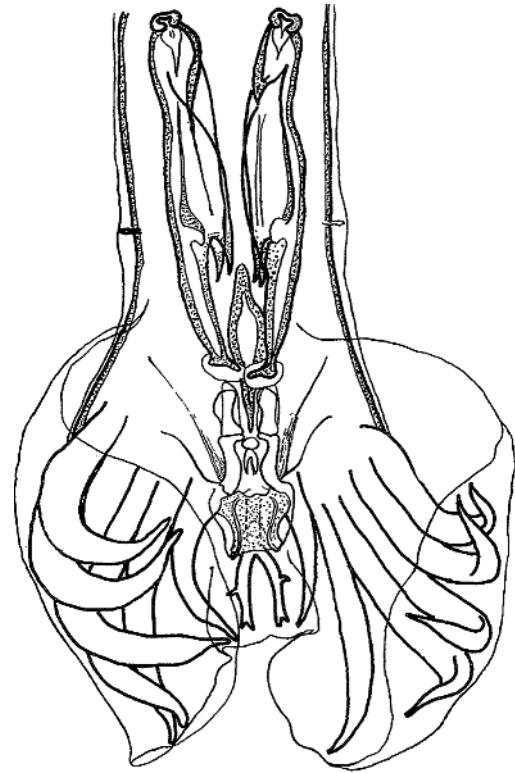


Fig. 1.25 Male bursa and spicules of *Ostertagia trifurcata*.

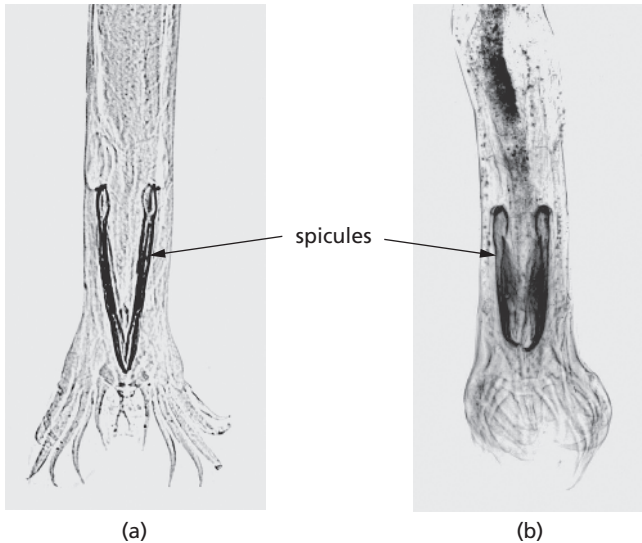


Fig. 1.24 Comparison of spicules of (a) *Teladorsagia circumcincta* and (b) *Ostertagia trifurcata*. Those of *T. circumcincta* are long and thin whereas *O. trifurcata* spicules are short and broad.

short and broad (Table 1.4f and Fig. 1.25) with the posterior ends divided into three processes, one long and thick with a truncated end, and two short slender branches each tapering to a point. The gubernaculum is somewhat spindle-shaped.

- *Teladorsagia davtiani*. This morph species is similar in appearance to *O. trifurcata*. The accessory bursal membrane is modified to form Sjöberg's organ and resembles a pair of sessile papillae on the posterior extremity of the genital cone (Fig. 1.26).

Spiculopteragia spiculoptera

Synonyms: *Apteragia spiculoptera*, *Rinadia spiculoptera*, *Mazamostrongylus spiculoptera*

Description: The spicules are of equal length, bifurcating distally where it contains a cavity, and distally ending in a fan-shaped expansion (Table 1.4g). The gubernaculum is absent.

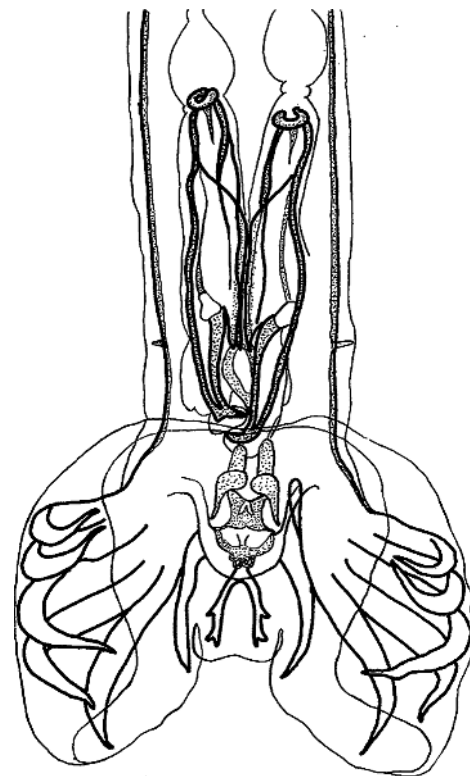


Fig. 1.26 Male bursa and spicules of *Teladorsagia davtiani*.

Spiculopteragia asymmetrica

Synonyms: *Ostertagia asymmetrica*, *Apteragia asymmetrica*, *Rinadia asymmetrica*, *Mazamostrongylus asymmetrica*

Description: Males measure 4.5–6 mm. Spicules are distally asymmetrical and pointed, with a T-shaped offshoot near the distal end of the right spicule. The gubernaculum is small and boat-shaped.

Apteragia quadrispiculata

Description: Males measure 6–8.5 mm. Spicules possess four branches distally.

Spiculopteragia bohmi

Synonym: *Apteragia bohmi*, *Rinadia bohmi*, *Mazamostrongylus bohmi*, *Ostertagia bohmi*

Morph species: *Spiculopteragia (Rinadia) mathevossiani*

Description: Males measure 6–7 mm.

- *Spiculopteragia bohmi*. Spicules of equal size but asymmetrical. The right spicule divides into three branches and the left spicule into two branches (Table 1.4h). The gubernaculum is absent.
- *Spiculopteragia mathevossiani*. The spicules have asymmetrical distal thirds each ending in three branches. The gubernaculum is absent.

Spiculopteragia peruvianus

Description: Males measure 6.5–8.0 mm and females 8.5–10 mm in length.

Camelostrongylus

Camelostrongylus species

Species	Hosts	Site
<i>Camelostrongylus mentulatus</i>	Camel, sheep, goat	Abomasum, small intestine

Camelostrongylus mentulatus

Synonym: *Ostertagia mentulatus*

Description: Males measure 6.5–7.5 mm. The spicules are long and narrow, bifurcating into pincer-like ends with one end shorter, and the longer end forming a hammer-like hook (Fig 1.27).

SUBFAMILY HAEMONCHINAE

Haemonchus

The adults are easily identified because of their specific location in the abomasum and their large size (2.0–3.0 cm). In fresh female specimens, the white ovaries winding spirally around the

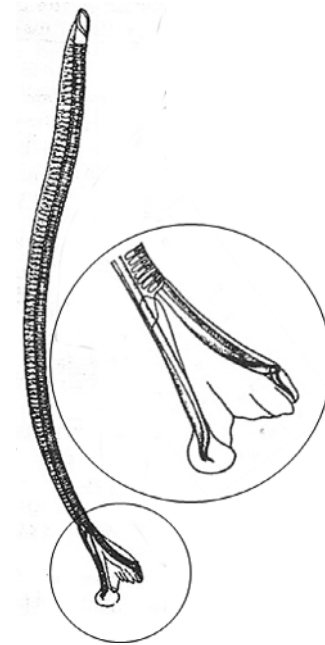


Fig. 1.27 Male bursa and spicule of *Camelostrongylus mentulatus*. (Redrawn from Skrjabin *et al.*, 1954.)

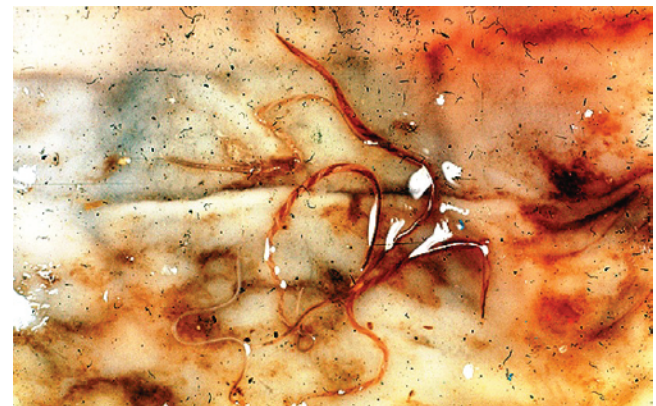


Fig. 1.28 Adult male and female worms of *Haemonchus contortus* on the abomasal mucosa.

blood-filled intestine produce a ‘barber’s pole’ appearance (Fig 1.28). The buccal cavity is small and contains a small lancet-like tooth. The anterior body possesses prominent cervical papillae. The vulva is usually protected by a cuticular flap which can have a range of shapes. In the male the lateral lobes of the bursa are large, whereas the dorsal ray is small and asymmetrical.

Life cycle: This is direct and the preparasitic phase is typically trichostrongyloid. The females are prolific egg layers. The eggs hatch to L₁ on the pasture and may develop to L₃ in as short a period as 5 days but development may be delayed for weeks or months under cool conditions. After ingestion, and exsheathment in the rumen, the larvae moult twice in close apposition to the gastric glands. Just before the final moult they develop the piercing lancet which enables them to obtain blood from the mucosal vessels. As adults they move freely on the surface of the mucosa. The prepatent period is 2–3 weeks in sheep and 4 weeks in cattle.

Haemonchus species

Species	Hosts	Site
<i>Haemonchus contortus</i> (syn. <i>Haemonchus placei</i>)	Sheep, goat, cattle, deer, camel, llama	Abomasum
<i>Haemonchus similis</i>	Cattle, deer	Abomasum
<i>Haemonchus longistipes</i>	Camel, sheep	Abomasum

Haemonchus contortus

Synonym: *Haemonchus placei*

Description: Males are about 10–22 mm and females 20–30 mm in length. The male has an asymmetrical dorsal lobe and barbed spicules (Fig. 1.29a); the female usually has a prominent vulval flap. In both sexes there are cervical papillae (Fig. 1.29b) and a tiny lancet inside the buccal capsule.

Notes: Until recently the sheep species was *H. contortus* and the cattle species *H. placei*. However, there is now increasing evidence that these are the single species *H. contortus* with only strain adaptations for cattle and sheep.

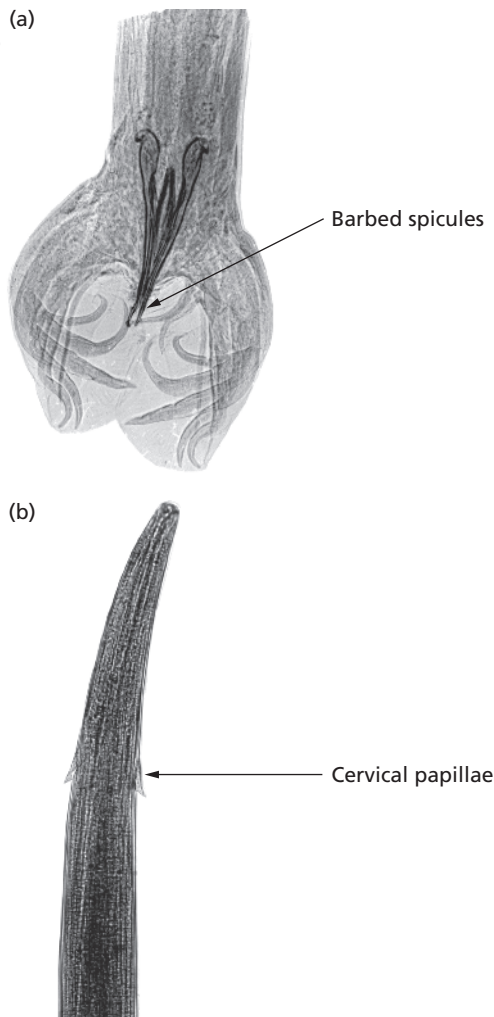


Fig. 1.29 (a) Barbed spicules and bursa of a mature *Haemonchus contortus* male worm. (b) Anterior of *H. contortus* showing the position of the cervical papillae.

Haemonchus similis

Description: The adults are 2.0–3.0 cm and reddish in colour. The male has an asymmetrical dorsal lobe and barbed spicules, differing from *H. contortus* in that the terminal processes of the dorsal ray are longer and the spicules shorter.

Haemonchus longistipes

Description: Adults are about 1–3 cm in size. The spicules are thin with small lateral processes at the distal ends and are much longer than in the other species.

FAMILY COOPERIDAE**Cooperia**

Relatively small worms (usually less than 9 mm long), which appear pinkish-white when fresh. The main generic features are the small cephalic vesicle and the marked transverse cuticular striations in the oesophageal region (Fig. 1.30). The body possesses longitudinal ridges. The male bursa is relatively large compared to the size of the body. It has a small dorsal lobe, and the brown-coloured spicules are short and stout with distinct wing-like expansions in the middle region, which often bear transverse ridged striations (except in *C. surnabada*) (see Table 1.5). There is no gubernaculum. The females have a long tapering tail and the vulva may be covered by a vulval flap and is located posterior to the middle of the body.

Life cycle: The life cycle is direct and typical of the superfamily. Ingested L₃ exsheath, migrate into the intestinal crypts for two moults and then the adults develop on the surface of the intestinal mucosa. The prepatent period is 2–3 weeks. The bionomic requirements of the free-living stages are similar to those of *Teladorsagia*.

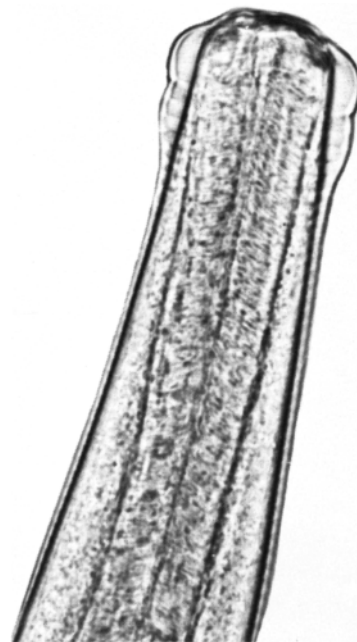







Fig. 1.30 Anterior of *Cooperia* spp showing the cephalic vesicle and cuticular striations.

Table 1.5 Identification of *Cooperia* spp. based on male spicule morphology.

Species	Spicules: description	Spicules: morphology
<i>Cooperia oncophora</i>	Spicules are 240–300 µm long and have a longitudinal line pattern with the distal end rounded and bearing cuticular formations	(a) 
<i>Cooperia curticei</i>	Spicules are equal in length (135–145 µm) and have a central protruberance with a transverse striation and end in a rounded 'disc-like' structure	(b) 
<i>Cooperia surnabada</i>	The spicules are 270 µm long and thin with a posterior bifurcation into an external branch with small conical appendage; and an internal branch that is shorter and pointed	(c) 
<i>Cooperia punctata</i>	Spicules are short (120–150 µm) and bear a large protruberance at the distal half, tapering to a slightly blunted point	(d) 
<i>Cooperia pectinata</i>	Spicules are 240–280 µm long with a large protruberance centrally, and are bent ventrally, with a wrinkled inner surface	(e) 

Cooperia species

Species	Hosts	Site
<i>Cooperia oncophora</i>	Cattle, sheep, goat, deer, camel	Small intestine
<i>Cooperia curticei</i>	Sheep, goat, deer (red deer, fallow deer)	Small intestine
<i>Cooperia punctata</i>	Cattle, deer, rarely sheep	Small intestine
<i>Cooperia pectinata</i>	Cattle, deer, rarely sheep	Small intestine
<i>Cooperia surnabada</i> (syn. <i>Cooperia mcmasteri</i>)	Cattle, sheep, goat, camel	Small intestine

Cooperia oncophora

Description: In size, *C. oncophora* is similar to *Ostertagia* but with a large bursa. Males measure around 5.5–9 mm and females 6–8 mm in length. Spicules have a longitudinal line pattern with the distal end rounded and bearing cuticular formations (Table 1.5a).

Cooperia curticei

Description: *Cooperia curticei* is moderately small with a large bursa. Males measure around 4.5–6.0 mm and females 6.0–8.0 mm in length. The most notable feature is the 'watch spring-like' posture. Spicules are equal in length and have a central protruberance with a transverse striation and end in a rounded 'disc-like' structure (Table 1.5b).

Cooperia surnabada

Synonym: *Cooperia mcmasteri*

Description: The males measure around 7 mm and the females 8 mm in length. The appearance is very similar to *C. oncophora*, although the bursa is larger and the bursal rays tend to be thinner. The spicules are thinner with a posterior bifurcation into an external branch with a small conical appendage; and an internal branch that is shorter and pointed (Table 1.5c).

Cooperia punctata

Description: Males measure around 4.5–6.0 mm and females 6–8 mm in length. Spicules are short and bear a large protruberance at the distal half, tapering to a slightly blunted point (Table 1.5d).

Cooperia pectinata

Description: Males measure around 7–8 mm and females 7.5–10 mm in length. Spicules bear a protruberance centrally and are bent ventrally, with a wrinkled inner surface (Table 1.5e).

FAMILY ORNITHOSTRONGYLIDAE
Ornithostromylus

The adult worms, which measure up to 2.5 cm, are bloodsuckers, have a reddish colour and can be seen by the naked eye.

Life cycle: The life cycle is direct and typically trichostrongyle.

***Ornithostromylus* species**

Species	Hosts	Site
<i>Ornithostromylus quadriradiatus</i>	Pigeon, dove	Crop, proventriculus, small intestine

Ornithostromylus quadriradiatus

Description: Males measure 9–12 mm and females 18–24 mm in length. The cuticle of the head is slightly inflated and the body bears longitudinal cuticular ridges. In the male bursa, the ventral rays are close together and the dorsal ray is short and the telamon is cross-like in appearance. Spicules terminate in three pointed processes. The female tail is truncated and terminates in a small spine.

FAMILY AMIDOSTOMIDAE
Amidostomum

The slender adult worms, bright red in colour when fresh and up to 2.5 cm in length, are easily recognised at necropsy where they predominate in the horny lining of the gizzard (Fig. 1.31). These worms have a shallow buccal cavity and do not possess leaf crowns. Three longitudinal ridges/plates line the oesophagus.

Life cycle: Direct and similar to other strongyles. Infection is via ingestion of L₃, or through skin penetration. Eggs passed in the faeces

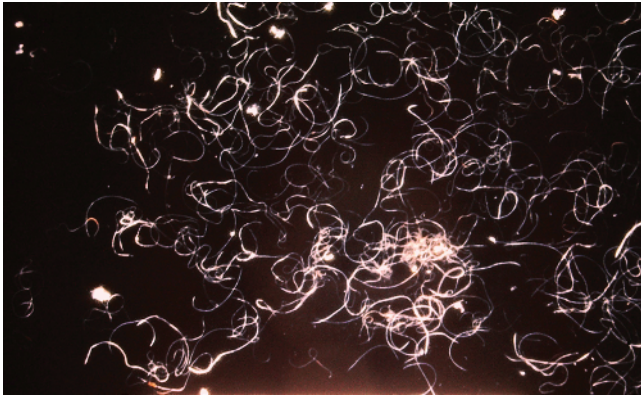


Fig. 1.31 Adult worms of *Amidostomum anseris*.

are already embryonated and develop to the L₃ in the egg. Ingested larvae penetrate the submucosa of the gizzard. Patency is around 2–3 weeks in geese.

Amidostomum species

Species	Hosts	Site
<i>Amidostomum anseris</i> (syn. <i>Amidostomum nodulosum</i>)	Goose, duck	Gizzard
<i>Amidostomum acutum</i> (syn. <i>Amidostomum skrjabini</i>)	Duck	Gizzard

Amidostomum anseris

Synonym: *Amidostomum nodulosum*

Description: Males measure about 10–17 mm and female worms 15–25 mm in length. Worms are characterised by a shallow buccal capsule with three pointed teeth in the base, the middle tooth being the largest. The male spicules are of equal length and are divided into two branches at the distal end.

Amidostomum acutum

Synonym: *Amidostomum skrjabini*

Description: Characterised by a shallow buccal capsule with one pointed tooth. The spicules have two to three branches at the distal end.

Epomidiostomum

These worms are similar to *Amidostomum* but smaller.

Epomidiostomum species

Species	Hosts	Site
<i>Epomidiostomum uncinatum</i> (syn. <i>Epomidiostomum anatinum</i> , <i>Strongylus uncinatus</i> , <i>Amidostomum anatinum</i>)	Duck	Gizzard
<i>Epomidiostomum orispinum</i> (syn. <i>Strongylus anseris</i> , <i>Strongylus orispinum</i>)	Duck, goose, swan	Gizzard, oesophagus
<i>Epomidiostomum skrjabini</i>	Goose	Gizzard

Epomidiostomum uncinatum

Synonyms: *Epomidiostomum anatinum*, *Strongylus uncinatus*, *Amidostomum anatinum*

Description: Males measure about 10 mm and females 15 mm in length. Teeth are absent from the rudimentary buccal capsule. The cuticle bears distinct thickenings, 'epaulettes', at the anterior end and tooth-like projections form a fringe around the mouth. The posterior of the female is rounded and has a small button-shaped tip. Three branches occur on each spicule.

Epomidiostomum orispinum

Synonyms: *Strongylus anseris*, *Strongylus orispinum*

Description: Males measure around 11 mm and females 16 mm in length. The anterior of the worm possesses four posteriorly pointing offshoots and lateral festoons bearing a pair of papillae. Spicules are equal with three shafts pointing distally. The body of the female tapers abruptly, towards the digitate tail.

Epomidiostomum skrjabini

Description: The size of the males and females is similar to that of *E. orispinum*. The head of the worm possesses a cuticular prominence which is armed with four symmetrical, lateral-pointing spines. There are also two epaulette formations. The mouth is surrounded by four small spines. The bursa has three lobes, the central lobe being poorly developed. Spicules are equal and the posterior ends are split into three sharp-tipped branches. The anterior ends are blunt. The female tail terminates in a finger-like appendage, which is bent ventrally.

FAMILY MOLINEIDAE

Nematodirus

Adult worms are whitish, slender, and relatively long, with the anterior thinner than the posterior region. They may appear slightly coiled. Adult males are 10–15 mm and females 15–24 mm in length. A small, but distinct, cephalic vesicle is present (Fig 1.32) and the cuticle possesses about 14–18 longitudinal ridges. The male bursa has elongate lateral lobes and the spicules are long and slender; the tips of the spicules are fused together and terminate in a small expansion, which varies in shape and is a useful feature for species differentiation (Table 1.6). The ventral rays are parallel and are situated close together. The female worm has a short tail with a slender terminal appendage. The eggs are large and readily distinguishable from other trichostrongylid species.

Life cycle: The preparasitic phase is almost unique in the trichostrongyloids in that development to the L₃ stage takes place within the eggshell. Species differences occur regarding the critical hatching requirements.

Nematodirus species

Species	Hosts	Site
<i>Nematodirus battus</i>	Sheep, goat, occasionally cattle	Small intestine
<i>Nematodirus filicollis</i>	Sheep, goat, occasionally deer	Small intestine
<i>Nematodirus spathiger</i>	Sheep, goat, cattle	Small intestine
<i>Nematodirus helvetianus</i>	Cattle, occasionally sheep, goat	Small intestine
<i>Nematodirus abnormalis</i>	Camel, sheep, goat	Small intestine
<i>Nematodirus mauritanicus</i>	Camel	Small intestine
<i>Nematodirus lamae</i>	Llama, alpaca, vicuna	Small intestine
<i>Nematodirus leporis</i>	Rabbit	Small intestine

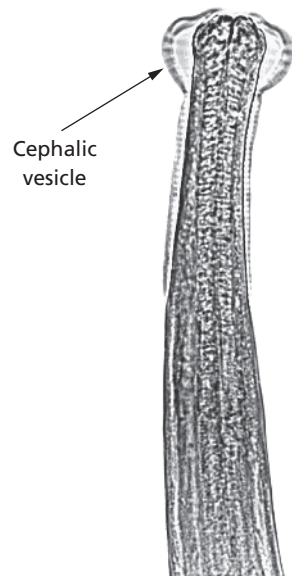







Fig. 1.32 Anterior of *Nematodirus battus* illustrating the small cephalic vesicle.

Table 1.6 Identification of *Nematodirus* species based on male spicule morphology.

Species	Spicules: description	Spicules: morphology
<i>Nematodirus battus</i>	The spicules are long and slender and the tips are fused into a small, flattened oval-shaped projection	(a) 
<i>Nematodirus filicollis</i>	The spicules are long and slender with fused tips and terminate in a narrow pointed swelling	(b) 
<i>Nematodirus spathiger</i>	The spicules are long and slender with fused tips and terminate in a spoon-shaped tip	(c) 
<i>Nematodirus helvetianus</i>	The long slender spicules terminate in a fused point with the surrounding membrane being lanceolate	(d) 
<i>Nematodirus abnormalis</i>	The spicules are asymmetrical with the distal ends bent to form an asymmetrical lancet	(e) 

Nematodirus battus

Description: Males measure about 10–16 mm and females 15–25 mm in length and are characterised by having only one set of divergent rays in each bursal lobe (Fig. 1.33) and the tips of the spicules are fused into a small, flattened, oval-shaped projection (Table 1.6a). The female worm has a long conical tail, which tapers to a point. The large egg is brownish with parallel sides.

Life cycle: Development to the L₃ takes place within the eggshell. Hatching of most eggs requires a prolonged period of chill followed by a mean day/night temperature of more than 10°C, conditions which occur in late spring in the northern hemisphere. Hence most of the eggs from one season's grazing remain unhatched on the ground during the winter and usually only one generation is possible each year for the bulk of this species. However, some *N. battus* eggs deposited in the spring are capable of hatching in the autumn of the same year, resulting in significant numbers of L₃ on the pasture at this time. The ingested L₃ penetrate the mucosa of the small intestine and moult to the L₄ stage around the fourth day. After moulting to the L₅ the parasites inhabit the lumen, sometimes superficially coiled around villi. The prepatent period is 14–16 days.

Nematodirus filicollis

Description: The male has two sets of parallel rays in each of the main bursal lobes (Fig. 1.34). The spicules are long and slender with fused tips and terminate in a narrow pointed swelling (Table 1.6b). The female has a truncate blunt tail with a small spine (similar to *N. spathiger*), and the egg is large, ovoid, thin-shelled and colourless and twice the size of the typical trichostrongyle egg.

Life cycle: Development to the L₃ takes place within the eggshell. *Nematodirus filicollis* does not have the same critical hatching requirements as *N. battus*. Hatching occurs over a more prolonged



Fig. 1.33 Male bursa and spicules of *Nematodirus battus* with single sets of parallel rays in the dorsal lobes.

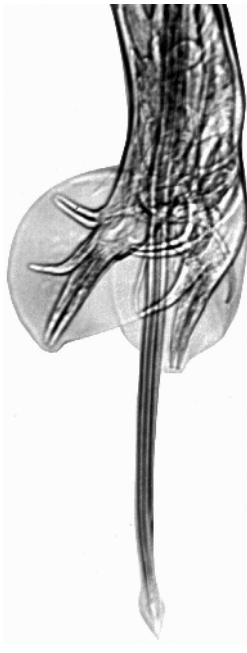


Fig. 1.34 Male bursa and spicules of *Nematodirus filicollis* with two sets of parallel rays in the dorsal lobes.

period and so larvae often appear on the pasture within 2–3 months of the eggs being excreted in the faeces. The parasitic phase within the host is similar to that of *N. battus*. The prepatent period is 2–3 weeks.

Nematodirus spathiger

Description: Males are around 10–15 mm and the females 15–25 mm in length. The male has two sets of parallel rays in each of the main bursal lobes. The spicules are long and slender with fused tips and terminate in a spoon-shaped tip (Table 1.6c). The female has a truncate blunt tail with a small spine (similar to *N. filicollis*), and the egg is large, ovoid, thin-shelled and colourless and twice the size of the typical trichostrongyle egg.

Life cycle: As for *N. filicollis*.

Nematodirus helvetianus

Description: Adult males measure around 11–16 mm and females 17–24 mm in length. The male has two sets of parallel rays in each of the main bursal lobes and the dorsal lobe is not separated from the lateral lobe. The long slender spicules terminate in a fused point, with the surrounding membrane being lanceolate (Table 1.6d). The female has a truncate tail with a small spine, and the egg is large, ovoid and colourless and twice the size of the typical trichostrongyle egg.

Life cycle: *Nematodirus helvetianus* does not have the same critical hatching requirements as *N. battus* and so the larvae often appear on the pasture within 2–3 weeks of the eggs being excreted in the faeces. More than one annual generation is therefore possible. The parasitic phase within the host is similar to that of *N. battus*. The prepatent period is around 3 weeks.

Nematodirus abnormalis

Description: Adult males measure around 11–17 mm and females 18–25 mm. The spicules are asymmetrical with the distal ends bent to form an asymmetrical lancet (Table 1.6e).

Nematodirus mauritanicus

Description: Adult females are 21–24 mm and males 13–15 mm long. Male spicules are joined for part of their length with the tips enclosed in a thin lanceolate membrane.

Nematodirus lamae

Description: These are small worms, females 14–20 mm, males 10–13 mm long. Male worms have a deeply emarginated dorsal lobe with two distinct lobules, and long spicules with the distal end enlarged and terminating in two distinct bifurcated medioventral processes.

Nematodirus leporis

Description: Male worms are 8–15 mm and female worms 16–20 mm in length. The bursa has rounded lobes with parallel posterolateral and mediolateral bursal rays and the spicules are long.

Nematodirella

The anterior of the worm is narrow and is similar to *Nematodirus*. Male spicules are extremely long and thin.

Nematodirella species

Species	Hosts	Site
<i>Nematodirella dromedarii</i>	Camel (dromedary)	Small intestine
<i>Nematodirella cameli</i>	Camel (Bactrian), elk, reindeer	Small intestine
<i>Nematodirella alcides</i> (syn. <i>Nematodirus longispiculata</i> , <i>Nematodirella longissimespiculata</i>)	Elk	Small intestine

Nematodirella dromedarii

Description: Males are 10–15 mm and females 10–30 mm in size. The very long spicules can measure up to half the body length and are equal in size (Fig. 1.35).

Nematodirella cameli

Description: Males are 16–17 mm and females 21–25 mm in size. In the males, the spicules are asymmetrical, thin and extremely long, adjoining each other closely over their entire length forming rounded swellings distally from which branch off spine-shaped distal extremities.

Nematodirella alcides

Synonym: *Nematodirus longispiculata*, *Nematodirella longissimespiculata*

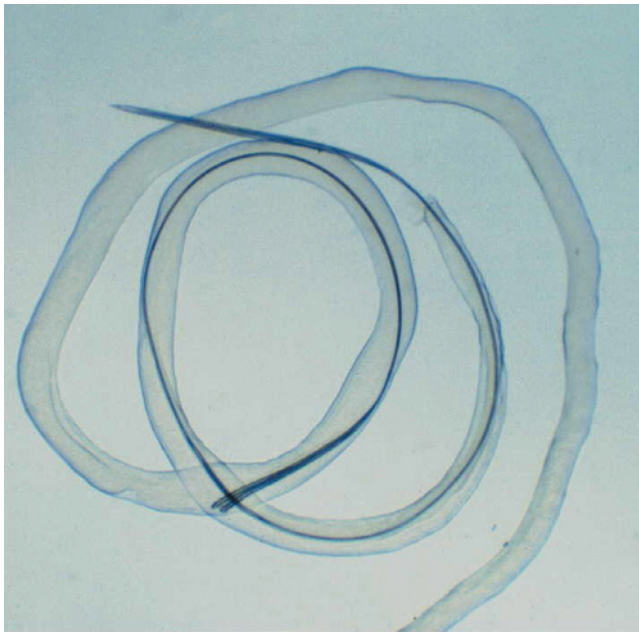


Fig. 1.35 *Nematodirella dromedarii* showing the very long male spicules.

Description: Males are 15–17 mm and females 23–25 mm in size. The spicules are long, thin and filiform with a spear-like tip.

Lamanema

Lamanema species

Species	Hosts	Site
<i>Lamanema chavezii</i>	Alpaca, vicuna	Small intestine

Lamanema chavezii

Description: Small worms, females measuring 14–18 mm and males 9–11 mm long. There is a shallow buccal capsule with dorsal tooth and two small lateroventral teeth at the base. In the male, the lateral lobes are large, dorsal lobe is small, and there are short spicules and a large gubernaculum.

Life cycle: Ingested infective larvae penetrate the intestinal mucosa and migrate to the liver and the lungs. Maturation is completed by migration of the worms back to the intestine via the trachea.

Ollulanus

These are very minute worms. Males are 0.7–0.8 mm and females 0.8–1 mm long. The buccal cavity is small. Microscopic identification is by the presence of the spiral coil of the head.

Life cycle: The worms are viviparous, the larvae developing to the L₃ stage in the uterus of the females. Autoinfection can occur, the shed L₃ developing into adult worms on the gastric mucosa in around 4–5 weeks. The whole life cycle may be completed endogenously and transmission, at least in the cat, is thought to be via ingestion of vomit containing the L₃. The worms live under a layer of mucus in the stomach wall and the anterior end of the worm is often located within the gastric crypts.

Ollulanus species

Species	Hosts	Site
<i>Ollulanus tricuspis</i>	Cat, wild felids, pig, dog, fox	Stomach

Ollulanus tricuspis

Description: The male bursa is well developed and the spicules are stout and each is split into two for a considerable portion of their length. The female has a tail, which terminates in three or four short cusps. The vulva is in the posterior part of the body and there is only one uterus and ovary.

FAMILY HELLIGMONELLIDAE

Nippostrongylus

Nippostrongylus species

Species	Hosts	Site
<i>Nippostrongylus brasiliensis</i> (syn. <i>Nippostrongylus muris</i> , <i>Heligmosomum muris</i>)	Rat, mouse, hamster, gerbil, rabbit, chinchilla	Small intestine

Nippostrongylus brasiliensis

Synonyms: *Nippostrongylus muris*, *Heligmosomum muris*

Description: Adults are filiform and reddish in colour; males measure 2.1–4.5 mm and females 2.5–6 mm.

Life cycle: The life cycle is direct and typically trichostrongyloid. Infection is usually percutaneous and larvae migrate via the lungs. Worms are adult by around 5 days post infection and are usually short-lived. The prepatent period is 5–6 days.

Nematospiroides

Nematospiroides species

Species	Hosts	Site
<i>Nematospiroides dubius</i> (syn. <i>Heligmosomoides polygyrus</i>)	Rat, mouse	Small intestine

Nematospiroides dubius

Description: Adults are long red worms measuring 0.6–1.3 cm in length, with a coiled tail and a cephalic vesicle.

Life cycle: Typically trichostrongyloid with infection via the L₃. The prepatent period is 9 days and patency may last for up to 8 months.

FAMILY DICTYOCAULIDAE

Dictyocaulus

The adults are slender thread-like worms, white/light grey in colour and up to 8.0–10 cm in length. Their location in the trachea and bronchi and their size are diagnostic. The buccal capsule and the bursa are small. The brown spicules are short and often have a



Fig. 1.36 First-stage larvae of *Dictyocaulus viviparus*.

slightly granular appearance. There is some debate over the species taxonomy in deer.

Life cycle: The female worms are ovoviviparous, producing eggs containing fully developed larvae, which hatch almost immediately. The L₁ migrate up the trachea, are swallowed and pass out in the faeces. The larvae are unique in that they are present in fresh faeces, are characteristically sluggish, and their intestinal cells are filled with dark-brown food granules (Fig. 1.36). In consequence, the preparasitic stages do not need to feed. Under optimal conditions the L₃ stage is reached within 5 days, but usually takes longer in the field. The L₃ leave the faecal pat to reach the herbage either by their own motility or through the agency of the ubiquitous fungus *Pilobolus*. After ingestion, the L₃ penetrate the intestinal mucosa and pass to the mesenteric lymph nodes where they moult. The L₄ then travel via the lymph and blood to the lungs, and break out of the capillaries into the alveoli about 1 week after infection. The final moult occurs in the bronchioles a few days later and the young adults then move up the bronchi and mature.

Dictyocaulus species

Species	Hosts	Site
<i>Dictyocaulus viviparus</i>	Cattle, buffalo, deer, camel	Trachea, lungs
<i>Dictyocaulus filaria</i>	Sheep, goat, camelids	Trachea, lungs
<i>Dictyocaulus arnfieldi</i>	Horse, donkey, zebra	Trachea, lungs
<i>Dictyocaulus eckerti</i> (syn. <i>Dictyocaulus noerneri</i>)	Deer (roe deer, fallow deer, red deer), cattle	Trachea, lungs
<i>Dictyocaulus capreolus</i>	Deer (roe deer, moose)	Trachea, lungs

Dictyocaulus viviparus

Description: The adults are slender thread-like worms; males measure around 4.0–5.5 cm and females 6–8 cm in length. The buccal ring is triangular in shape. They are very similar to *D. filaria* but the posterolateral and mediolateral rays are entirely fused together.

Life cycle: The prepatent period is around 3–4 weeks in cattle. The prepatent period in red deer is 20–24 days.

Dictyocaulus filaria

Description: The worms are white with the intestine visible as a dark band. Males measure around 4–8 cm and the females 6–10 cm

in length. In the bursa the posterolateral and the mediolateral rays are fused together, except at their extremities. The dark-brown spicules are stout and shaped like a boot. The vulva is located just posterior to the middle of the worm.

Life cycle: The prepatent period is about 4–5 weeks.

Dictyocaulus arnfieldi

Description: The adults are slender, thread-like and whitish in colour, the adult males measuring around 3.5 cm and the females 6.5 cm in length. Male worms have a small non-lobulated bursa with short rays, with the mediolateral and posterolateral rays fused for half their length. The spicules are short, of equal length and slightly curved.

Life cycle: The detailed life cycle is not fully known, but is considered to be similar to that of the bovine lungworm, *D. viviparus*, except in the following respects. The adult worms are most often found in the small bronchi and their thin-shelled eggs, containing the first-stage larvae, are coughed up before they are swallowed, passed in the faeces and then hatch soon after being deposited. The prepatent period is around 2–3 months. Patent infections are common in donkeys of all ages, but in horses generally only occur in foals and yearlings. In older horses the adult lungworms rarely attain sexual maturity.

Dictyocaulus eckerti

Synonym: *Dictyocaulus noerneri*

Description: Similar to *D. viviparus* but the mouth opening is elongate and the buccal ring is kidney-shaped.

Dictyocaulus capreolus

Description: Distinguished from *D. eckerti* on the basis of the morphology of the buccal capsule and the bursa.

SUPERFAMILY STRONGYLOIDEA

There are several important parasites of domestic mammals and birds in this superfamily of bursate nematodes. Most are characterised by a large buccal capsule, which often contains teeth or cutting plates, and in some there are prominent leaf crowns surrounding the mouth opening. The bursa of males is well developed and a gubernaculum or telamon is usually present. The spicules are usually of equal length. The adults occur on mucosal surfaces of the gastrointestinal and respiratory tracts and feeding is generally by the ingestion of plugs of mucosa.

With the exception of three genera, *Syngamus*, *Mammomonogamus* and *Cyathostoma*, which are parasitic in the trachea and major bronchi, and *Stephanurus* found in the perirenal area, all other genera of veterinary importance in this superfamily are found in the intestine and can be conveniently divided into two groups, the **strongyles** and **hookworms**.

The strongyles are parasitic in the large intestine and the important genera are *Strongylus*, *Triodontophorus* ('large strongyles' of

horses), *Chabertia* and *Oesophagostomum*. Also in this group of small strongyles are the genera *Poteriostomum*, *Craterostomum* and *Oesophagodontus*.

The cyathostomins (cyathostomes or trichonemes) or 'small strongyles' of horses (subfamily Cyathostominae) include the genera *Cyathostomum*, *Cylicocyclus*, *Cylicodontophorus* and *Cylicostephanus* (formerly the single genus *Trichonema*).

Syngamus and *Cyathostoma* are important parasites of the respiratory tract of birds. *Mammomonogamus* are parasites of the respiratory tract of cattle, sheep and goats.

FAMILY STRONGYLIDAE

SUBFAMILY STRONGYLINAE

Strongylus

Members of this genus live in the large intestine of horses and donkeys. These are robust dark-red worms which are easily seen against the intestinal mucosa (Fig. 1.37). The well-developed deep buccal capsule of the adult parasite is prominent as is the bursa of the male. The anterior margin of the buccal capsule usually bears leaf-like cuticular structures (leaf crowns or corona radiata). Species differentiation is based on size and the presence and shape of the teeth in the base of the buccal capsule.

Strongylus species

Species	Hosts	Site
<i>Strongylus edentatus</i> (syn. <i>Alfortia edentatus</i>)	Horse, donkey	Large intestine
<i>Strongylus equinus</i>	Horse, donkey	Large intestine
<i>Strongylus vulgaris</i> (syn. <i>Delafondia vulgaris</i>)	Horse, donkey	Large intestine



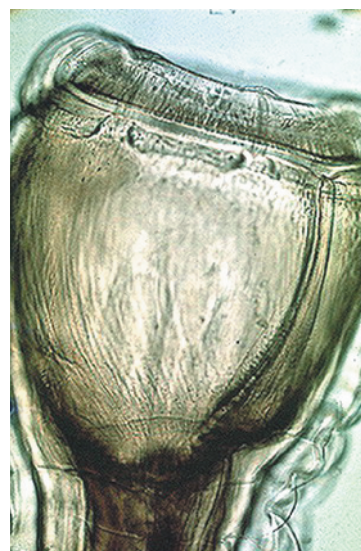
Fig. 1.37 *Strongylus* spp. Adult worms (large strongyles) on the intestinal mucosa with smaller cyathostomins (small strongyles) also present.

Strongylus edentatus

Description: Male worms are 2.3–2.8 cm and females 3.3–4.4 cm in size. The truncate head end is wider than the rest of the body. The buccal capsule is wider anteriorly than at the middle and teeth are absent (Fig. 1.38a).

Life cycle: Eggs, which resemble those of the trichostrongyles, are passed in the faeces and development from egg to the L₃ under summer conditions in temperate climates requires approximately 2 weeks. Infection is by ingestion of the L₃. Subsequently, parasitic larval development of the three species of *Strongylus* differs and will be dealt with separately.

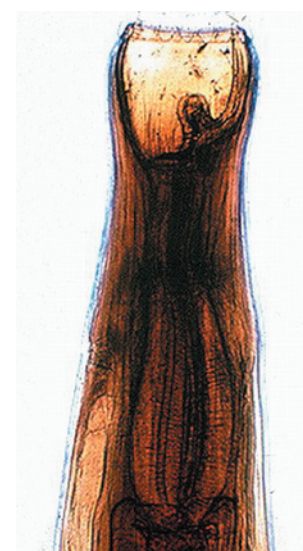
After penetration of the intestinal mucosa L₃ travel via the portal system, and reach the liver parenchyma within a few days. About



(a)



(b)



(c)

Fig. 1.38 (a) Anterior of *Strongylus edentatus* showing the cup-shaped buccal capsule, which is devoid of teeth. (b) Anterior of *Strongylus equinus* showing oval buccal capsule with a large dorsal tooth and smaller subventral conical teeth. (c) Anterior of *Strongylus vulgaris* showing ear-shaped rounded teeth at the base of the buccal capsule.

2 weeks later the moult to L₄ takes place; further migration then occurs in the liver and, by 6–8 weeks post infection, larvae can be found subperitoneally around the hepatorenal ligament. The larvae then travel under the peritoneum to many sites, with a predilection for the flanks and hepatic ligaments. The final moult occurs after 4 months and each L₅ then migrates, still subperitoneally, to the wall of the large intestine where a large purulent nodule is formed, which subsequently ruptures with release of the young adult parasite into the lumen. The prepatent period is usually about 10–12 months and is the longest of the strongyles.

Strongylus equinus

Description: These sturdy worms (about 2 mm thick) are usually coloured dark grey. Males are 2.6–3.5 cm and females 3.8–4.7 cm in size. The head end is not demarcated from the rest of the body. The deep buccal capsule is oval and possesses both external and internal leaf crowns. The base of the buccal capsule is armed with a large dorsal tooth with a bifid tip and also two smaller subventral teeth (Fig. 1.38b). The dorsal oesophageal gland connects to the buccal capsule through several pores located in the dorsal gutter. This thickened ridge is formed by the wall of the buccal capsule. The male has two slender spicules of similar appearance.

Life cycle: The adult parasites live in the caecum and colon. The free-living phase is as described for *S. edentatus*. Of the three *Strongylus* species, least is known of the larval migration of *S. equinus*. It appears that the L₃ lose their sheaths while penetrating the wall of the caecum and ventral colon and within 1 week provoke the formation of nodules in the muscular and subserosal layers of the intestine. The moult to L₄ occurs within these nodules and the larvae then travel across the peritoneal cavity to the liver where they migrate within the parenchyma for 6 weeks or more. After this time, L₄ and L₅ have been found in and around the pancreas before their appearance in the large intestinal lumen. The prepatent period is 8–9 months.

Strongylus vulgaris

Description: Adults of this species are shorter and thinner than the other two *Strongylus* species, with males 14–16 mm and females 20–24 mm in size. The head end is not marked off from the rest of the body. The buccal capsule is oval in outline and contains two ear-shaped rounded teeth at its base (Fig. 1.38c). The distal extremities of elements of the leaf crowns are fringed.

Life cycle: The free-living phase is as described for the other two species. Following ingestion, the L₃ penetrate the intestinal mucosa and moult to L₄ in the submucosa of the caecum and ventral colon 7 days later. These then enter small arteries and arterioles and migrate on the endothelium to their predilection site in the cranial mesenteric artery and its main branches. After a period of development of several months the larvae moult to L₅ and return to the intestinal wall via the arterial lumina. Nodules are formed around the larvae mainly in the wall of the caecum and colon when, due to their size, they can travel no further within the arteries and subsequent rupture of these nodules releases the young adult parasites into the lumen of the intestine. The prepatent period is 6–7 months.

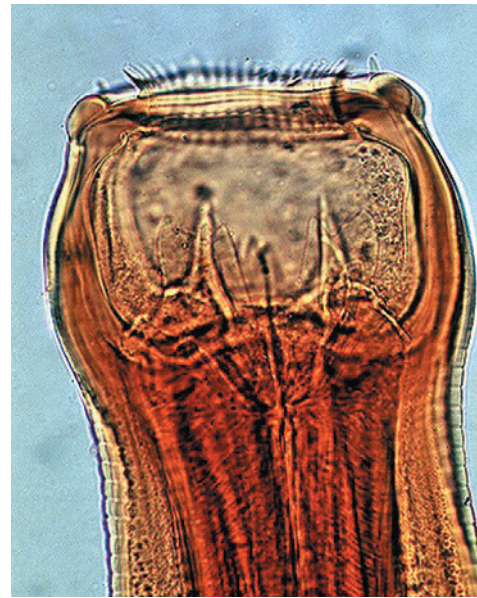


Fig. 1.39 Head of *Triodontophorus* spp. showing the location of teeth at the base of the buccal capsule.

Triodontophorus

Members of the genus *Triodontophorus* are non-migratory, large strongyles frequently found in large numbers in the colon of horses and donkeys. They are reddish worms 1.0–2.5 cm in length readily visible on the colonic mucosa. The buccal capsule is subglobular and thick-walled with three pairs of large oesophageal teeth, each composed of two plates, the anterior rim of which is thickened and surrounded by six plate-like structures (Fig. 1.39). The dorsal gutter is prominent. The spicules of the male terminate in small hooks.

Life cycle: Little information is available on the developmental cycle of this genus, but it is thought to be similar to that of cyathostomes.

***Triodontophorus* species**

Species	Hosts	Site
<i>Triodontophorus brevicauda</i>	Horse, donkey	Large intestine
<i>Triodontophorus minor</i>	Horse, donkey	Large intestine
<i>Triodontophorus nipponicus</i>	Horse, donkey	Large intestine
<i>Triodontophorus serratus</i>	Horse, donkey	Large intestine
<i>Triodontophorus tenuicollis</i>	Horse, donkey	Large intestine

Triodontophorus brevicauda

Description: The males measure around 10–15 mm and females 20–25 mm in length. The buccal plates are smooth, except for three elevations on each, and protrude into the buccal capsule. The sub-median papillae are short, broad and conical. The external leaf crown consists of numerous slender elements protruding from the buccal collar, with an equal number of inner leaf crown elements.

Triodontophorus minor

Description: The males measure around 12 mm and the females 14 mm in length. The buccal plates are strongly denticulated and protrude into the buccal capsule. The cuticle is strongly serrated in the cervical region. The external leaf crown consists of 44–50 slender elements protruding from the buccal collar, with an equal number of inner leaf crown elements.

Triodontophorus nipponicus

Description: The buccal plates have three large denticulations that protrude into the buccal capsule. The cuticle is strongly serrated in the cervical region. The external leaf crown consists of 56–69 slender elements protruding from the buccal collar, with an equal number of inner leaf crown elements.

Triodontophorus serratus

Description: This is the largest species of the genus. Males measure 18–20 mm and females 20–26 mm in length. The mouth collar appears as an inflated round tube around the mouth. The external leaf crown consists of numerous slender elements protruding from the buccal collar, with an equal number of inner leaf crown elements.

Triodontophorus tenuicollis

Description: Males are around 17 mm and females 22 mm long. The cuticle is strongly serrated in the cervical region; the dorsal lobe of the bursa is short, and teeth are finely denticulated.

Chabertia

Worms of this genus are usually found in low numbers in the majority of sheep and goats. The adults are 1.5–2.0 cm in length and are the largest nematodes found in the colon of ruminants. They are white with a markedly truncated and enlarged anterior end due to the presence of the very large buccal capsule. The anterior is curved slightly ventrally (Fig. 1.40).

Life cycle: The life cycle is direct. Eggs are passed in the faeces and hatch on the ground releasing the first-stage larva, which moults to the second stage, and then to the infective third stage. The host is infected by ingestion of the larva with the herbage. In the parasitic phase the L₃ enter the mucosa of the small intestine and occasionally that of the caecum and colon; after a week they moults, the L₄ emerge on to the mucosal surface and migrate to congregate in the caecum where development to the L₅ is completed about 25 days after infection. The young adults then travel to the colon. There is no migration stage in the body. The prepatent period is about 6–7 weeks.

Chabertia species

Species	Hosts	Site
<i>Chabertia ovina</i>	Sheep, goat, occasionally cattle	Large intestine

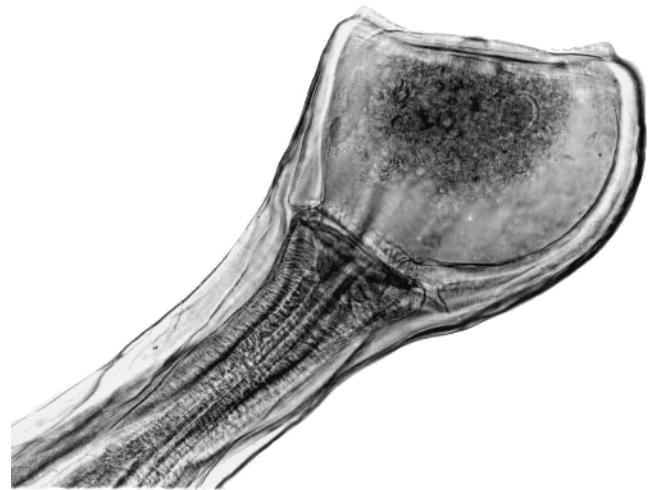


Fig. 1.40 Head of *Chabertia ovina* illustrating the large bell-shaped buccal capsule.

Chabertia ovina

Description: Males measure 13–14 mm and females 17–20 mm in length. The huge buccal capsule, which is bell-shaped, has a double row of small papillae around the rim. There are no teeth. There is a shallow ventral cervical groove, and anterior to this is a cephalic vesicle. In the male, the bursa is well developed with a gubernaculum and the spicules are of medium size.

Oesophagostomum

Worms of this genus are stout and whitish with a narrow cylindrical buccal capsule and measure 1–2 cm in length (Fig. 1.41). The body is often slightly curved. A ventral cervical groove is located near the anterior end of the worm, and the anterior cuticle is dilated to form a cervical vesicle. Leaf crowns are present.

Life cycle: The preparasitic phase is typically strongyloid. The egg hatches on the ground releasing the first-stage larva, which moults to the second stage, and then to the infective third stage. Infection is by ingestion of L₃. There is no migration stage in the body, although there is limited evidence that skin penetration is possible. The larvae

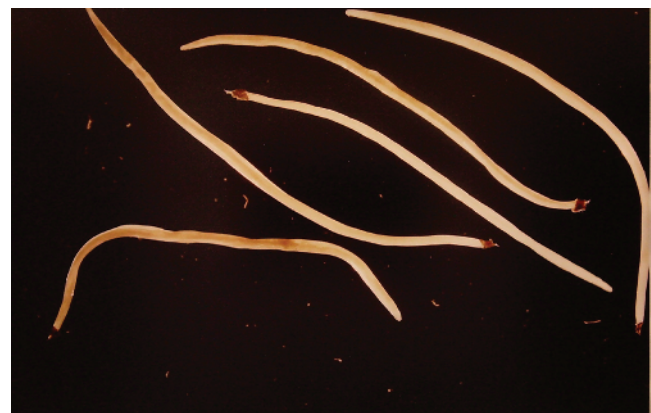


Fig. 1.41 Adult worms of *Oesophagostomum venulosum*.

moult again and the fourth-stage larvae attach to, or enter, the wall of the intestine. These L₄ then emerge on to the mucosal surface, migrate to the colon, and develop to the adult stage. The prepatent period is 5–7 weeks. On reinfection, the larvae may remain arrested as L₄ in nodules for up to 1 year.

Oesophagostomum species

Species	Hosts	Site
<i>Oesophagostomum columbianum</i>	Sheep, goat, camel, wild ruminants	Large intestine
<i>Oesophagostomum venulosum</i> (syn. <i>Oesophagostomum virginimembrum</i>)	Sheep, goat, deer, camel	Large intestine
<i>Oesophagostomum asperum</i>	Sheep, goat	Large intestine
<i>Oesophagostomum multifoliatum</i>	Sheep, goat	Large intestine
<i>Oesophagostomum radiatum</i>	Cattle, water buffalo	Large intestine
<i>Oesophagostomum dentatum</i>	Pig	Large intestine
<i>Oesophagostomum brevicaudum</i>	Pig	Large intestine
<i>Oesophagostomum longicaudatum</i>	Pig	Large intestine
<i>Oesophagostomum quadrispinulatum</i>	Pig	Large intestine
<i>Oesophagostomum georgianum</i>	Pig	Large intestine
<i>Oesophagostomum granatensis</i>	Pig	Large intestine
<i>Oesophagostomum apiostomum</i>	Primates	Large intestine
<i>Oesophagostomum bifurcum</i>	Primates	Large intestine
<i>Oesophagostomum aculeatum</i>	Primates	Large intestine
<i>Oesophagostomum stephanostomum</i>	Primates	Large intestine

Oesophagostomum columbianum

Description: Male worms are 12–17 mm and females 15–22 mm with large cervical alae, which induce a dorsal curvature of the anterior part of the body. The cuticle forms a high mouth collar shaped like a truncate cone. This is separated from the remainder of the body by a constriction. The cephalic vesicle is anterior to a cervical groove, behind which arise the cervical alae pierced by cervical papillae. External leaf crowns consist of 20–24 elements and the internal ones have two small elements to each external element. The male bursa is well developed with two alate spicules of equal length.

Life cycle: The prepatent period is about 45 days.

Oesophagostomum venulosum

Synonym: *Oesophagostomum virginimembrum*

Description, gross: Males worms are 11–16 mm and females 13–24 mm long. Around the anterior oesophagus there is an inflated cuticular cephalic vesicle (Fig. 1.42). The head has a shallow buccal capsule with an external leaf crown of 18 elements. The external crown is compressed and so there is only a narrow opening into the buccal capsule. There are no lateral cervical alae and the worms are therefore not curved anteriorly. The cervical papillae are posterior to the oesophagus.

Life cycle: The prepatent period is about 5–7 weeks.

Oesophagostomum multifolium

Description: Males measure 12–14 mm and females 14–17 mm in length.

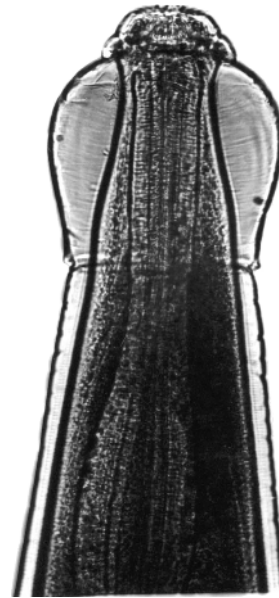


Fig. 1.42 Anterior of *Oesophagostomum venulosum* showing the large inflated cephalic vesicle.

Oesophagostomum radiatum

Description: Adult male worms are 12–17 mm and females 16–22 mm long. The cephalic vesicle is large and is constricted around the middle by a shallow annular groove (Fig. 1.43). The cuticle forms a rounded mouth collar. External leaf crowns are missing and the internal ring consists of 38–40 small triangular denticles. Cervical papillae are present, just posterior to the cervical groove. The male bursa is well developed.

Life cycle: The prepatent period is about 40 days.



Fig. 1.43 Anterior of *Oesophagostomum radiatum* showing the large cephalic vesicle.

Oesophagostomum dentatum

Description: Adult males are 8–10 mm and females 11–14 mm in length. The cephalic vesicle is prominent, but cervical alae are virtually absent. The nine elements of the leaf crown project forward and the internal leaf crown has 18 elements. The buccal capsule is shallow with parallel sides and the oesophagus is club-shaped with a narrow anterior end.

Oesophagostomum brevicaudum

Description: Males measure 6–7 mm and females 6.5–8.5 mm in length. There are 28–32 elements and 14–16 elements in the internal and external leaf crowns respectively. In the female the tail is bent dorsally.

Oesophagostomum quadrispinulatum

Description: This worm is similar to *O. dentatum*, although the oesophagus is slightly more slender and the tail of the female is almost twice as long.

Poteriostomum

These worms measure about 9–21 mm in length. This genus is closely related to the genus *Cylicodontophorus*. The two genera are easily separated based on characteristics of the buccal capsule, especially the point of insertion of the internal leaf crowns, and on the character of the dorsal rays. The externo-dorsal ray and the dorsal ray of the bursa in this genus arise from a common trunk and the dorsal ray gives off, almost at 90°, two lateral branches near the origin of the externo-dorsal rays and the dorsal ray is cleft only to about half its length.

Poteriostomum species

Species	Hosts	Site
<i>Poteriostomum imparidentatum</i>	Horse, donkey	Large intestine
<i>Poteriostomum ratzii</i>	Horse, donkey	Large intestine
<i>Poteriostomum skrjabini</i>	Horse, donkey	Large intestine

Poteriostomum imparidentatum

Description: The six elements of the internal leaf crown are markedly longer than in the other species.

Poteriostomum ratzii

Description: All elements of the internal leaf crown are of equal lengths.

Poteriostomum skrjabini

Description: Distinguished by a poorly defined dorsal gutter.

Craterostomum

These are relatively small worms, 6–11 mm long, and in general are similar to *Triodontophorus* (apart from the lack of protruding teeth and also the female vulva is located more anteriorly). The buccal capsule is of greatest diameter in the middle, with the wall thickened behind the anterior edge. The dorsal gutter is strongly developed. There is a shallow oesophageal funnel with three small triangular teeth that do not project into the buccal cavity. Elements of the external leaf crown are large and transparent and less numerous than the short broad elements of the inner leaf crown that ring the anterior ridge of the buccal capsule. Sub-median papillae extend beyond the depressed mouth collar. In the female the tail is long and pointed and the vulva is relatively far from the anus.

Craterostomum species

Species	Hosts	Site
<i>Craterostomum acuticaudatum</i> (syn. <i>Craterostomum mucronatum</i>)	Horse, other equines	Large intestine
<i>Craterostomum tenuicauda</i>	Horse, zebra	Large intestine

Craterostomum acuticaudatum

Description: The males measure about 6–10 mm and the females 7–11 mm in length. The internal leaf crown has 22–26 short elements and the external leaf crown bears six to eight petal-shaped elements. The bottom of the buccal capsule is funnel-shaped and possesses a row of papillae which appear like a leaf crown. Teeth are absent from the buccal cavity.

Craterostomum tenuicauda

Description: The inner leaf crown has 18 elements and the external leaf crown nine elements.

Oesophagodontus

There is only one species in the genus. Male worms are 15–18 mm and females 19–24 mm in size. There is a slight constriction between the anterior region and the remainder of the body.

Oesophagodontus species

Species	Hosts	Site
<i>Oesophagodontus robustus</i>	Horse, donkey	Large intestine

Oesophagodontus robustus

Description: Males measure around 18 mm and females 19–22 mm long. The buccal capsule is shaped like a funnel with a thickened ring encircling its posterior margin. The oesophageal funnel has three lancet-like teeth that do not project into the buccal capsule. There are prominent sub-median papillae and the dorsal gutter is absent.

Codiostomum

Codiostomum species

Species	Hosts	Site
<i>Codiostomum struthionis</i>	Ostrich, rhea	Large intestine, caecum

Codiostomum struthionis

Description: Adult worms are 13–17 mm in length. The large buccal capsule is subglobular with external and internal leaf crowns, but no teeth. The male bursa has a large projecting dorsal lobe.

Life cycle: The life cycle is unknown but is considered to be direct.

SUBFAMILY CYATHOSTOMINAE

The 'small strongyles' embraces over 50 species, popularly known as trichonemes, cyathostomes or cyathostomins. For many years there has been a great deal of confusion in the classification of this group of parasites and in a new revision it has been proposed that the genus *Trichonema* be discarded and replaced by four main genera, namely *Cyathostomum*, *Cylicocyclus*, *Cylicodontophorus* and *Cylicocostephanus*, these being collectively referred to as cyathostomes or, more recently, cyathostomins.

Small strongyles are small (5–12 mm long) bursate nematodes ranging in colour from white to dark red, the majority being visible on close inspection of the large intestinal mucosa or contents (Fig. 1.44). The well-developed short buccal capsule is cylindrical, without teeth, and species differentiation is based on characteristics of the buccal capsule, and the internal and external leaf crowns.

Life cycle: Hatching of eggs and development to L₃ is complete within 2 weeks during the summer in temperate areas, after which the larvae migrate from the faeces on to the surrounding herbage. After ingestion, the L₃ exsheath and invade the wall of the ileum and large intestine where they develop to L₄ before emerging into the gut lumen and moulting to become young adult worms. The prepatent periods of members of this genus are generally between 2 and 3 months, although this may be extended due to hypobiosis in some species.



Fig. 1.44 Small strongyles (cyathostomins) on the mucosa of the ventral colon.

Cyathostomum

Cyathostomum have a moderately high mouth collar, with cephalic papillae not very prominent. The buccal capsule is broader than deep, thin-walled, and has no dorsal gutter. Elements of the external leaf crown are larger, broader and fewer than elements of the internal leaf crown. The inner leaf crown is situated deep in the buccal capsule and has sclerotised extra-chitinous supports at or near the anterior edge of the buccal capsule (Fig. 1.45a).

The dorsal ray of the male bursa is split to the origin of the externo-dorsal rays and the spicules are filiform, equal in length with pick-shaped tips. In the female, the vulva is close to the anus. The tail may be straight or bent dorsally with a ventral bulge, anterior to the vulva.

Cyathostomum species

Species	Hosts	Site
<i>Cyathostomum alveatum</i> (syn. <i>Cylichnostomum alveatum</i> , <i>Cylicostomum alveatum</i> , <i>Trichonema alveatum</i> , <i>Cylicocercus alveatus</i>)	Horse, donkey	Large intestine
<i>Cyathostomum catinatum</i> (syn. <i>Cylichnostomum catinatum</i> , <i>Cylicostomum catinatum</i> , <i>Trichonema catinatum</i> , <i>Cylicocercus catinatum</i>)	Horse, donkey	Large intestine
<i>Cyathostomum coronatum</i> (syn. <i>Cylichnostomum coronatum</i> , <i>Cylicostomum coronatum</i> , <i>Trichonema coronatum</i> , <i>Cylicostomias coronatum</i>)	Horse, donkey	Large intestine
<i>Cyathostomum labiatum</i> (syn. <i>Cyathostomum labratum</i> , <i>Cylichnostomum labiatum</i> , <i>Cylicostomum labiatum</i> , <i>Trichonema labiatum</i> , <i>Cylicostomias labiatum</i>)	Horse, donkey	Large intestine
<i>Cyathostomum labratum</i> (syn. <i>Cylichnostomum labratum</i> , <i>Cylicostomum labratum</i> , <i>Trichonema labratum</i> , <i>Cylicostomias labratum</i>)	Horse, donkey	Large intestine
<i>Cyathostomum montgomeryi</i> (syn. <i>Cylicostomum montgomeryi</i> , <i>Trichonema labratum</i> , <i>Cylicotoichus montgomeryi</i>)	Horse, donkey	Large intestine
<i>Cyathostomum pateratum</i> (syn. <i>Cylicodontophorus pateratum</i> , <i>Cylicostomum pateratum</i> , <i>Trichonema pateratum</i> , <i>Cylicostocercus pateratum</i>)	Horse, donkey	Large intestine
<i>Cyathostomum saginatum</i> (syn. <i>Cylicostomum sagittatum</i> , <i>Trichonema sagittatum</i> , <i>Cylicostomias sagittatum</i> , <i>Cylicodontophorus sagittatum</i>)	Horse, donkey	Large intestine
<i>Cyathostomum tetracanthum</i> (syn. <i>Strongylus tetracanthus</i> , <i>Sclerostomum tetracanthum</i> , <i>Cylichnostomum tetracanthum</i> , <i>Cylicostomum tetracanthum</i> , <i>Trichonema tetracanthum</i> , <i>Trichonema arcuata</i> , <i>Trichonema aegypticum</i> , <i>Cylicostomum aegypticum</i>)	Horse, donkey	Large intestine

Cyathostomum alveatum

Description: The walls of the buccal capsule have a uniform thickness posterior to the inner leaf crown, which is about one-third the depth of the buccal capsule.

Cyathostomum catinatum

Description: The inner leaf crown is more anterior on the lateral sides of the buccal capsule compared with the dorsal and ventral sides, but not in a sinuous line.

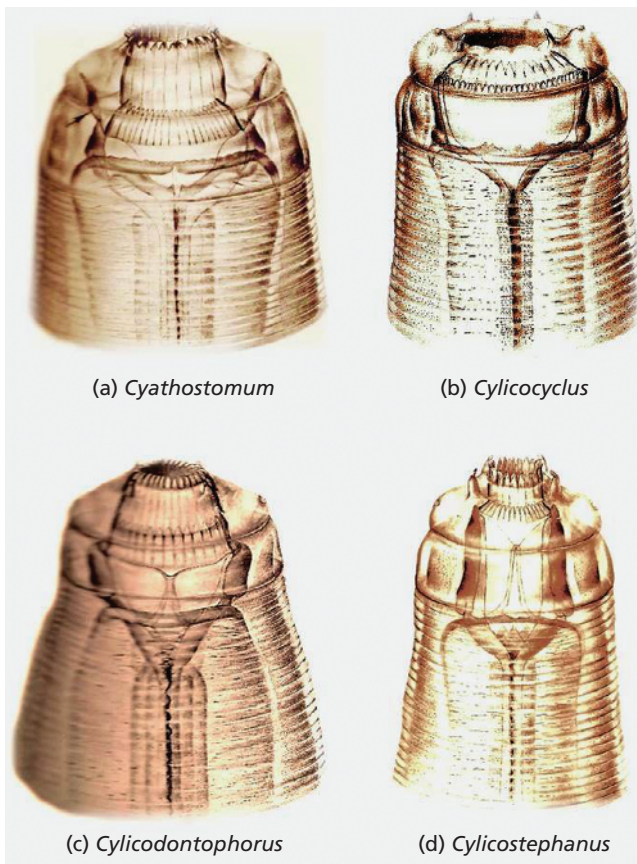


Fig. 1.45 Cystostomins showing characteristic features of the heads and buccal capsules used in generic and species identification: (a) *Cyathostomum*; (b) *Cylicocyclus*; (c) *Cylicodontophorus*; (d) *Cylicostephanus*. (Redrawn from Lichtenfels, 1975. Reproduced with permission from the Helminthological Society of Washington.)

Cyathostomum coronatum

Description: Extra-chitinous supports are prominent and the inner leaf crown forms an even line around the buccal cavity, which is as deep as it is broad and with walls that are thick and bent inwards.

Cyathostomum labiatum

Description: The mouth collar is notched and forms four distinct lips; the inner leaf crown elements are half the length of the external leaf crowns. Chitinous supports are spindle-shaped. The excretory pore is sited near the junction of the mid to posterior third of the oesophagus.

Cyathostomum labratum

Description: The mouth collar is not notched; the inner leaf crown elements are greater than half the length of the external leaf crowns. Chitinous supports are pyriform-shaped and the excretory pore is located near the middle of the oesophagus.

Cyathostomum montgomeryi

Description: Similar to *C. labiatum* but without well-defined lips. The wall of the buccal capsule is longer in dorsoventral view.

Cyathostomum pateratum

Description: The inner leaf crown is in a sinuous line deep in the buccal cavity (seen in lateral view).

Cyathostomum saginatum

Description: Similar to *C. coronatum* but the buccal capsule is shallow.

Cyathostomum tetracanthum

Description: The extra-chitinous supports are nearly as large as the wall of the buccal capsule and appear as extensions of the buccal capsule wall.

Cylicocyclus

These parasites are about 10–25 mm in length. *Cylicocyclus* have a high mouth collar with broad lateral papillae. Elements of the external leaf crown are larger, fewer and broader than the inner leaf crown, the latter being short, with thin rods at or near the anterior edge of the buccal capsule. The buccal capsule is short, broader than deep, with thin walls tapering anteriorly, with a hoop-shaped thickening around the posterior margin. A dorsal gutter is usually absent from the buccal capsule (Fig. 1.45b). In the male the dorsal ray is split to the region of origin of the externo-dorsal rays and the spicules are filiform, of equal length with pick-shaped tails. In females, the vulva is near the anus and the tail is usually straight but may be bent slightly dorsally.

Cylicocyclus species

Species	Hosts	Site
<i>Cylicocyclus adersi</i> (syn. <i>Cylicostomum adersi</i> , <i>Trichonema adersi</i>)	Horse, donkey	Large intestine
<i>Cylicocyclus auriculatus</i> (syn. <i>Cylichostomum auriculatum</i> , <i>Cylicostomum auriculatum</i> , <i>Trichonema auriculatum</i> , <i>Cyathostomum auriculatum</i>)	Horse, donkey	Large intestine
<i>Cylicocyclus brevicapsulatus</i> (syn. <i>Cylicostomum brevispiculatum</i> , <i>Cylicobrachytus brevispiculatum</i> , <i>Trichonema brevispiculatum</i>)	Horse, donkey	Large intestine
<i>Cylicocyclus elongatus</i> (syn. <i>Cylicostomum elongatum</i> , <i>Cylichostomum elongatum</i> , <i>Trichonema elongatum</i> , <i>Cylicostomum elongatum</i>)	Horse, donkey	Large intestine
<i>Cylicocyclus insigne</i> (syn. <i>Cylichostomum insigne</i> , <i>Cylicostomum insigne</i> , <i>Cylicostomum zebra</i> , <i>Trichonema insigne</i>)	Horse, donkey	Large intestine
<i>Cylicocyclus largocapsulatus</i> (syn. <i>Trichonema largocapsulatus</i>)	Horse, donkey	Large intestine
<i>Cylicocyclus leptostomus</i> (syn. <i>Cylichostomum leptostomum</i> , <i>Trichonema leptostomum</i> , <i>Schultzitrichonema leptostomum</i> , <i>Cylicotetrapedon leptostomum</i>)	Horse, donkey	Large intestine

Species	Hosts	Site
<i>Cylicocycclus maturmurai</i> (syn. <i>Trichonema maturmurai</i>)	Horse, donkey	Large intestine
<i>Cylicocycclus nassatus</i> (syn. <i>Cyathostomum nassatum</i> , <i>Cylichnostomum nassatum</i> , <i>Cylicostomum nassatum</i> , <i>Trichonema nassatum</i> , <i>Cylicocycclus</i> <i>bulbiferus</i>)	Horse, donkey	Large intestine
<i>Cylicocycclus radiatus</i> (syn. <i>Cyathostomum radiatum</i> , <i>Cylichnostomum radiatum</i> , <i>Trichonema radiatum</i> , <i>Cylicostomum prionodes</i>)	Horse, donkey	Large intestine
<i>Cylicocycclus tiramosus</i> (syn. <i>Cylicostomum tiramosum</i> , <i>Trichonema tiramosum</i>)	Horse, donkey	Large intestine
<i>Cylicocycclus ultrajectinus</i> (syn. <i>Cylicostomum ultrajectinum</i> , <i>Trichonema ultrajectinum</i>)	Horse, donkey	Large intestine

Cylicocycclus adersi

Description: Buccal capsule is not shallow and the walls are of uniform thickness. The dorsal gutter is short but well developed. The inner leaf crown elements are few and wider than the external leaf crown elements and are of uniform length.

Cylicocycclus auriculatus

Description: The buccal capsule is not shallow and the dorsal gutter is absent. Lateral papillae are long ear-like or horn-like extending much higher than the mouth collar. The excretory pore and cervical papillae are located behind the oesophago-intestinal junction.

Cylicocycclus brevicapsulatus

Description: The buccal capsule is extremely shallow with delicate inconspicuous walls.

Cylicocycclus elongatus

Description: The buccal capsule is not shallow, the dorsal gutter is absent and the lateral papillae are not long. The excretory pore and cervical papillae are anterior to the oesophago-intestinal junction. The oesophageal funnel is nearly as large as the buccal capsule, and the oesophagus is greatly elongated with the posterior half enlarged and cylindrical.

Cylicocycclus insigne

Description: The buccal capsule is not shallow, the dorsal gutter is absent and the lateral papillae are not long. The excretory pore and the cervical papillae are anterior to the oesophago-intestinal junction. The external leaf crown elements are narrow; the inner leaf crown elements are much shorter than the external leaf crown elements and are of uniform length.

Cylicocycclus largocapsulatus

Description: The oesophago-intestinal valve is not elongate, the buccal capsule is large and the elements of the external leaf crown are almost about half as long as the buccal capsule is deep.

Cylicocycclus leptostomus

Description: The oesophago-intestinal valve is elongate, the buccal capsule is small and elements of the external leaf crown are almost as long as the buccal capsule is deep.

Cylicocycclus maturmurai

Description: The buccal capsule is not shallow and the walls are of uniform thickness. The inner leaf crown elements outnumber the external leaf crown elements and are of uniform length.

Cylicocycclus nassatus

Description: The buccal capsule is not shallow with both lateral papillae and external leaf crown extending beyond the mouth collar. A dorsal gutter is present extending half of the depth of the buccal capsule. Sub-median papillae are long and extend beyond the mouth collar. The external leaf crown has 20 elements. The buccal capsule has an internal shelf-like cuticular projection.

Cylicocycclus radiatus

Description: The oesophago-intestinal valve is not elongate, the buccal capsule is large and the elements of the external leaf crown are almost about one-third as long as the buccal capsule is deep.

Cylicocycclus tiramosus

Description: The buccal capsule is not shallow, with both lateral papillae and the external leaf crown extending beyond the mouth collar. The dorsal gutter is short and button-like. The sub-median papillae are short and do not extend beyond the mouth collar. The external leaf crown has 30 elements. The buccal capsule is without an internal projection.

Cylicocycclus ultrajectinus

Description: The buccal capsule is not shallow, the dorsal gutter is absent and the lateral papillae are not long. The excretory pore and the cervical papillae are located near the oesophago-intestinal junction. The external leaf crown elements are broad; the inner leaf crown elements are as long, or longer, than the external leaf crown elements.

Cylicodontophorus

These are small to medium-sized worms about 7–15 mm in length. *Cylicodontophorus* have a high mouth collar, with lateral papillae inconspicuous and sub-median papillae short and conical. The buccal capsule is short, thick-walled, of nearly uniform thickness, and broader than deep. Inner leaf crown elements are longer, broader and less numerous than the external leaf crown elements, and are inserted near the anterior edge of the buccal capsule (Fig. 1.45c).

The dorsal ray of the male bursa is split only to the proximal branch, and the spicules are filiform, equal in length with hook-shaped tips. In the female, the tail is short with a sharp tip and a prominent ventral bulge may be present anterior to the vulva.

Cylicodontophorus species

Species	Hosts	Site
<i>Cylicodontophorus bicoronatus</i> (syn. <i>Cyathostomum bicoranatum</i> , <i>Cylichnostomum bicoronatum</i> , <i>Cylicostomum bicoranatum</i> , <i>Trichonema bicoranatum</i>)	Horse, donkey	Large intestine
<i>Cylicodontophorus euproctus</i> (syn. <i>Cylichnostomum euproctus</i> , <i>Cylicostomum euproctus</i> , <i>Trichonema euproctus</i>)	Horse, donkey	Large intestine
<i>Cylicodontophorus mettami</i> (syn. <i>Cylicostoma mettami</i> , <i>Cylicostomum mettami</i> , <i>Trichonema mettami</i> , <i>Cylicocercus mettami</i> , <i>Cylicostomum ihlei</i>)	Horse, donkey	Large intestine

Cylicodontophorus bicoronatus

Description: The dorsal gutter is well developed. The elements of the external and internal leaf crowns are nearly equal in size.

Cylicodontophorus euproctus

Description: The dorsal gutter is absent. The elements of the internal leaf crowns are twice as long as the elements of the external leaf crown. The oesophageal funnel is not well developed.

Cylicodontophorus mettami

Description: The dorsal gutter is absent. The elements of the internal leaf crowns are less than twice as long as the elements of the external leaf crown. The oesophageal funnel is well developed.

Cylicostephanus

These small worms are only about 4–10 mm in length. *Cylicostephanus* have a depressed mouth collar, with lateral papillae inconspicuous and sub-median papillae prominent. The buccal capsule is slightly narrow anteriorly, with a wall of varying thickness, and with a dorsal gutter. External leaf crown elements are longer, broader and less numerous than the internal leaf crown elements, which are short thin rods inserted near the anterior edge of the buccal capsule (Fig. 1.45d).

The dorsal ray of the male bursa is split only to the proximal branch, and the spicules are filiform, equal in length with pick-shaped tips. In the female, the vulva is near the anus, and the tail is usually straight.

Cylicostephanus species

Species	Hosts	Site
<i>Cylicostephanus asymmetricus</i> (syn. <i>Cylicostomum asymmetricum</i> , <i>Cylicotrapedon asymmetricum</i> , <i>Schulzitriconema asymmetricum</i>)	Horse, donkey	Large intestine
<i>Cylicostephanus bidentatus</i> (syn. <i>Cylicostomum bidentatum</i> , <i>Cylicotrapedon bidentatum</i> , <i>Trichonema bidentatum</i> , <i>Schulzitriconema bidentatum</i>)	Horse, donkey	Large intestine

Species	Hosts	Site
<i>Cylicostephanus calicatus</i> (syn. <i>Cyathostomum calicatum</i> , <i>Cylichnostomum calicatum</i> , <i>Cylicostomum calicatum</i> , <i>Trichonema calicatum</i> , <i>Cylicostomum barbatum</i> , <i>Trichonema tsengi</i>)	Horse, donkey	Large intestine
<i>Cylicostephanus goldi</i> (syn. <i>Cylichnostomum goldi</i> , <i>Cylicostomum goldi</i> , <i>Trichonema goldi</i> , <i>Schulzitriconema goldi</i> , <i>Cylicostomum tridentatum</i>)	Horse, donkey	Large intestine
<i>Cylicostephanus hybridus</i> (syn. <i>Cylicostomum hybridus</i> , <i>Trichonema hybridum</i> , <i>Schulzitriconema hybridum</i> , <i>Trichonema parvibursatus</i>)	Horse, donkey	Large intestine
<i>Cylicostephanus longibursatus</i> (syn. <i>Cylicostomum longibursatum</i> , <i>Trichonema longibursatum</i> , <i>Cylicostomum nanum</i> , <i>Cylicostomum caliciforme</i>)	Horse, donkey	Large intestine
<i>Cylicostephanus minutus</i> (syn. <i>Cylicostomum minutum</i> , <i>Trichonema minutum</i>)	Horse, donkey	Large intestine
<i>Cylicostephanus ornatus</i> (syn. <i>Cylicostomum ornatum</i> , <i>Trichonema ornatum</i> , <i>Cylicostomias ornatum</i> , <i>Cyathostomum ornatum</i> , <i>Cylicodontophorus ornatum</i>)	Horse, donkey	Large intestine
<i>Cylicostephanus poculatus</i> (syn. <i>Cyathostomum poculatum</i> , <i>Cylichnostomum poculatum</i> , <i>Cylicostomum poculatum</i> , <i>Trichonema poculatum</i> , <i>Petrovina poculatum</i>)	Horse, donkey	Large intestine
<i>Cylicostephanus skrbjani</i> (syn. <i>Trichonema skrbjani</i> , <i>Petrovinema skrbjani</i>)	Horse, donkey	Large intestine

Cylicostephanus asymmetricus

Description: The walls of the buccal capsule are markedly thicker anteriorly, the elements of the external leaf crown are as broad as long, and the dorsal gutter extends almost to the base of the inner leaf crown. The buccal capsule is asymmetrical in lateral view and the walls of the capsule are concave. The teeth in the oesophageal funnel are not prominent.

Cylicocyclus bidentatus

Description: The walls of the buccal capsule are markedly thicker anteriorly, the elements of the external leaf crown are as broad as long, and the dorsal gutter extends almost to the base of the inner leaf crown. The buccal capsule is asymmetrical in lateral view and the walls of the capsule are concave. The teeth in the oesophageal funnel are not prominent.

Cylicostephanus calicatus

Description: The buccal capsule is as broad as deep and the wall is of uniform thickness. The external leaf crowns are composed of 8–18 triangular elements and the sub-median papillae are notched near their tips.

Cylicostephanus goldi

Description: The walls of the buccal capsule are of uniform thickness, the elements of the external leaf crown are twice as numerous as the elements of the inner leaf crown, and the dorsal gutter is button-like. The walls of the buccal capsule have a slight compound curve, being slightly thicker posteriorly. The female tail is bent dorsally. There are no prominent teeth in the oesophageal funnel.

Cylicostephanus hybridus

Description: The walls of the buccal capsule are of uniform thickness, the elements of the external leaf crown are twice as long as broad, and the dorsal gutter extends halfway to the base of the inner leaf crown. The walls of the buccal capsule are straight, slightly thicker posteriorly in dorsal view.

Cylicostephanus longibursatus

Description: The walls of the buccal capsule are of uniform thickness, the elements of the external leaf crown are twice as long as broad, and the dorsal gutter is button-like. The walls of the buccal capsule have a slight compound curve and are slightly thicker posteriorly.

Cylicostephanus minutus

Description: The buccal capsule is as broad as deep and the walls are of uniform thickness. The external leaf crowns are composed of 8–18 triangular elements and the sub-median papillae are notched midway.

Cylicostephanus ornatus

Description: The walls of the buccal capsule are markedly thicker anteriorly, the elements of the external leaf crown are as broad as long, and the dorsal gutter extends almost to the base of the inner leaf crown. The buccal capsule is asymmetrical in lateral view and the walls of the capsule are concave. The teeth in the oesophageal funnel are not prominent.

Cylicostephanus poculatus

Description: The buccal capsule is deeper than broader in lateral view and the walls are much thicker posteriorly. The external leaf crown is composed of approximately 36 elements.

Cylicostephanus skrjabini

Description: The buccal capsule is deeper than broader in lateral view and the walls are much thicker posteriorly. The external leaf crown is composed of approximately 36 elements. It lacks a lateral projection on the inner wall of the buccal capsule and has a rim of dentiform processes at the bottom of the buccal capsule.

FAMILY SYNGAMIDAE

Syngamus

The large reddish female and the small whitish male are permanently *in copula* forming a 'Y' shape (Fig. 1.46). They are the only parasites found in the trachea of domestic birds. Males possess two spicules.

Life cycle: Eggs escape under the bursa of the male and are carried up the trachea in the excess mucus produced in response to infection; they are then swallowed and passed in the faeces. Unlike other strongyloids the L₃ develops within the egg. Infection may



Fig. 1.46 *Syngamus trachea* male and female worms *in copula*. (Redrawn from Neumann, trans. Fleming, 1892.)

occur by one of three ways: firstly by ingestion of the L₃ in the egg, secondly by ingestion of the hatched L₃, or thirdly by ingestion of a transport (paratenic) host containing the L₃. The most common paratenic host is the common earthworm, but a variety of other invertebrates including slugs, snails, beetles and some flies may act as transport hosts. After penetrating the intestine of the final host the L₃ travel, via the liver, to the lungs, probably in the blood since they are found in the alveoli 4–6 hours after experimental infection. The two parasitic moults take place in the lungs within 5 days, by which time the parasites are 1.0–2.0 mm long. Copulation occurs around day 7 in the trachea or bronchi after which the female grows rapidly. The prepatent period is 16–20 days. Longevity is around 9 months.

Syngamus species

Species	Hosts	Site
<i>Syngamus trachea</i>	Chicken, turkey, gamebirds (pheasants, partridges, guinea fowl), pigeons and various wild birds	Trachea

Syngamus trachea

Synonyms: *Syngamus parvis*, *Syngamus gracilis*

Description: Female worms are reddish and 1–3 cm in size; the small whitish males measure up to 0.5 cm in length. The worms have large shallow cup-shaped buccal capsules, which have up to 10 teeth at their base. There are no leaf crowns. The bursal rays are short and thick and the spicules are long and of simple form.

Cyathostoma

The male bursa is well developed but worms in this species are not permanently *in copula*, as observed in *Syngamus*.

Life cycle: The life cycle is thought to be similar to that of *Syngamus*.

Cyathostoma species

Species	Hosts	Site
<i>Cyathostoma bronchialis</i>	Goose, duck, swan	Trachea, bronchi
<i>Cyathostoma variegatum</i>	Duck, emu	Trachea, bronchi

Cyathostoma bronchialis

Synonym: *Syngamus bronchialis*

Description: The worms are reddish in colour when fresh. Adult male worms are 4–6 mm and females much larger at 15–30 mm in length. The buccal capsule is large, deep and cup-shaped with six to seven teeth at its base. The male bursa is well developed but worms in this species are not permanently *in copula*, as seen in *Syngamus trachea*.

Cyathostoma variegatum

Description: Adult worms are 0.4–3 cm long; males are 4–6 mm and females 16–31 mm.

Mammomonogamus

These nematodes are similar to *Syngamus*. The worms are reddish in appearance and about 0.6–2 cm long. The females and males are found in permanent copulation. The large buccal capsule lacks a cuticular crown. There is a cervical papilla. Species of *Mammomonogamus* found in cats may be synonyms of the species found in ruminants.

Life cycle: The life cycle is direct but the mode of transmission is unknown.

Mammomonogamus species

Species	Hosts	Site
<i>Mammomonogamus nasicola</i> (syn. <i>Syngamus nasicola</i> , <i>Syngamus kingi</i>)	Sheep, goat, cattle, deer	Nasal cavities
<i>Mammomonogamus laryngeus</i> (syn. <i>Syngamus laryngeus</i>)	Cattle, buffalo, goat, sheep, deer, rarely human	Larynx
<i>Mammomonogamus auris</i> (syn. <i>Syngamus auris</i>)	Cat	Ear canals
<i>Mammomonogamus ierei</i> (syn. <i>Syngamus ierei</i>)	Cat	Nasal cavities
<i>Mammomonogamus mcgaughei</i> (syn. <i>Syngamus mcgaughei</i>)	Cat	Nasal sinuses, pharynx

Mammomonogamus nasicola

Synonym: *Syngamus nasicola*, *Syngamus kingi*

Description: Males are 4–6 mm and females 11–23 mm long.

Mammomonogamus laryngeus

Synonym: *Syngamus laryngeus*

Description: Male worms are 3–6.3 mm and the larger females 8.7–23.5 mm long. Males possess spicules ranging from 23 to 30 µm in length and have cup-shaped buccal capsules that open at the

anterior end. Located deep in the buccal cavity are 8–10 teeth that are not thought to be used for attachment.

Mammomonogamus ierei

Synonym: *Syngamus ierei*

Description: Female worms are about 20 mm long, while male worms are 5–6.9 mm long and rather stocky in appearance. The worms are found with the bursa of the male attached at the level of the vulva of the female. There is a large buccal capsule that has eight large teeth at its base.

Stephanurus

Large worms found in the kidneys and perirenal tissues.

Life cycle: Preparasitic development from egg to L₃ is typically strongyloid, though earthworms may intervene as transport hosts. There are three modes of infection: by ingestion of the free L₃, ingestion of earthworms carrying the L₃ and percutaneously. After entering the body, there is an immediate moult and the L₄ travel to the liver in the bloodstream, either from the intestine by the portal stream or from the skin by the lungs and systemic circulation. In the liver the final moult takes place, and the young adults wander in the parenchyma for 3 months or more before piercing the capsule and migrating in the peritoneal cavity to the perirenal region. There they are enclosed in a cyst by the host reaction, and complete their development. The cyst communicates with the ureter either directly or, if it is more distant, by a fine connecting canal, allowing the worm eggs to be excreted in the urine. The prepatent period ranges from 6 to 19 months and the worms have a longevity of about 2–3 years.

Stephanurus species

Species	Hosts	Site
<i>Stephanurus dentatus</i>	Pig	Kidney

Stephanurus dentatus

Description: A large stout worm up to 4.5 cm long, with a prominent buccal capsule and transparent cuticle through which the internal organs may be seen. Males are 2–3 cm and females 3–4.5 cm long. The colour is usually pinkish. The size and site are diagnostic. The buccal capsule is cup-shaped with small leaf crowns and six external cuticular thickenings (epaulettes), of which the ventral and dorsal are most prominent, and six cusped teeth at the base. The male bursa is short and the two spicules of either equal or unequal length.

FAMILY DELETROCEPHALIDAE**Deletrocephalus****Deletrocephalus species**

Species	Hosts	Site
<i>Deletrocephalus dimidiatus</i>	Rhea	Small intestine

Deletrocephalus dimidiatus

Description: Adult worms are stout and robust with a well-developed buccal capsule. Male worms are 9–11 mm and females 14–16 mm long. Males are bursate with long thin spicules.

Paradeletrocephalus

Paradeletrocephalus species

Species	Hosts	Site
<i>Paradelorocephalus minor</i>	Rhea	Small intestine

Paradeletrocephalus minor

Description: Adult worms are similar in size and appearance to *Deletrocephalus* spp. The buccal capsule has vertical ridges and there are no external, or internal, coronary rings.

SUPERFAMILY ANCYLOSTOMATOIDEA

Hookworms are parasites of the small intestine and the genera of veterinary importance are *Ancylostoma*, *Uncinaria*, *Bunostomum* and, to a lesser extent, *Gaigeria*, *Globocephalus* and *Agriostomum*. In humans important hookworm genera are *Ancylostoma* and *Necator*.

FAMILY ANCYLOSTOMATIDAE

Ancylostoma

Ancylostoma are reddish-grey worms, the colour depending on whether the worm has fed, and are readily recognised on the basis of size. The anterior extremity is usually bent dorsally. The worms have a well-developed buccal capsule, which is devoid of leaf crowns, but is armed with teeth or chitinous cutting plates on its ventral edge.

Ancylostoma species

Species	Hosts	Site
<i>Ancylostoma braziliense</i>	Dog, fox, cat, wild canids	Small intestine
<i>Ancylostoma caninum</i>	Dog, fox, wild canids, occasionally human	Small intestine
<i>Ancylostoma ceylanicum</i>	Dog, cat, wild felids, occasionally human	Small intestine
<i>Ancylostoma tubaeforme</i> (syn. <i>Strongylus tubaeforme</i>)	Cat	Small intestine
<i>Ancylostoma duodenale</i>	Human, primates	Small intestine

Ancylostoma caninum

Description: This is the largest species. Male worms are about 12 mm and females 15–20 mm in length. The anterior end is angled dorsal and the oral aperture is directed anterodorsally. The buccal capsule is large, with three pairs of marginal teeth and a pair of ventrolateral teeth, and possesses a dorsal gutter (Fig. 1.47). A dorsal cone is absent. The male bursa is well developed.



Fig. 1.47 Head of *Ancylostoma caninum* showing the large buccal capsule containing pairs of teeth.

Life cycle: The life cycle is direct and, given optimal conditions, the eggs may hatch and develop to L₃ in as little as 5 days. Infection is by skin penetration or by ingestion, both methods being equally successful. Paratenic hosts can also be important. In percutaneous infection, larvae migrate via the bloodstream to the lungs where they moult to L₄ in the bronchi and trachea, and are then swallowed and pass to the small intestine where the final moult occurs. If infection is by ingestion, the larvae may either penetrate the buccal mucosa and undergo the pulmonary migration or pass directly to the intestine where the adult worms burrow their buccal capsules into the mucosa. Whichever route is taken, the prepatent period is 14–21 days. The worms are prolific egg layers and an infected dog may pass millions of eggs daily for several weeks.

An important feature of *A. caninum* infection is that, in susceptible bitches, a proportion of the L₃ that reach the lungs migrate to the skeletal muscles where they remain dormant until the bitch is pregnant. They are then reactivated and, still as L₃, are passed in the milk of the bitch for a period of about 3 weeks after whelping. Transplacental transmission does not occur.

Ancylostoma braziliense

Description: In the dog, males measure around 7.5 mm and females 9–10 mm in length. The buccal capsule is deep with two pairs of large dorsal and very small ventral teeth.

Life cycle: Similar in many respects to *A. caninum*, with both oral and percutaneous routes of infection, but transmammary transmission has not been demonstrated. Rodents can act as paratenic hosts. The prepatent period is about 2 weeks in the dog and cat.

Ancylostoma ceylanicum

Description: Almost identical to *A. braziliense*. The cuticular striations are wider than in *A. braziliense* and the inner pair of ventral teeth in the buccal capsule are larger.

Life cycle: Similar to *A. braziliense*. The prepatent period is about 2 weeks in the dog.

Ancylostoma tubaeforme

Synonym: *Strongylus tubaeforme*

Description: Almost identical to *A. caninum*, but slightly smaller, the males measuring around 10 mm and the females 12–15 mm. The buccal capsule is deep with the dorsal gutter ending in a deep notch on the dorsal margin of the buccal capsule, the ventral margin of which bears three teeth on each side. The cuticle is thicker and the deep ‘oesophageal’ teeth are slightly larger than in *A. caninum*. The male bursa is well developed and the spicules are about 50% longer than in *A. caninum*.

Life cycle: As for *A. braziliense*. The prepatent period is about 3 weeks.

Ancylostoma duodenale

Description: A small greyish-white worm ranging from around 8–13 mm in size. The buccal capsule is armed with two large teeth and a lower pair of small teeth.

Life cycle: Similar to *A. caninum*. The prepatent period is about 5 weeks in the dog.

Uncinaria

The genus consists of a single species. The worms are small, up to about 1.0 cm long; males are 5–8.5 mm and females 7–12 mm long.

Life cycle: Infection with infective L₃ by oral infection, without pulmonary migration, is the usual route. Although the infective larvae can penetrate the skin, the infection rarely matures and there is no evidence as yet of transmammary or intrauterine transmission. Carnivores may become infected via the consumption of paratenic hosts, such as infected mice. The prepatent period is about 15 days.

Uncinaria species

Species	Hosts	Site
<i>Uncinaria stenocephala</i>	Dog, cat, fox, other wild canids and felids	Small intestine

Uncinaria stenocephala

Description: The adult whitish worms have a large funnel-shaped buccal capsule, which has a pair of chitinous plates, lacks dorsal teeth but has a pair of subventral teeth at the base (Fig. 1.48). The dorsal cone does not project into the buccal capsule. The male worm has a well-developed bursa with a short dorsal lobe and two large lateral lobes, which are separate. The spicules are narrow.

Necator

Male worms are usually 7–9 mm long and females about 9–11 mm in length.

Necator species

Species	Hosts	Site
<i>Necator americanus</i>	Human, primates, dog, cat, pig	Small intestine



Fig. 1.48 Head of *Uncinaria stenocephala* showing the funnel-shaped buccal capsule and the pair of chitinous plates.

Necator americanus

Description: The buccal capsule has two dorsal and two ventral cutting plates around the anterior margin. There is also a pair of subdorsal, and a pair of subventral teeth located close to the rear of the buccal capsule.

Bunostomum

Bunostomum is one of the larger nematodes of the small intestine of ruminants, being 1.0–3.0 cm long, stout, greyish-white and characteristically hooked at the anterior end, with the buccal capsule opening anterodorsally (Fig. 1.49). In the buccal capsule area there are cuticular festoons.

Life cycle: Infection with the L₃ may be percutaneous or oral. After skin penetration, the larvae travel to the lungs and moult to fourth-stage larvae before re-entering the gastrointestinal tract after approximately 11 days. Ingested larvae usually develop without a migration. Further development continues in the gut.

Bunostomum species

Species	Hosts	Site
<i>Bunostomum phlebotomum</i>	Cattle	Small intestine
<i>Bunostomum trigonocephalum</i>	Sheep, goat, deer, camel	Small intestine

Bunostomum phlebotomum

Description: Male worms are 10–18 mm and female worms 24–28 mm in length. This species is very similar to *B. trigonocephalum* in sheep, but the dorsal cone is shorter and there are two pairs of small subventral lancets at its base. In the male, the bursa is well developed and has very long and slender spicules.



Fig. 1.49 Head of *Bunostomum phlebotomum* showing the large buccal capsule and cutting plates.

Life cycle: The prepatent period is about 6 weeks after skin penetration, and 7–10 weeks after ingestion.

Bunostomum trigonocephalum

Synonym: *Monodontus trigonocephalum*

Description: Male worms are 12–17 mm and females 19–26 mm. The large buccal capsule opens anterodorsally and bears on the ventral margin a pair of chitinous cutting plates and internally a large dorsal cone. Dorsal teeth are absent from the buccal capsule but there are a pair of small subventral lancets at its base. In the male the bursa is well developed and the dorsal lobe is asymmetrical. The right externo-dorsal ray emerges higher up on the dorsal stem and is longer than the left. The left externo-dorsal ray arises near the bifurcation of the dorsal ray, which divides into two tri-digitate branches. The spicules are slender, twisted and relatively short. In the female the vulva opens a short distance in front of the middle of the body.

Life cycle: The prepatent period is 4–8 weeks.

Gaigeria

The single species of this genus is a hookworm that occurs mainly in the duodenum of small ruminants.

Life cycle: The life cycle is thought to be direct; the main route of infection is percutaneous. Infective L₃ larvae resemble those of *Bunostomum trigonocephalum* and are susceptible to desiccation.

Gaigeria species

Species	Hosts	Site
<i>Gaigeria pachyscelis</i>	Sheep, goats, wild ruminants	Duodenum and small intestine

Gaigeria pachyscelis

Description: The worms are very similar in shape and size to *Bunostomum trigonocephalum*. Adult male worms measure up to 2 cm and females up to 3 cm long. The buccal capsule contains a large dorsal cone, and a pair of subventral lancets, which have several cusps each. There is no dorsal tooth. The male bursa has a large dorsal lobe and small lateral lobes, which are joined together ventrally. The anterolateral ray is short and rounded and is separated quite widely from the other lateral rays. The externo-dorsal rays arise from the main stem of the dorsal ray. The dorsal ray is split for about one-quarter of its length, and the two short branches terminate in three minute digitations. The spicules are short and stout and terminate with recurved unbarbed ends.

Globocephalus

Several species of this genus parasitise the small intestine of pigs. The worms are stout and whitish, and approximately 4–8 mm in length. The mouth opens subdorsally and the buccal capsule is globular in shape but with an absence of chitinous structures in the buccal capsule. There are no leaf crowns. The male bursa is well developed and possesses a gubernaculum and the spicules are slender.

Life cycle: The life cycle is direct, either by oral ingestion of L₃ larvae or by percutaneous penetration. Larval migration through the heart, lungs, trachea, oesophagus and stomach occurs.

Globocephalus species

Species	Hosts	Site
<i>Globocephalus urosubulatus</i> (syn. <i>Globocephalus longemucronatus</i> , <i>Globocephalus samoensis</i>)	Pig, wild boar	Small intestine

Globocephalus urosubulatus

Synonym: *Globocephalus longemucronatus*, *Globocephalus samoensis*

Description: A very small, stout, whitish worm. Males measure 4–7 mm and females 6–9 mm in length. The mouth opens subdorsally and the buccal capsule is globular. There are two raised cuticular rings near the opening of the mouth. There are small triangular chitinous plates in the buccal capsule. Leaf crowns are absent. The male bursa is well developed and the spicules are slender.

Agriostomum

Worms are stout and greyish-white in colour. Males are around 9–11 mm and females 13–16 mm in length.

Agriostomum species

Species	Hosts	Site
<i>Agriostomum vryburgi</i>	Cattle, buffalo, ox, zebu	Small intestine

Agriostomum vryburgi

Description: The shallow buccal capsule opens anterodorsally and contains four pairs of large teeth on its margin and has a rudimentary

leaf crown. The large wide oesophageal opening at the base of the buccal capsule houses two small subventral lancets. The bursa is well developed and the ventral rays are close together and parallel. A gubernaculum is present and the spicules are equal in length.

SUPERFAMILY DIAPHANOCEPHALOIDEA

FAMILY DIAPHANOCEPHALIDAE

Nematodes of the genus *Kalicephalus* are hookworms of snakes. The life cycle is direct with a prepatent period of 2–4 months.

SUPERFAMILY METASTRONGYLOIDEA

Most worms in this superfamily inhabit the lungs or the blood vessels adjacent to the lungs. The typical life cycle is indirect, and the intermediate host is usually a mollusc.

They may be conveniently divided into four groups according to host: those occurring in **pigs** (*Metastrongylidae*: *Metastrongylus*); in **sheep** and **goats** (*Protostrongylidae*: *Muellerius*, *Protostrongylus*, *Cystocaulus*, *Spiculocaulus*, *Neostrongylus* and *Varestrongylus*); in **deer** (*Elaphostrongylus*, *Parelaphostrongylus*); and in the domestic and wild **carnivores** (*Filaroididae*: *Oslerus*, *Filaroides*, *Aelurostrongylus*; *Angostrongylidae*: *Angiostrongylus*; and *Crenosomidae*: *Crenosoma*).

FAMILY METASTRONGYLIDAE

Metastrongylus

Members of this genus are slender white worms, up to 6.0 cm in length, found in pigs. The site and long slender form are sufficient for generic identification. These worms have two lateral trilobed lips. Individual species are differentiated on the size and shape of the male spicules. The dorsal ray of the bursa is small. The life cycle involves an earthworm intermediate host.

Life cycle: In cold temperatures the eggs are very resistant and can survive for over a year in soil. Normally, however, they hatch almost immediately, the intermediate host ingesting the L₁. In the earthworm, development to L₃ takes about 10 days at optimal temperatures of 22–26°C. The longevity of the L₃ in the earthworm is similar to that of the intermediate host itself and may be up to 7 years. The pig is infected by ingestion of earthworms and the L₃, released by digestion, travel to the mesenteric lymph nodes and moult. The L₄ then reach the lungs by the lymphatic–vascular route, the final moult occurring after arrival in the air passages.

Metastrongylus species

Species	Hosts	Site	Intermediate hosts
<i>Metastrongylus apri</i> (syn. <i>Metastrongylus elongatus</i>)	Pig, wild boar	Lung	Earthworms (<i>Lumbricus</i> , <i>Dendrobaena</i> , <i>Eisena</i> , <i>Helodrilus</i> spp.)
<i>Metastrongylus pudendotectus</i> (syn. <i>Metastrongylus brevivaginus</i>)	Pig, wild boar	Lung	Earthworms (<i>Lumbricus</i> , <i>Dendrobaena</i> , <i>Eisena</i> , <i>Helodrilus</i> spp.)
<i>Metastrongylus salmi</i>	Pig, wild boar	Lung	Earthworms (<i>Lumbricus</i> , <i>Dendrobaena</i> , <i>Eisena</i> , <i>Helodrilus</i> spp.)

Metastrongylus apri

Synonym: *Metastrongylus elongatus*

Description: The slender white adult male worms measure up to 25 mm and the females up to 58 mm in length. There are six small papillae located around the oral opening. The male bursa is relatively small and the dorsal rays are reduced. The spicules are filiform, around 4 mm long, and each terminates in a single hook. The vulva of the female is near the anus and both are covered in cuticular swellings.

Life cycle: The prepatent period is about 24 days.

Metastrongylus pudendotectus

Synonym: *Metastrongylus brevivaginus*

Description: Differs from *M. apri* in having a larger bursa, and smaller spicules (<1.5 mm long) with double hooks in the male. Males are about 16–18 mm and females 20–37 mm in length. The female possesses a straight tail.

Life cycle: The prepatent period is about 4 weeks.

Metastrongylus salmi

Description: Similar to *M. pudendotectus* but with longer spicules, which are approximately 2 mm in length.

FAMILY PROTOSTRONGYLIDAE

Muellerius

These are grey-reddish, slender hair-like worms about 1.0–4.0 cm long, which, although large, are often difficult to discern with the naked eye as they are embedded in lung tissue.

Life cycle: The life cycle is indirect and involves a molluscan intermediate host. The worms are ovoviviparous, the L₁ being passed in the faeces; these penetrate the foot of the molluscan intermediate host, and develop to L₃ in a minimum period of 2–3 weeks. The sheep or goat is infected by ingesting the mollusc. The L₃, freed by digestion, travel to the lungs by the lymphatic–vascular route, the parasitic moults occurring in the mesenteric lymph nodes and lungs. The prepatent period of *Muellerius* is 6–10 weeks. The period of patency is very long, exceeding 2 years.

Muellerius species

Species	Hosts	Site	Intermediate hosts
<i>Muellerius capillaris</i>	Sheep, goat, deer, wild ruminants	Lung	Slugs (<i>Limax</i> , <i>Agrolima</i> spp.) and snails (<i>Helix</i> , <i>Succinea</i> spp.)

Muellerius capillaris

Description: Males are 12–14 mm and females 19–25 mm. The posterior end of the adult male is spirally coiled and the bursa is very small and folded inwards. The curved spicules consist of a proximal alate region and two distal serrated arms, which terminate in points. Two sclerotised rods represent the gubernaculum.

Protostrongylus

Adult worms are slender, hair-like, reddish worms found in the small bronchioles of the lung.

Life cycle: The worms are ovoviviparous, the L₁ being passed in the faeces; these penetrate the foot of the molluscan intermediate host, and develop to L₃ in a minimum period of 2–3 weeks. The final host is infected by ingesting the mollusc. The L₃, freed by digestion, travel to the lungs by the lymphatic–vascular route, the parasitic moults occurring in the mesenteric lymph nodes and lungs. The prepatent period of *Protostrongylus* is 5–6 weeks. The period of patency is very long, exceeding 2 years.

Protostrongylus species

Species	Hosts	Site	Intermediate hosts
<i>Protostrongylus rufescens</i>	Sheep, goat, deer, wild ruminants	Lung	Snails (<i>Helicella</i> , <i>Theba</i> , <i>Abida</i> , <i>Zebrina</i> spp.)
<i>Protostrongylus brevispiculum</i>	Sheep	Lung	Snails
<i>Protostrongylus stilesi</i>	Sheep	Lung	Snails
<i>Protostrongylus skrjabini</i>	Sheep	Lung	Snails
<i>Protostrongylus rushi</i>	Sheep	Lung	Snails
<i>Protostrongylus davtiani</i>	Sheep	Lung	Snails

Protostrongylus rufescens

Description: Male worms are up to 4.5 cm and females up to 6.5 cm in length. In the male, the bursa is well developed but small and reinforced by two chitinous plates. The dorsal ray is thick and globular in shape with six papillae on the ventral side. The tubular spicules are almost straight; the distal ends bear two membranous alae. The gubernaculum has two boot-shaped prolongations bearing several knobs posteriorly. A telamon is also present. In the female, the vulva is close to the conoid tail.

Protostrongylus brevispiculum

Description: The adult worms are small and hair-like. In the male, the dorsal ray is small and rounded and the externo-dorsal rays are elongate. The spicules are much shorter than in *P. rufescens* and the gubernaculum consists of two parts that are smooth and pointed and curve medially and ventrally. The telamon is well developed.

Cystocaulus

Adult worms are slender, thread-like, dark-brown worms found in the small bronchioles of the lung.

Life cycle: Similar to *Muellerius*. The prepatent period is 5–6 weeks.

Cystocaulus species

Species	Hosts	Site	Intermediate hosts
<i>Cystocaulus ocreatus</i>	Sheep, goat, deer, wild ruminants	Lung	Snails (<i>Helix</i> , <i>Helicella</i> , <i>Theba</i> , <i>Cepaea</i> , <i>Monacha</i> spp.)
<i>Cystocaulus nigrescens</i>	Sheep	Lung	Snails

Cystocaulus ocreatus

Description: Male worms are up to 4–5 cm and females up to 9 cm long. In the male, the bursa is small; the spicules consist of a proximal cylindrical region joined distinctly to a distal lance-shaped region. The gubernaculum has a complex structure, with the posterior part consisting of two pointed boot-shaped structures. In the female, the vulva is protected by a bell-shaped expansion of the cuticle.

Spiculocaulus

Spiculocaulus species

Species	Hosts	Site	Intermediate hosts
<i>Spiculocaulus austriacus</i>	Sheep, goat	Lung	Snails

Neostrongylus

Small worms found in the lungs.

Life cycle: Similar to the other metastrongylid lungworms. The prepatent period in sheep is around 8–10 weeks.

Neostrongylus species

Species	Hosts	Site	Intermediate hosts
<i>Neostrongylus linearis</i>	Sheep, goat	Lung	Snails

Neostrongylus linearis

Description: Adult worms are small worms; the males are 5–8 mm and females 13–15 mm long. In the male, the spicules are unequal in size.

Varestrongylus

Thread-like worms found in the lung parenchyma and bronchioles.

Life cycle: Ingested third-stage larvae present within the intermediate host migrate through the intestinal wall to the lymph nodes, migrating via the lymph and blood to the lungs. They then form 'breeding clusters' in which they grow to sexual maturity. Female worms are ovoviviparous with first-stage larvae coughed up and swallowed. When ingested by a molluscan intermediate host the larvae develop to infective L₃ in 3–4 weeks.

Varestrongylus species

Species	Hosts	Site	Intermediate hosts
<i>Varestrongylus schulzi</i> (syn. <i>Bicaulus schulzi</i>)	Sheep, goats	Lung	Snails
<i>Varestrongylus sagittatus</i>	Red deer, fallow deer	Lung	Slugs and snails
<i>Varestrongylus capreoli</i>	Red deer, fallow deer	Lung	Snails

Varestrongylus schulzi

Description: Adult worms are slender small worms; males are 12–15 mm and females 13–15 mm long.

Varestrongylus sagittatus

Description: Worms are slender and measure 14–34 mm in length.

Elaphostrongylus

Elaphostrongylus species

Species	Hosts	Site	Intermediate hosts
<i>Elaphostrongylus cervi</i> (syn. <i>Elaphostrongylus rangiferi</i>)	Deer (red, roe, sika, reindeer)	Connective tissue, CNS	Slugs and snails

Elaphostrongylus cervi

Synonym: *Elaphostrongylus rangiferi*

Description: The mature reddish worms are long and slender. Males are up to 40 mm long and females up to 60 mm long.

Parelaphostrongylus

Parelaphostrongylus species

Species	Hosts	Site	Intermediate hosts
<i>Parelaphostrongylus tenuis</i> (syn. <i>Odocoileostrongylus tenuis</i> , <i>Elaphostrongylus tenuis</i>)	White-tailed deer, moose, wapiti, other deer species, llama, guanaco, alpaca	Cranial meninges, CNS	Slugs and snails

Parelaphostrongylus tenuis

Synonyms: *Odocoileostrongylus tenuis*, *Elaphostrongylus tenuis*

Description: The mature worms are reddish in colour, long and thread-like; males are up to 40 mm long and females 90 mm.

FAMILY FILAROIDIDAE

Oslerus

This genus was part of the larger genus *Filaroides*, but has now been separated on morphological grounds from the other members. Though distinction has been made on morphology, it is also useful from the veterinary standpoint, for it separates the single harmful species, *Oslerus osleri*, living in the upper air passages, from the relatively harmless species which are retained in the genus *Filaroides*, and which live in the lung parenchyma. *Oslerus*, and its closely related genus *Filaroides*, are exceptional in the superfamily Metastrongyloidea in having direct life cycles.

Life cycle: The females are ovoviviparous, and most eggs hatch in the trachea. Many larvae are coughed up and swallowed and passed in the faeces and infection may occur by ingestion of these; more commonly, transmission occurs when an infected bitch licks the pup and transfers the newly hatched L₁, which are present in her sputum. After ingestion, the first moult occurs in the small intestine and the L₂ travel to the lungs by the lymphatic-

vascular route. Development through to L₅ takes place in the alveoli and bronchi, and the adults migrate to their predilection site, the tracheal bifurcation. The prepatent period varies from 10 to 18 weeks.

Oslerus species

Species	Hosts	Site
<i>Oslerus osleri</i> (syn. <i>Filaroides osleri</i>)	Dog, wild canids	Trachea, bronchi
<i>Oslerus rostratus</i> (syn. <i>Anafilaroides rostratus</i> , <i>Filaroides rostratus</i>)	Wild cats, cat	Bronchi

Oslerus osleri

Description: The worms, which are embedded in fibrous nodules in the trachea in the region of the bifurcation and in the adjacent bronchi, are small, pale and slender; males are 5 mm and females 9–15 mm long and slightly thicker. The tail of the male is rounded without obvious bursal lobes and bears a few papillae. The short spicules are slightly unequal. In the female the vulva is located close to the anus.

Oslerus rostratus

Synonym: *Anafilaroides rostratus*, *Filaroides rostratus*

Description: The adult males are about 28–37 mm long and the adult females 48–64 mm long. The vulva in the female is located just anterior to the anus.

Filaroides

The worms are very small (0.5–1.0 cm long), slender, hair-like and greyish, and are not only difficult to see with the naked eye in the lung parenchyma but are also unlikely to be recovered intact from the tissue. These lungworms have a direct life cycle.

Filaroides species

Species	Hosts	Site
<i>Filaroides hirthi</i>	Dog	Lung
<i>Filaroides milksi</i> (syn. <i>Andersonstrongylus milksi</i>)	Dog	Lung
<i>Filaroides bronchialis</i> (syn. <i>Filaroides martis</i>)	Mink, polecat, other Mustelidae	Lung

Filaroides hirthi

Description: The worms are very small (0.5–1.0 cm long), slender, hair-like and greyish, and are not only difficult to see with the naked eye in the lung parenchyma but are unlikely to be recovered intact from the tissue.

Life cycle: The life cycle is direct. The worms are ovoviviparous and the hatched L₁ are passed in faeces or expelled in sputum. Though infection may be acquired by ingestion of faecal larvae, the important route, as in *Oslerus* infection, is thought to be by transfer of L₁

in the bitch's saliva when the pup is licked. The prepatent period of *F. hirthi* is around 5 weeks.

Filaroides milksi

Description: As for *F. hirthi*. *Filaroides milksi* is larger than *F. hirthi*.

Aelurostrongylus

The genus consists of one species, *Aelurostrongylus abstrusus*, which is common in the lungs of the domestic cat.

Life cycle: The life cycle is indirect. The worms are ovoviviparous, and the L₁ are passed in the faeces. These penetrate the foot of the molluscan intermediate host and develop to the infective L₃ and during this phase paratenic hosts, such as birds and rodents, may eat the mollusc. The cat is usually infected by ingestion of these paratenic hosts and less frequently by ingestion of the intermediate hosts. The L₃ released in the alimentary tract travel to the lungs by the lymphatics or bloodstream. After the final moult the adults are located in the alveolar ducts and the terminal bronchioles. The prepatent period is between 4 and 6 weeks, and the duration of patency is about 4 months, though some worms may survive in the lungs for several years despite the absence of larvae in the faeces.

Aelurostrongylus species

Species	Hosts	Site	Intermediate hosts
<i>Aelurostrongylus abstrusus</i>	Cat	Lung	Slugs and snails

Aelurostrongylus abstrusus

Description: Aggregations of worms, eggs and larvae are present throughout the lung tissue. The worms, about 1.0 cm long, are very slender and delicate, and are difficult to recover intact for examination; a squeeze preparation from a cut surface of the lung will show the worm material including the characteristic L₁, which bear a subterminal spine on their S-shaped tail (Fig. 1.50). The male bursa is short and the lobes are indistinct. The spicules are simple in form.

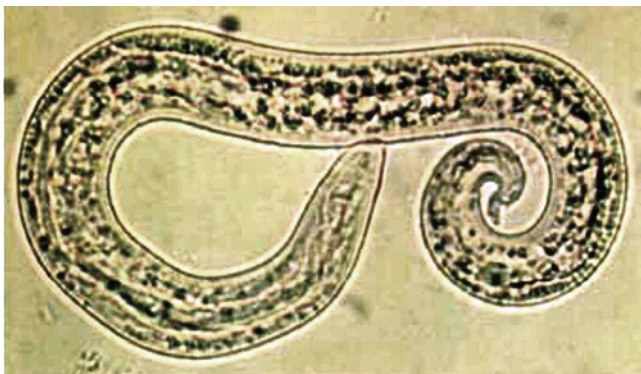


Fig. 1.50 *Aelurostrongylus abstrusus* L₁: S-shaped tail bears a subterminal spine.

FAMILY ANGIOSTRONGYLIDAE

Angiostrongylus

Angiostrongylus species

Species	Hosts	Site	Intermediate hosts
<i>Angiostrongylus vasorum</i>	Dog, fox	Heart, pulmonary vessels	Slugs and snails
<i>Angiostrongylus cantonensis</i>	Rat, human	Pulmonary artery (rat), meninges (human)	Slugs and snails
<i>Angiostrongylus costaricensis</i>	Rat, human	Ileocaecal arteries (rat), intestines (human)	Slugs and snails

Angiostrongylus vasorum

Description: These are small reddish worms. The slender male worms measure 14–18 mm and the stouter females 18–25 mm in length. Males have a small bursa and the female has a 'barber's pole' appearance with the white ovaries coiled round the red intestine, similar to that in *Haemonchus*.

Life cycle: The genus is ovoviviparous. The adult worms in the larger pulmonary vessels lay eggs, which are carried to the capillaries, where they hatch. The L₁ break into the alveoli, migrate to the trachea and thence to the alimentary tract to be passed in the faeces. Further development takes place after entry into the intermediate host, the infective third stage being reached in 17 days. After the mollusc has been ingested by the dog, the infective L₃, freed by digestion, travel to the lymph nodes adjacent to the alimentary tract, where both parasitic moults take place, and then to the vascular predilection site. L₅ have also been found in the liver. The prepatent period is around 7 weeks, and the worms can live in the dog for more than 2 years.

Angiostrongylus cantonensis

Description: The body is filariform and tapered at both ends. Males measure about 18 mm and females 23 mm in length. Fresh female worms have a 'barber's pole' appearance as the white uterine tubules spiral round the blood-filled intestine. The slender spicules are of equal length and are striated. A gubernaculum is present.

Life cycle: Infection is acquired through ingestion of a mollusc containing L₃ larvae. The larvae are released in the digestive tract and migrate via the hepatic portal system and lungs to the central nervous system where they undergo two moults. The young worms eventually migrate via the cerebral vein to the pulmonary arteries. The adult worms mate and lay eggs that pass to the capillaries; these eggs embryonate and hatch and L₁ larvae enter the alveoli and eventually are coughed up, swallowed and pass out in the faeces. These larvae are about 270–300 µm long. The L₁ are ingested by, or penetrate, the intermediate host. The prepatent period is around 6 weeks.

Angiostrongylus costaricensis

Description: The worms are tapered at both ends and are filiform in shape. Males measure about 20 mm and females 30–40 mm in length. The spicules are equal in length, slender and striated. The cephalic ends of the spicules are blunt and the caudal tips are pointed. A gubernaculum is present.

Life cycle: Larvae are shed in the faeces of the rodent and are ingested by a mollusc in which development to the L₃ stage takes place. Following ingestion of the mollusc by rats, or ingestion of vegetation that is contaminated with infective mucous trails, the L₃ migrate via the lymphatics. After two moults the worms migrate to the ileocaecal arteries where they mature, reproduce and lay eggs, which are then carried to the intestinal wall. Eggs embryonate and hatch to L₁ larvae which migrate to the lumen of the intestine and pass out in the faeces. The prepatent period is around 3–4 weeks.

FAMILY CRENOSOMATIDAE

Crenosoma

This genus contains several species that are parasitic in carnivores and insectivores.

Crenosoma species

Species	Hosts	Site	Intermediate hosts
<i>Crenosoma vulpis</i>	Dog, fox, wolf	Trachea, bronchi, bronchioles	Slugs and snails

Crenosoma vulpis

Description: These slender white worms are characterised by having a crenated cuticle that is thrown into folds (18–26 overlapping circular folds) on the anterior end, making this portion of the worm appear superficially segmented. The males are 4–8 mm long and possess a well-developed bursa and a gubernaculum. The posterior third of the spicules possess a dorsal slender spur. The females are 12–16 mm long and have the vulva located near the mid-body. *Crenosoma vulpis* is ovoviviparous.

Life cycle: Adult females deposit thin-shelled eggs containing first-stage larvae (L₁), which ascend the trachea and pass into the intestinal tract and out in the faeces. These larvae penetrate the foot of the intermediate molluscan host and are present as infective third-stage larvae (L₃) in about 3 weeks. After ingestion of the molluscan host by the final host, the L₃ are released by digestion and travel to the lungs, via the lymphatic glands and hepatic circulation, where both parasitic moults take place. The prepatent period is around 3 weeks.

SUPERFAMILY RHABDITOIDEA

This is a primitive group of nematodes which are mostly free-living, or parasitic in lower vertebrates and invertebrates. *Rhabdias* are respiratory parasites in reptiles. Although a few normally free-living genera such as *Halicephalobus* (*Micronema*) and *Rhabditis* occasionally cause problems in animals, the only important genus from the veterinary point of view is *Strongyloides*.

FAMILY STRONGYLOIDIDAE

Strongyloides

Members of this genus are common parasites of the small intestine in very young animals and although generally of little pathogenic

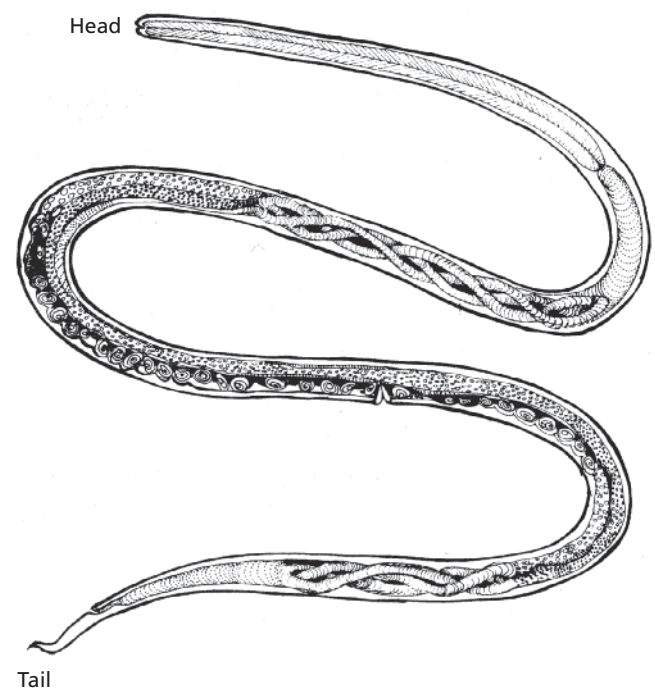


Fig. 1.51 *Strongyloides* spp. adult female.

significance, under certain circumstances may give rise to severe enteritis.

These are slender, hair-like, colourless worms generally less than 10 mm long and only the female worms are parasitic. The long cylindrical oesophagus (typically rhabditiform in shape) may occupy up to one-third of the body length and the filamentous uterus is intertwined with the intestine, giving the appearance of contorted twisted thread (Fig. 1.51). Unlike other intestinal parasites of similar size the tail has a blunt point. Species identification is generally based on identification of the characteristic female worms, or eggs, in the host species.

Life cycle: *Strongyloides* is unique among the nematodes of veterinary importance, being capable of both parasitic and free-living reproductive cycles. The parasitic phase is composed entirely of female worms in the small intestine and these produce larvated eggs by parthenogenesis, i.e. development from an unfertilised egg. In herbivores it is the larvated egg which is passed out in the faeces, but in other animals it is the hatched L₁. After hatching, larvae may develop through four larval stages into free-living adult male and female worms and this can be followed by a succession of free-living generations. However, under certain conditions, possibly related to temperature and moisture, the L₃ can become parasitic, infecting the host by skin penetration or ingestion and migrating via the venous system, the lungs and trachea to develop into adult female worms in the small intestine.

Young animals may acquire infection immediately after birth from the mobilisation of arrested larvae in the tissues of the ventral abdominal wall of the dam, which are subsequently excreted in the milk. In addition, prenatal infection has been demonstrated experimentally in cattle. The prepatent period in most species is 8–14 days.

Strongyloides species

Species	Hosts	Site
<i>Strongyloides papillosus</i>	Sheep, cattle, goat, wild ruminants, rabbit	Small intestine
<i>Strongyloides westeri</i>	Horse, donkey, zebra, rarely pig	Small intestine
<i>Strongyloides ransomi</i>	Pig	Small intestine
<i>Strongyloides avium</i>	Chicken, turkey, goose, wild birds	Small intestine, caecae
<i>Strongyloides stercoralis</i> (syn. <i>Strongyloides canis</i> , <i>Strongyloides intestinalis</i> , <i>Anguillula stercoralis</i>)	Dog, fox, cat, human, Old World monkeys, apes	Small intestine
<i>Strongyloides planiceps</i>	Cat	Small intestine
<i>Strongyloides felis</i> (syn. <i>Strongyloides cati</i>)	Cat	Small intestine
<i>Strongyloides tumefaciens</i>	Cat	Large intestine
<i>Strongyloides ratti</i>	Rat	Small intestine
<i>Strongyloides cebus</i>	New World monkeys	Small intestine
<i>Strongyloides fulleborni</i>	Old World monkeys, apes	Small intestine

Strongyloides papillosus

Description: Adult female worms are 3.5–6 mm long with an oesophagus 0.6–0.8 mm in length.

Strongyloides westeri

Description: Adult female worms are up to 9 mm long with an oesophagus measuring 1.2–1.5 mm in length.

Strongyloides ransomi

Description: Female worms are around 3.5–4.5 mm long.

Life cycle: The prepatent period is 6–9 days.

Strongyloides avium

Description: Adult female worms are approximately 2 mm long with an oesophagus 0.7 mm in length.

Strongyloides stercoralis

Synonym: *Strongyloides canis*, *Strongyloides intestinalis*, *Anguillula stercoralis*

Description: The parasitic female is approximately 2.2 mm long. The oesophagus is about 0.6 mm in length.

Strongyloides planiceps

Description: Parasitic females are 2.4–3.3 mm long (mean 2.8 mm). The tail of the parasitic female narrows abruptly to a blunt tip, and the worms have ovaries with a spiral appearance.

Strongyloides felis

Synonym: *Strongyloides cati*

Description: Similar to *S. planiceps*. Parasitic females of *S. felis* have a long tail narrowing slowly to the tip. Ovaries are straight.

Strongyloides tumefaciens

Description: The parasitic females are 5 mm long and found in tumours of the large intestine.

FAMILY PANAGROLAIMIDAE***Halicephalobus* (syn. *Micronema*)**

Occasional cases of infection of horses with the saprophytic free-living nematode *Halicephalobus deletrix* (syn. *Halicephalobus gingivalis*, *Micronema deletrix*) have been described from various parts of the world. In affected animals the very small worms, less than 0.5 mm in length, have been found in nasal and maxillary granulomas and in the brain and kidney.

FAMILY RHABDITIDAE***Rhabditis***

Several members of this free-living genus of nematodes may become casual parasites, the larvae invading the skin and causing an intense pruritus. The larvae do not migrate but die and so adults are not present in animals. Cases have been most frequently reported in dogs housed in kennels with damp hay or straw bedding and the lesions, usually confined to areas of the body in contact with the ground, show hair loss, erythema and pustule formation if infected with bacteria. The very small worms (1.0–2.8 mm in length) with a rhabditiform oesophagus may be recovered from skin scrapings. Treatment is symptomatic and the condition can be prevented by housing animals on clean dry bedding.

Rhabditis infection has also been associated with otitis externa in cattle in the tropics.

***Rhabditis* species**

Species	Hosts	Site
<i>Rhabditis strongyloides</i> (syn. <i>Pelodera strongyloides</i>)	Dog, cattle, horse	Subcutaneous tissue, skin

FAMILY RHABDIASIDAE

Lungworms of the genus *Rhabdias* are common parasites of amphibians and reptiles, with about 60 species reported worldwide.

Life cycle: Only females are parasitic and these produce larvated, oval, thin-shelled eggs. After hatching, larvae may develop through four larval stages into free-living adult male and female worms and this can be followed by a succession of free-living generations. Infection is usually via the oral route (but percutaneous infection is also possible) and larvae penetrate the oesophageal tissue and then pass via the body cavity and primarily reside near the lower lung as

ungravid adults. These adults then penetrate the lungs and feed on blood, becoming gravid and passing embryonated eggs in the faeces. Usually no intermediate hosts are involved. However, transport hosts such as physid snails, earthworms or frogs can be involved for some *Rhabdias* species.

SUPERFAMILY ASCARIDOIDEA

The ascaridoids are among the largest nematodes and occur in most domestic animals, both larval and adult stages being of veterinary importance. While the adults in the intestine may cause unthriftiness in young animals, and occasional obstruction, an important feature of the group is the pathological consequences of the migratory behaviour of the larval stages.

With a few exceptions the genera have the following characters in common. They are large, white or cream, opaque worms that inhabit the small intestine. There is no buccal capsule, the mouth consisting simply of a small opening surrounded by three large conspicuous lips. A posterior bulb is usually absent from the oesophagus. The males possess two spicules but do not have a bursa. The common mode of infection is by ingestion of the thick-shelled egg containing the L₂. However, the cycle may involve transport and paratenic hosts.

Genera of veterinary interest include *Ascaris*, *Toxocara*, *Toxascaris*, *Parascaris*, *Ascaridia*, *Heterakis*, *Porrocaecum*, *Bayliascaris*, *Paraspidodera* and to a lesser extent the anisakids (Anisakidae: *Anisakis*, *Contracaecum*, *Hysterothylacium*, *Pseudoterranova*). Other ascaridoids occur in reptiles and include *Ophidascaris* and *Polydelphus* found in snakes and *Angusticaecum* and *Sulcascaris* found in chelonia.

FAMILY ASCARIDIDAE

Ascaris

Large, stout, white worms around 15–40 cm in length.

Ascaris species

Species	Hosts	Site
<i>Ascaris suum</i>	Pig	Small intestine
<i>Ascaris lumbricoides</i>	Human (some primates)	Small intestine

Ascaris suum

Description: The rigid females are up to 40.0 cm long and 5 mm in width and the males up to 25 cm in length. The dorsal lip possesses two double papillae, and each ventrolateral lip has one double papilla and a small lateral papilla. These lips have a row of very small denticles on their interior surface. The oesophagus is about 6.5 mm long and simple in shape. The male spicules are stout and the males tend to be slightly curved posteriorly.

Life cycle: The life cycle is direct. Though the preparasitic moults occur by about 3 weeks after the egg is passed, a period of maturation is necessary, and the egg is not usually infective until a minimum of 4 weeks after being passed, even in the optimal temperature range of 22–26°C. The egg is very resistant to temperature extremes, and is viable for more than 4 years. After ingestion, the larvated egg

hatches in the small intestine, the L₃ larva penetrates the intestinal mucosa and then travels to the liver. The larva then passes in the bloodstream to the lungs and thence to the small intestine via the bronchi, trachea and pharynx. In the intestine the final moult occurs and the young adult worms inhabit the lumen of the small intestine. If the eggs are ingested by an earthworm or dung beetle they will hatch, and the L₃ travel to the tissues of these paratenic hosts, where they can remain, fully infective for pigs, for a long period. The prepatent period is between 7 and 9 weeks, and each female worm is capable of producing more than 200,000 eggs per day. Longevity is around 6–9 months.

Ascaris lumbricoides

Description: Male worms are 15–31 cm long and the posterior end is curved ventrally and has a bluntly pointed tail. Female worms are 20–49 cm long with the vulva located in the anterior end, which accounts for about one-third of its body length.

Toxocara

Nematodes in this genus are large white/cream-coloured worms, with females up to 18 cm and males up to 10 cm in length. There are no interlabia or intestinal caeca.

Toxocara species

Species	Hosts	Site
<i>Toxocara canis</i>	Dog, fox	Small intestine
<i>Toxocara mystax</i> (syn. <i>Toxocara cati</i>)	Cat	Small intestine
<i>Toxocara malayiensis</i>	Cat	Small intestine
<i>Toxocara vitulorum</i> (syn. <i>Neosascaris vitulorum</i>)	Buffalo, cattle	Small intestine

Toxocara canis

Description: Adult male worms measure up to 10 cm and females 18 cm in length, although the size can vary considerably (see Fig. 12.3). The adult head is elliptical due to the presence of a pair of large lanceolate cervical alae and the anterior body is curved ventrad. The mouth is surrounded by three large lips. There is no buccal capsule and the oesophagus lacks a posterior bulb. The tail of the male has caudal alae and a narrow terminal appendage. Female genital organs extend both anteriorly and posteriorly to the vulval area.

Life cycle: This species has the most complex life cycle in the superfamily, with four possible modes of infection. The basic form is typically ascaridoid, the egg containing the L₃ being infective, at optimal temperatures, 4 weeks after being passed. After ingestion, and hatching in the small intestine, the larvae travel by the bloodstream via the liver to the lungs, where the second moult occurs. The larvae then return via the trachea to the intestine where the final two moults take place. This form of ascaridoid migration occurs regularly only in dogs of up to about 2–3 months old.

In dogs over 3 months of age, hepatic–tracheal migration occurs less frequently, and at around 4–6 months it has almost ceased and

is replaced by somatic migration, followed by hypobiosis. However, some dogs will support hepatic–tracheal migration as adults. Instead of hepatic–tracheal migration, the L₃ travel to a wide range of tissues including the liver, lungs, brain, heart and skeletal muscle, and the walls of the alimentary tract.

In the pregnant bitch, prenatal infection occurs, larvae becoming mobilised at about 3 weeks prior to parturition and migrating to the lungs of the fetus where they moult just before birth. In the newborn pup the cycle is completed when the larvae travel to the intestine via the trachea, and the final moults occur. A bitch, once infected, will usually harbour sufficient larvae to infect all her subsequent litters, even if she never again encounters the infection. A few of these mobilised larvae, instead of going to the uterus, complete the normal migration in the bitch, and the resulting adult worms produce a transient but marked increase in faecal *Toxocara* egg output in the weeks following parturition.

The suckling pup may also be infected by ingestion of L₃ in the milk during the first 3 weeks of lactation. There is no migration in the pup following infection by this route. Paratenic intermediate hosts such as rodents, sheep, pigs or birds may ingest the infective eggs and the L₃ travel to their tissues where they remain until eaten by a dog, when subsequent development is apparently confined to the gastrointestinal tract.

A final complication is recent evidence that bitches may be reinfected during late pregnancy or lactation, leading directly to transmammary infection of the suckling pups and, once patency is established in the bitch, to contamination of the environment with eggs. The bitch may be reinfected via the ingestion of larval stages from the fresh faeces of puppies through her coprophagic activities.

The known minimum prepatent periods are as follows.

- Direct infection following ingestion of eggs or larvae in a paratenic host: 4–5 weeks.
- Prenatal infection: 2–3 weeks.

Toxocara mystax

Synonym: *Toxocara cati*

Description: Males are 3–6 cm and females 4–10 cm long. The anterior end of the worm is curved ventrad. The striated cervical alae have a broad arrowhead form, with the posterior margins almost at a right angle to the body (Fig. 1.52a). The tail of the male has a terminal narrow appendage.

Life cycle: The life cycle of *T. mystax* is migratory when infection occurs by ingestion of the L₂ in the egg, and non-migratory after transmammary infection with L₃ or after ingestion of a paratenic host.

Following ingestion of eggs containing an infective second-stage larva, the larvae enter the stomach wall and then migrate via the liver, lungs and trachea back to the stomach and moult to L₃, while L₄ occur in the stomach contents, the intestinal wall and bowel contents. Rodent infections also play an important part in the life cycle. In these, larvae remain as second-stage forms but when an infected mouse is eaten by a cat the larvae, liberated by digestion, enter the stomach wall of the cat and develop to L₃. As well as mice acting as ‘intermediate hosts’, L₂ may be found in the tissues of earthworms, cockroaches, chickens, sheep and other animals fed infective eggs.

Transmammary infection is common throughout lactation, particularly in acutely infected cats, and the lactogenic route of

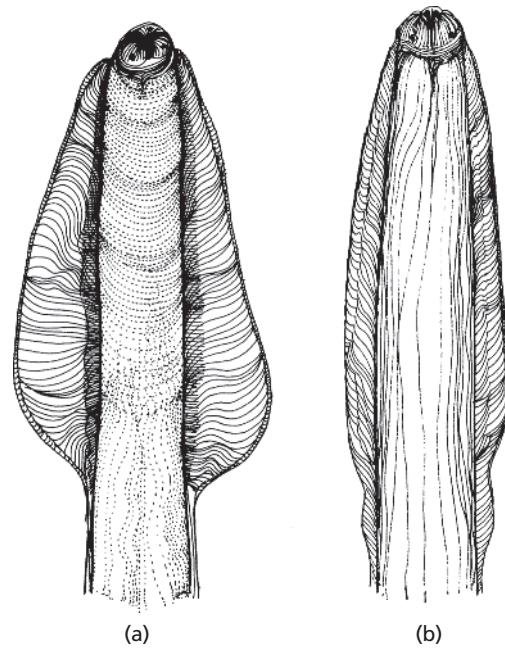


Fig. 1.52 Comparison of the anterior region of (a) *Toxocara mystax* and (b) *Toxascaris leonina*. The cervical alae of *Toxocara mystax* are arrow-shaped whereas those of *Toxascaris leonina* are more slender and less protrusive.

transmission is the most important. Prenatal infection through the placenta does not occur, which is dissimilar to *T. canis*. The prepatent period from egg infection is about 8 weeks.

Toxocara malayiensis

Description: *Toxocara malayiensis* is a large white worm; males are 5.3–8.5 cm, females 1.1–1.4 cm, morphologically similar to *T. canis* in dogs. There are three well-defined lips, each with a deep median notch lined with denticles: a dorsal lip with two large outer papillae, and two subventral lips each with one outer papilla. Cervical alae arise immediately behind the lips, gradually increasing in width to mid-length, then tapering gradually posteriorly.

Life cycle: The life cycle has not been fully described.

Toxocara vitulorum

Description: Adult male worms measure 20–25 cm and females 25–30 cm in length. There are three lips, which are broad at the base and narrow anteriorly. The tail of the male has a small spike-like appendage. There are a variable number of pre-cloacal papillae and five post-cloacal papillae, of which the anterior pair are large and double.

Life cycle: The most important source of infection is the milk of the dam, in which larvae are present for up to 3–4 weeks after parturition. There is no tissue migration in the calf following milk-borne infection and the prepatent period is 3–4 weeks. The ingestion of larvated eggs by calves over 6 months of age seldom results in patency, the larvae migrating to various tissues where they remain dormant; in female animals, resumption of development in late pregnancy allows further transmammary transmission.

Toxascaris

Large worms grossly very similar to *Toxocara canis* with cervical alae present. A posterior bulb is absent from the oesophagus. The tail of the male does not possess a narrow terminal appendage as is the case for *T. canis* and *T. mystax*.

Toxascaris species

Species	Hosts	Site
<i>Toxascaris leonina</i> (syn. <i>Toxascaris limbata</i>)	Dog, cat, fox, wild canids and felids	Small intestine

Toxascaris leonina

Synonym: *Toxascaris limbata*

Description: Males measure up to 7 cm long and females up to 10 cm and their anterior bodies are curved dorsad. The cervical alae are slender and arrow-like, tapering posteriorly (Fig. 1.52b). The tail of the male is simple. The female genital organs are positioned behind the level of the vulva.

Life cycle: The infective stage is the egg containing a second-stage larva or the third-stage larvae present in a mouse intermediate host. The eggs develop rapidly to the infective stage (about 1 week) compared with that for *Toxocara* species (around 4 weeks). Following ingestion and hatching, larvae enter the wall of the small intestine and remain for about 2 weeks. No migration of larvae occurs, as with other ascarid species. Third-stage larvae appear after about 11 days and moult to L₄ about 3–5 weeks post infection. Adult stages appear from about 6 weeks post infection and lie in the lumen of the intestine. The prepatent period is 10–11 weeks.

Parascaris

This very large, rigid, stout, whitish nematode, up to 40 cm in length, is found in the small intestine of equids (Fig. 1.53).

Life cycle: The life cycle is direct and migratory, involving a hepatopulmonary route. Eggs produced by the adult female worms are passed in the faeces and can reach the infective stage containing the L₂ in as little as 10–14 days, although development may be delayed



Fig. 1.53 *Parascaris equorum* adult worms in the small intestine.

at low temperatures. After ingestion and hatching the larvae penetrate the intestinal wall and within 48 hours have reached the liver. By 2 weeks they have arrived in the lungs where they migrate up the bronchi and trachea, are swallowed and return to the small intestine. The site of occurrence and timing of the parasitic larval moults of *P. equorum* are not precisely known, but it would appear that the moult from L₂ to L₃ occurs between the intestinal mucosa and the liver and the two subsequent moults occur in the small intestine. The minimum prepatent period of *P. equorum* is 10 weeks; longevity is up to 2 years. There is no evidence of prenatal infection.

Parascaris species

Species	Hosts	Site
<i>Parascaris equorum</i> (syn. <i>Ascaris equorum</i> , <i>Ascaris megacephala</i>)	Horse, donkey, zebra	Small intestine

Parascaris equorum

Description: Males measure 15–28 cm and females up to 40–50 cm long with a stout head. In heavy infections the worms can be smaller. The three main lips are separated by three smaller intermediate lips (interlabia) and are divided into anterior and posterior sections by horizontal grooves. Small lateral alae are present on the tail of the male. There are three single pairs and two double pairs of post-cloacal papillae. A large number of pre-cloacal papillae are present, with a single median papilla on the anterior border of the cloaca.

Ascaridia

These large worms are stout and densely white, the females measuring up to 12.0 cm in length (Fig. 1.54). The narrow lateral alae are often not apparent grossly.

Life cycle: The egg becomes infective at optimal temperatures in a minimum of 3 weeks and the parasitic phase is non-migratory, consisting of a transient histotrophic phase in the intestinal mucosa after which the adult parasites inhabit the lumen of the intestine. The egg is sometimes ingested by earthworms, which may act as transport hosts. Eggs can remain viable for several months under moist cool conditions but are killed by a dry hot environment. The



Fig. 1.54 *Ascaridia galli* adult worms in the small intestine.

prepatent period ranges from 4 to 6 weeks in chicks to 8 weeks or more in adult birds. The worms live for about 1 year.

Ascaridia species

Species	Hosts	Site
<i>Ascaridia galli</i> (syn. <i>Ascaridia lineata</i> , <i>Ascaridia perspicillum</i>)	Chicken, turkey, goose, duck, guinea fowl and a number of wild galliform birds	Small intestine
<i>Ascaridia dissimilis</i>	Turkey	Small intestine
<i>Ascaridia columbae</i> (syn. <i>Ascaridia maculosa</i>)	Pigeon	Small intestine

Ascaridia galli

Synonyms: *Ascardia lineata*, *Ascaridia perspicillum*

Description: Male worms are 50–75 mm and female worms 70–120 mm long. The anterior end is characterised by a prominent mouth, which is surrounded by three large trilobed lips. The edges of the lips bear teeth-like denticles. A posterior bulb is absent from the oesophagus. The tail of the male possesses small alae and also bears 10 pairs of papillae. Spicules are almost equal in length. In the male there is a circular pre-cloacal sucker, which has a thick cuticular rim.

Ascaridia dissimilis

Description: The worms are stout and densely white. Males measure 35–50 mm and females 50–75 mm in length. The males of this species and those of *A. galli* are separated by differences in the position of the first and fourth pairs of ventral caudal papillae, and by the form of the spicules.

Ascaridia columbae

Synonym: *Ascardia maculosa*

Description: The worms are stout and densely white; males are 16–70 mm and females 20–95 mm in length.

Heterakis

These are small to medium whitish worms up to 1.5 cm long, with elongated pointed tails. Gross examination readily indicates the genus, but for specific identification microscopic examination is necessary to determine the shape of the oesophagus (in *Heterakis* the oesophagus has a large posterior bulb) and the size and shape of spicules. A buccal capsule is absent. Generic identity may be confirmed by the presence of a large, chitinous, circular pre-cloacal sucker in the male and prominent caudal alae supported by 12 pairs of caudal papillae (Fig. 1.55). The pre-cloacal sucker is much less prominent in *Ascaridia*.

Life cycle: The direct life cycle is similar to that of *Ascaridia* spp. The egg is infective on the ground in about 2 weeks at optimal temperatures. Eggs may remain viable in the soil for several months. Earthworms may be transport hosts, the eggs simply passing through the gut, or paratenic hosts in which the egg

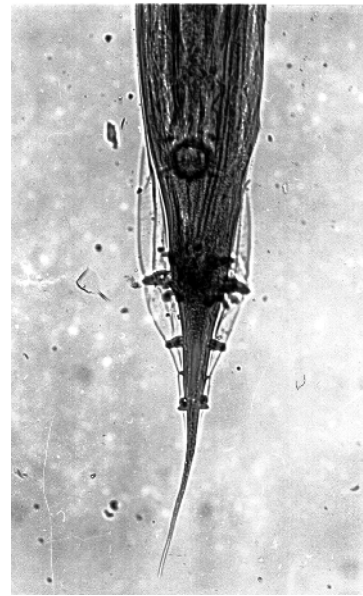


Fig. 1.55 Tail of male *Heterakis gallinarum* showing prominent caudal alae supported by 12 pairs of caudal papillae.

hatches and the L₃ travel to the tissues to await ingestion by the fowl. The prepatent period of the genus is about 4 weeks. Longevity is about 12 months.

Heterakis species

Species	Hosts	Site
<i>Heterakis gallinarum</i> (syn. <i>Heterakis papillosa</i> , <i>Heterakis gallinae</i> , <i>Heterakis vesicularis</i>)	Chicken, turkey, pigeon, pheasant, partridge, grouse, quail, guinea fowl, duck, goose and a number of wild galliform birds	Caeca
<i>Heterakis isolonche</i>	Pheasant, grouse, quail, duck, chicken	Caeca
<i>Heterakis dispar</i>	Duck, goose, chicken	Caeca
<i>Heterakis brevispeculum</i>	Duck, goose, guinea fowl, chicken	Caeca

Heterakis gallinarum

Description: The male is 7–13 mm and the female 10–15 mm long. The body possesses large lateral alae. The spicules are unequal in length, the left (about 0.7 mm long) has broad alae and the right is slender and longer (about 2 mm).

Heterakis isolonche

Description: Male worms measure about 7–13 mm and females 10–15 mm in length. The spicules are long and of equal length.

Heterakis dispar

Description: Worms are larger than the other species, with males measuring 11–18 mm and females 16–23 mm in length. The spicules are short and equal in length (40–50 μm).

Heterakis brevispeculum

Description: The spicules are of equal length (about 0.5 mm) and possess a barb near the tip.

Porrocaecum

Species of this genus are parasites of a range of birds and various fish-eating mammals.

Life cycle: Similar to other ascarid species.

Porrocaecum species

Species	Host	Intermediate host	Site
<i>Porrocaecum crassum</i>	Duck	Earthworms	Small intestine

Porrocaecum crassum

Description: The worms are reddish-white in colour, males measuring 12–30 mm and females 40–55 mm in length. Caudal alae are absent. The tail of the male is conical.

Bayliascaris

Species of the genus *Bayliascaris* are found in a wide range of mammal hosts. *Bayliascaris procyonis*, whose definitive host is the raccoon, is of veterinary importance because it has the ability to infect a wide range of wild and domestic animals and occasionally humans, causing visceral larva migrans.

Life cycle: The definitive hosts for this parasite are mammals such as skunks and raccoons, which when infected pass eggs out in their faeces. These eggs can remain viable in the environment for several years. When ingested by a ratite paratenic host the larvae develop and penetrate into the circulation and eventually enter the brain and spinal cord.

Bayliascaris species

Species	Hosts	Site
<i>Bayliascaris procyonis</i>	Raccoon, skunk Dog, cat, rodents, lagomorphs, gallinaceous birds, ostrich, occasionally humans	Small intestine Other organs (e.g. brain)

Bayliascaris procyonis

Description: Adult worms are whitish in colour, and measure 15–20 cm in length and 1 cm in width.

Other ascarids found in reptiles are briefly mentioned and covered in Chapter 16. Members of the genera *Ophidascaris* and *Polydelphus* are mainly parasites of snakes and lizards, occasionally of amphibians. *Angusticaecum* spp. are ascarids of tortoises.

Reptilian ascarid species

Species	Hosts	Site
<i>Ophidascaris</i> spp.	Snakes, lizards	Intestine
<i>Polydelphus</i> spp.	Snakes	Intestine
<i>Angusticaecum holopteryum</i>	Reptiles (chelonians)	Intestine

FAMILY ANISAKIDAE

Members of the Anisakidae have life cycles involving marine mammals and fish and are of importance mainly in human medicine as some species can cause disease through the ingestion of raw or uncooked fish. Detailed descriptions are not within the scope of this book.

Anisakidae species

Species	Final hosts	Site	Intermediate hosts
<i>Anisakis simplex</i>	Whales, dolphins, seals	Stomach and intestine	Crustaceans, fish
<i>Contracaecum spiculigerum</i>	Duck, goose, swan, waterfowl	Small intestine	Invertebrates (copepods, crustacea, insects, etc.) Damsel flies, fish, tadpoles
<i>Contracaecum</i> spp.	Whales, dolphins, seals	Stomach and intestine	Copepods, fish
<i>Hysterothylacium aduncum</i>	Fish	Intestine	Crustaceans
<i>Pseudoterranova decipiens</i> (syn. <i>Phocanema decipiens</i>)	Seals	Stomach	Crustaceans, fish
<i>Sulcascaris</i> spp.	Reptiles (turtles)	Intestine	Molluscs

SUPERFAMILY DIOCTOPHYMATOIDEA

This group contains three genera: *Dioctophyma*, found in the kidney of carnivores, and *Hystrichis* and *Eustrongyloides*, which occur in aquatic fowl. The alimentary canal is attached to the abdominal wall by four longitudinal muscles and the tail of the male has a terminal cup-shaped bursa which lacks bursal rays. A single spicule is present.

FAMILY DIOCTOPHYMATIDAE

Dioctophyma

Dioctophyma renale ('kidney worm') is the largest parasitic nematode known in domestic animals and is found in the kidneys of carnivores.

Dioctophyma species

Species	Hosts	Site	Intermediate hosts
<i>Dioctophyma renale</i> (syn. <i>Dictophyme renale</i> , <i>Eustrongylus gigas</i>)	Dog, fox, mink, ferret, otter, pine marten, polecat, mink; seal, occasionally in cat, pig, horse, cattle and human	Kidney, abdominal cavity	Aquatic oligochaetes (annelids)

Dioctophyma renale

Synonym: *Dictophyme renale*, *Eustrongylus gigas*

Description: Female worms usually measure more than 60 cm in length, with a diameter of around 1.0 cm but can occasionally be as long as 100 cm. The male is about 35–40 cm long with a bell-shaped bursa which is lined with papillae and a supporting ray is absent

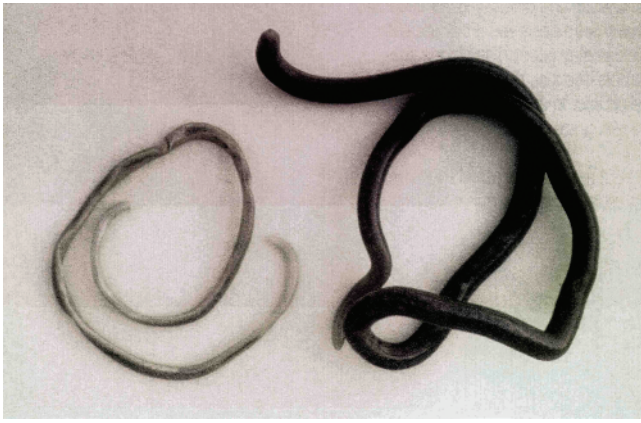


Fig. 1.56 Male and female worms of the kidney worm *Dioctophyma renale*.

(Fig. 1.56). A single brown spicule is present. The worms are deep red–purple in colour. Their size and predilection site are sufficient for identification.

Life cycle: The worms are oviparous. The eggs, in the single-cell stage, are passed in the urine in clumps or chains and are ingested by the annelid intermediate host, in which the two preparasitic moults occur. The development phase in the annelid is about 2–4 months. The final host is infected by swallowing the annelid with the drinking water, or by the ingestion of a paratenic host, such as a frog or fish, which has itself eaten the infected annelid. In the final host, the infective larvae penetrate the intestinal wall, enter the peritoneal cavity and eventually penetrate the kidney. The prepatent period is about 6 months but has been observed to be as long as 2 years.

Hystrichis

Hystrichis species

Species	Hosts	Site	Intermediate hosts
<i>Hystrichis tricolor</i>	Domestic and wild ducks and anatic birds	Proventriculus, oesophagus	Aquatic oligochaetes (annelids)

Hystrichis tricolor

Description: Adult female worms are up to about 4 cm and males 2.5 cm in length. The cephalic area is expanded, and possesses many regularly positioned spines.

Life cycle: This is indirect. Fowl and other birds become parasitised through ingestion of infected oligochaetes. The adult worms are deeply embedded in the mucosa, with their caudal and cephalic regions lying within the lumen of the tract. The prepatent period is around 2 weeks.

Eustrongyloides

Parasites of waterfowl found in the oesophagus and proventriculus.

Life cycle: The life cycles of *Eustrongyloides* species are not fully known but oligochaetes are likely to be involved as intermediate hosts and various fish as paratenic hosts.

Eustrongyloides species

Species	Hosts	Site	Intermediate hosts
<i>Eustrongyloides papillosus</i>	Duck, goose	Proventriculus, oesophagus	Aquatic oligochaetes Fish
<i>Eustrongyloides tubifex</i> (syn. <i>Strongylus tubifex</i> , <i>Eustrongylus tubifex</i> , <i>Hystrichis tubifex</i>)	Waterfowl	Proventriculus, oesophagus	Aquatic oligochaetes Fish

Eustrongyloides papillosus

Description: Females measure about 3 cm in length. The male has a bursal cup with a fringed margin.

Eustrongyloides tubifex

Description: Males measure around 3.0–3.5 cm and females 3.5–4.5 cm in length. This worm has a small mouth and the head lacks spines. The cuticle is annulated. The male bursal cup is shaped like a trumpet and the spicule is slender and long.

SUPERFAMILY OXYUROIDEA

Adult oxyuroids of animals inhabit the large intestine and are commonly called ‘pinworms’ because of the long pointed tail of the female parasite. The ventrolateral papillae are often absent and where present are very much reduced. The number of spicules can vary in the males from zero, one or two depending on the species. They have a double bulb oesophagus, the posterior bulb being well developed. The life cycle is direct. The genera of veterinary interest are *Oxyuris* and *Probstmayria*, both parasitic in the horse; *Skrjabinema*, which are parasites of ruminants; *Syphacia* and *Aspicularis* found in rodents; *Paraspidodera* found in guinea pigs; *Passalurus* and *Dermatoyxys* found in rabbits and hares; and *Tachygonetria* found in reptiles. Oxyurids also include the common human pinworm, *Enterobius*.

FAMILY OXYURIDAE

Oxyuris

The adult female worms, which may reach 10–15 cm in length, are found in the lumen of the caecum and large colon of equids. The much smaller males are difficult to observe in digesta.

Life cycle: The life cycle is direct. The adult worms are found in the lumen of the caecum and the small and large colon. After fertilisation the gravid female migrates to the anus, extrudes her anterior end and lays her eggs in clumps (up to 50,000 eggs per female), seen grossly as yellowish-white gelatinous streaks on the perineal skin or perianal region. Development is rapid, and within 4–5 days the egg contains the infective L₃. Eggs are rubbed off and contaminate the environment. Infection is by ingestion of embryonated eggs on fodder, grass, bedding, etc. The larvae are released in the small intestine, move into the large intestine and migrate into the mucosal crypts of the caecum and colon where development to L₄ takes place within 10 days. The L₄ then emerge and feed on the mucosa before maturing to adult stages that inhabit the lumen and feed

on intestinal contents. The prepatent period of *O. equi* is about 5 months. Longevity of female worms is around 6 months.

Oxyuris species

Species	Hosts	Site
<i>Oxyuris equi</i>	Horse, donkey	Caecum, colon, rectum

Oxyuris equi

Description: The mature females are large greyish-white opaque worms with very long narrow tapering tails (the tail can account for about three times the length of the rest of the body). Mature males are generally less than 12 mm long. There is a double oesophageal bulb in both sexes (see Fig. 1.3 and Fig. 1.57) and the tiny males have a pair of expanded caudal alae, a blunt tail and a single pin-shaped spicule. In the female the vulva is situated anteriorly.

Skrjabinema

Skrjabinema are small non-pathogenic pinworms in the caecum of domestic and wild ruminants.

Life cycle: The life cycle is direct. Embryonated eggs are deposited on the perineal skin by the adult female worms. Infection is by ingestion of the embryonated egg.

Skrjabinema species

Species	Hosts	Site
<i>Skrjabinema ovis</i> (syn. <i>Oxyuris ovis</i>)	Goat, sheep	Caecum, colon
<i>Skrjabinema alata</i>	Sheep	Caecum, colon
<i>Skrjabinema caprae</i>	Goat	Caecum, colon
<i>Skrjabinema parva</i>	Deer (white-tailed)	Caecum, colon



Fig. 1.57 Head of *Oxyuris equi* with double oesophageal bulb.

Skrjabinema ovis

Description: Small worms, up to 7 mm in size; male are around 3 mm and females 6–7 mm in length. There are three large intricate lips and three small intermediate lips. The oesophagus is cylindrical in cross-section and ends in a large spherical bulb. The male worm has a single spicule and the tail is rounded with a cuticular expansion supported by two pairs of processes.

Life cycle: The prepatent period for this species is about 25 days.

Aspicularis

These are small pinworms of rodents. Males are 2–4 mm and females 3–4 mm long.

Life cycle: The life cycle is direct. Females deposit embryonated eggs on the perineal skin. Infection occurs in three ways:

- 1 directly by ingestion of embryonated eggs from the perineum;
- 2 indirectly with food;
- 3 by retro-infection when eggs hatch in the perineal region and migrate back via the anus.

Aspicularis species

Species	Hosts	Site
<i>Aspicularis tetraptera</i>	Mouse, rat	Caecum, colon

Aspicularis tetraptera

Description: The oesophageal bulb is oval, the oesophagus is club-shaped and the mouth has three lips. The cervical alae are broad and their posterior margin ends abruptly. There is no spicule or gubernaculum in the male.

Syphacia

These are small whitish worms, up to 6 mm in size. Males measure 1.0–1.5 mm and females 3.4–6 mm. The mouth has three distinct lips without a buccal capsule. The oesophagus has a pre-bulbular swelling and a posterior globular bulb. Small cervical alae, with rounded posterior margins, are present. The males have a single long slender spicule.

Syphacia species

Species	Hosts	Site
<i>Syphacia obvelata</i>	Mouse, rat	Caecum, colon
<i>Syphacia muris</i>	Mouse, rat	Caecum, colon

Syphacia obvelata

Description: The adult male is 1.1–1.6 mm long and 125 µm wide with the tail length about equal to its body width. Female worms measure 3.4–5.0 mm in length.

Syphacia muris

Description: The adult male is 1.2–1.3 mm long and 100 µm wide and the tail length is about twice its body width. The females

measure 2.8–3.4 mm in length. The vulva of *S. muris* is further posterior, in relation to the esophageal bulb, than that of *S. obvelata*.

Passalurus

Species of *Passalurus* are common pinworms of rabbits and hares.

Life cycle: Development is direct and infection occurs through the ingestion of infective eggs. Immature stages are found in the mucosa of the small intestine and caecum.

Passalurus species

Species	Hosts	Site
<i>Passalurus ambiguus</i>	Rabbit, hare	Caecum, colon
<i>Passalurus nonannulatus</i>	Rabbit, hare	Caecum, colon

Passalurus ambiguus

Description: Adult worms are 4–11 mm in size and semi-transparent; males are 4–5 mm and females 9–11 mm. The oesophagus has the typical oxyurid oesophageal bulb. The distal extremity of the female tail possesses around 40 circular striations. The male spicule is simple in appearance and the tail has an appendix shaped like a whip.

Dermatoxys

Species of *Dermatoxys* are common pinworms of rabbits and hares.

Life cycle: Details of the life cycle are not known. It is probably direct and similar to other pinworms.

Dermatoxys species

Species	Hosts	Site
<i>Dermatoxys veligera</i>	Rabbit, hare	Caecum, colon

Dermatoxys veligera

Description: Female worms are 16–17 mm and males 8–11 mm long. Males have small spicules. Females have a vulva located in the cranial half of their body.

Enterobius

This genus includes the human pinworm, *Enterobius vermicularis*, which is also found in apes.

Life cycle: Gravid female worms in the caecum and colon migrate to the rectum and deposit eggs on the perineum. Eggs become infective within a few days and infection is via the embryonated egg. The prepatent period is about 8 weeks.

Enterobius species

Species	Hosts	Site
<i>Enterobius vermicularis</i>	Human, chimpanzee	Caecum, colon
<i>Enterobius anthropopithecii</i>	Chimpanzee	Caecum, colon

Enterobius vermicularis

Description: Adults are slender cream-coloured worms with long tails. Males measure 2–5 mm and females 8–13 mm in length.

FAMILY COSMOCERCIDAE

Probstmayria

Small, slender, viviparous nematodes that are perpetual parasites, living from generation to generation in the equine large intestine.

Probstmayria species

Species	Hosts	Site
<i>Probstmayria vivipara</i>	Horse	Colon

Probstmayria vivipara

Description: Adult worms are 2–3 mm long with long filamentous tails. The mouth has six small lips and the buccal capsule is cylindrical and long. The oesophagus has an expanded posterior bulb. A large sucker-like excretory pore is present. The tail of the male is curved into a hook shape.

Life cycle: *Probstmayria vivipara* is unusual in that it is a perpetual parasite and lives from generation to generation in the equine caecum and colon. The females are viviparous and give birth to larvae almost as large as the adults. Both adults and larvae may be passed in the faeces.

FAMILY ASPIDODERIDAE

Paraspidodera

Paraspidodera species

Species	Hosts	Site
<i>Paraspidodera uncinata</i>	Guinea pig	Large intestine

Paraspidodera uncinata

Description: Male worms are 16–17 mm and females 18–21 mm in length. Both sexes have a large bulb-shaped oesophagus. Caudal alae are absent. The male spicules are of equal length. The male has a pre-cloacal sucker.

FAMILY PHARYNGODONIDAE

The Pharyngodonidae includes a number of genera that are pinworms of reptiles. The genus *Tachygonetria* is commonly found in Mediterranean tortoises (*Testudo* spp.).

SUPERFAMILY SPIRUROIDEA

The precise classification of a number of genera currently assigned to this superfamily is controversial, but there are some of significance in veterinary medicine: *Spirocerca*, *Habronema*,

Draschia, *Parabronema*, *Thelazia*, *Gnathostoma*, *Gongylonema* and to a lesser extent *Ascarops*, *Physocephalus*, *Simondsia*, *Physaloptera*, *Spirura*, *Odontospirura*, *Tetrameres*, *Histiocephalus*, *Hartertia*, *Oxyspirura*, *Metathalazia* and *Vogeloides*. A major characteristic of this group is the tight spirally-coiled tail of the male. The life cycles are indirect involving arthropod intermediate hosts.

Members of the genus *Thelazia* are principally found in or around the eyes of animals and can be responsible for keratitis. Unlike most spiruroids, the L₁ stage is not ingested from the faeces but by flies feeding on ocular secretions.

The genus *Gongylonema* is unusual among the spiruroids in having a very wide final host range, which includes all the domesticated animals, though it is most prevalent in ruminants. Like most spiruroids the favoured location of the adults is in the upper alimentary tract, in the oesophagus, and in the forestomachs and stomach of mammals and the crop of birds.

Species belonging to the genera *Cheilospirura*, *Echinuria*, *Dispharynx* and *Streptocara* are now considered to be members of the superfamily Acuarioidea.

FAMILY SPIROCERCIDAE

Spirocerca

These are stout, reddish, spirally-coiled worms, 3–8 cm long and are found in tumour-like granulomas in the wall of the oesophagus and stomach.

Life cycle: The thick-shelled elongate egg containing a larva is passed in the faeces or vomit, and does not hatch until ingested by a dung beetle. In this, the intermediate host, the larva develops to the L₃ and encysts. Paratenic hosts may also be involved if the dung beetle, in turn, is ingested by any of a variety of other animals including the domestic chicken, wild birds and lizards. In these the L₃ becomes encysted in the viscera. On ingestion of the intermediate or paratenic host by the final host the L₃ are liberated, penetrate the stomach wall and migrate via the coeliac artery to the thoracic aorta. About 3 months later the majority of larvae cross to the adjacent oesophagus where they provoke the development of granulomas as they develop to the adult stage in a further 3 months. Adults are usually located in cystic nodules which communicate with the lumen of the stomach or oesophagus through fistulae. The prepatent period is therefore about 5–6 months. Eggs, however, may not be found in the faeces of a proportion of animals with adult infections where the granulomas have no openings into the oesophageal lumen.

Spirocerca species

Species	Hosts	Site	Intermediate hosts
<i>Spirocera lupi</i>	Dog, fox, wild canids; occasionally cat and wild felids	Oesophagus, stomach, aorta	Coprophagous beetles

Spirocera lupi

Description: Adult male worms are around 30–55 mm and females 55–80 mm long. The mouth aperture is hexagonal in shape and the pharynx is short and the lips are trilobed. The male tail possesses caudal alae (four pairs and one unpaired), median pre-cloacal papillae and post-cloacal papillae (two pairs). There is a group of minute papillae near the tail tip. The right spicule is only about one-quarter the length of the left spicule. The tail of the female is blunt.

Ascarops

Worms of this genus, and of the genera *Physocephalus* and *Simondsia*, live on the stomach wall of pigs under a layer of mucus.

Life cycle: The life cycle is typically spiruroid. Eggs passed in the faeces of the infected host develop into infective larvae, if ingested by coprophagous beetles. The life cycle is completed when pigs ingest the beetles. The prepatent period is about 4 weeks.

Ascarops species

Species	Hosts	Site	Intermediate hosts
<i>Ascarops strongylina</i> (syn. <i>Arduenna strongylina</i>)	Pig, wild boar	Stomach, occasionally small intestine	Coprophagous beetles
<i>Ascarops dentata</i> (syn. <i>Arduenna dentata</i>)	Pig	Stomach, occasionally small intestine	Coprophagous beetles

Ascarops strongylina

Synonym: *Arduenna strongylina*

Description: Small slender filiform worms, the males measuring up to 15 mm and the reddish females about 22 mm long. A cervical alae is located only on the left side of the body. The wall of the pharynx contains several spiral supports and a small tooth is present on each of the two lips. The right caudal alae in the male are much larger than the left and there are four pairs of asymmetrical pre-cloacal papillae and one pair of caudal papillae. The left spicule is about four to five times longer than the right spicule.

Ascarops dentata

Synonym: *Arduenna dentata*

Description: Similar to *A. strongylina* but much bigger; male worms are 35 mm and female worms are 55 mm long. The buccal capsule has two teeth anteriorly.

Physocephalus

Small slender worms found on the surface of the stomach wall.

Life cycle: The life cycle is typically spiruroid. Eggs passed in the faeces of the infected host develop into infective larvae, if ingested by coprophagous beetles. The prepatent period is about 6 weeks.

Physocephalus species

Species	Hosts	Site	Intermediate hosts
<i>Physocephalus sexalatus</i>	Pig, camel, rarely rabbit, hare	Stomach	Coprophagous beetles

Physocephalus sexalatus

Description: Small slender filiform worms which are reddish when fresh, the males measuring about 10–12 mm and the females up to 22 mm long. The anterior of the body is thinner than the posterior region and just posterior to the vestibule is a cuticular swelling. There are three cervical alae on either side and the cervical papillae

are asymmetrically located. The wall of the pharynx contains a single spiral support. In the male worm the caudal alae are narrow and symmetrical and there are four pairs of pre-cloacal papillae. The left spicule is about six to seven times longer than the right spicule.

Simondsia

Male worms live on the surface of the gastric mucosa, but the females are found in small cysts in the mucosal crypts with their anterior ends protruding.

Life cycle: The life cycle is indirect. Eggs are passed in the faeces and ingested by beetles in which they hatch and develop to infective larvae. The parasites continue development when the intermediate host is ingested by a pig.

Simondsia species

Species	Hosts	Site	Intermediate hosts
<i>Simondsia paradoxa</i> (syn. <i>Spiroptera cesticillus</i>)	Pig, rarely rabbit, hare	Stomach	Coprophagous beetles

Simondsia paradoxa

Synonym: *Spiroptera cesticillus*

Description: The males are small slender worms measuring about 12–15 mm in length and possess a spirally-coiled tail. Female worms measure up to about 15–20 mm in length. They have large lateral alae and a large ventral and dorsal tooth. The gravid female has a characteristic form, the posterior end of the body being a rounded sac filled with eggs and the anterior end is slender.

Streptopharagus

Worms of this genus are found in the stomachs of Old World monkeys and apes.

Streptopharagus species

Species	Hosts	Site	Intermediate hosts
<i>Streptopharagus armatus</i>	Rhesus, cynomolgus monkeys, Japanese macaque, guenon, baboon, gibbon	Stomach	Coprophagous beetles
<i>Streptopharagus pigmenatus</i>	Rhesus, cynomolgus monkeys, Japanese macaque, guenon, baboon, gibbon	Stomach	Coprophagous beetles

FAMILY HABRONEMATIDAE

Habronema

Members of the genus *Habronema* are small, slender, white translucent worms 1.5–2.5 cm long (Fig. 1.58). The male has wide caudal alae and the tail has a spiral twist. Together with the closely related genus *Draschia*, they are parasitic in the stomach of the horse. *Habronema* inhabits the mucus layer of the gastric mucosa and may cause a catarrhal gastritis, but is not considered an important pathogen. The chief importance of these parasites is as a cause of cutaneous habronematidosis or 'summer sores' in warm countries.



Fig. 1.58 Adult *Habronema* worms alongside a bot larva (*Gastrophilus*).

Life cycle: The life cycle is similar for all species. Eggs or L₁ are passed in the faeces and the L₁ are ingested by the larval stages of various muscid flies that are often present in faeces. Development to L₃ occurs synchronously with the development to maturity of the fly intermediate host. When the fly feeds around the mouth, lips, ocular conjunctiva, and nostrils of the horse, the larvae pass from its mouthparts on to the skin and are swallowed. Alternatively, infected flies may be swallowed whole in feed and drinking water. Development to adult takes place in the stomach where the larvae burrow into the glandular area of the mucosa and induce the formation of nodules. The worms develop to mature adults within the nodules in about 8 weeks. When the larvae are deposited on a skin wound or around the eyes they can invade the tissues; they do not complete their development but may cause granulomatous skin lesions.

Habronema species

Species	Hosts	Site	Intermediate hosts
<i>Habronema microstoma</i> (syn. <i>Habronema majus</i>)	Horse	Stomach	Dipteran flies, <i>Musca</i> , <i>Stomoxys</i> , <i>Haematobia</i> (<i>Lyperosia</i>)
<i>Habronema muscae</i>	Horse	Stomach	Dipteran flies, <i>Musca</i> , <i>Stomoxys</i> , <i>Haematobia</i> (<i>Lyperosia</i>)

Habronema microstoma

Synonym: *Habronema majus*

Description: Adult males are 16–22 mm and females 15–25 mm long. The anterior region of the cylindrical pharynx contains a small dorsal and ventral tooth in its anterior region. Four pairs of pre-cloacal papillae are present in the male worm. Spicules are uneven in length, with the left spicule (0.8 mm) being about twice as long as the right (0.4 mm).

Habronema muscae

Description: Adult males are 8–14 mm and females 13–22 mm in length. There are two lateral trilobed lips; the pharynx is cylindrical in cross-section and has a thick cuticular lining. The male possesses wide caudal alae. There are four pairs of pre-cloacal papillae and one or two papillae behind the cloaca. Small cuticular ridges cover the cloacal region. Spicules are uneven in length, with the left

spicule being long and slender (2.5 mm long) and the right spicule much shorter (0.5 mm) and stouter. The vulva is situated near the middle of the body and opens dorsolaterally.

Draschia

These worms are very similar to *Habronema* but smaller with a distinct collar in the anterior region. *Draschia* parasitises the fundic region of the stomach wall and provokes the formation of large fibrous nodules that are occasionally significant. The female worms are ovoviviparous.

Draschia species

Species	Hosts	Site	Intermediate hosts
<i>Draschia megastoma</i> (syn. <i>Habronema megastoma</i>)	Horse, other equids	Stomach	Dipteran flies, <i>Musca</i> , <i>Stomoxys</i> , <i>Haematobia</i> (<i>Lyperosia</i>)

Draschia megastoma

Description: Slender white translucent worms 7–13 mm long; adult males are 7–10 mm and females 10–13 mm. The worms are recognised by their heads, which are slightly constricted from the main body by a deep groove which circles the body just posteriorly to the oral region (Fig. 1.59). The pharynx is funnel-shaped. Male worms have four pairs of pre-cloacal papillae. The spicules are short and uneven in length with the left (0.5 mm) longer than the right (0.25 mm).

Parabronema

Parabronema are found in the abomasum of ruminants. The genus is readily distinguished from the other abomasal worms by the presence of large cuticular shields and cordons in the cephalic region.



Fig. 1.59 Head of *Draschia megastoma*.

Life cycle: Eggs or L₁ are passed in the faeces and the L₁ are ingested by the larval stages of various muscid flies that are often present in faeces. Development to L₃ occurs synchronously with the development to maturity of the fly intermediate host. When the fly feeds around the mouth, lips and nostrils of the host the larvae pass from its mouthparts on to the skin and are swallowed. Alternatively, infected flies may be swallowed whole in feed and drinking water. Development to adult takes place in the glandular area of the abomasum.

Parabronema species

Species	Hosts	Site	Intermediate hosts
<i>Parabronema skrjabini</i>	Sheep, goat, cattle, camel	Abomasum	Muscid flies of the genera <i>Stomoxys</i> , <i>Lyperosia</i> , <i>Haematobia</i>

Parabronema skrjabini

Description: The white slender adult worms are up to 3.6 cm long. Males are 15–18 mm with a spiral tail, four pairs of pre-anal papillae and with one spicule.

Histiocephalus

Histiocephalus species

Species	Hosts	Site	Intermediate hosts
<i>Histiocephalus laticaudatus</i>	Chicken, duck	Gizzard	Unknown

Histiocephalus laticaudatus

Description: Males measure around 7–7.5 mm and females 13–16 mm in length. The mouth is surrounded by four lips and the pseudolips are indented forming 10 finger-like expansions, each with two or three points. Adult worms have ornate leaf-like structures and the presence of a cervical collar. The buccal cavity is cylindrical. Males have two large alae and four pairs of pre-cloacal papillae and two pairs of post-cloacal papillae. Spicules are long and of equal length. A gubernaculum is absent. The vulva in the female is situated anteriorly.

Life cycle: Little is known of the life cycle.

FAMILY THELAZIDAE

Thelazia

Members of this genus are parasites of the conjunctival sac and lacrimal duct and because of their location are also known as 'eye-worms'. Worms have a large vestibule and lips are absent in this genus. Prominent striations are present on the anterior cuticle. Caudal alae are absent in the male worms.

Life cycle: The worms are viviparous. The L₁ passed by the female worm into the lacrimal secretion is ingested by the fly intermediate host as it feeds. Development from L₁ to L₃ occurs in the ovarian follicles of the fly in 15–30 days during the summer months. L₃ migrate to the mouthparts of the fly and are transferred to the final host when the fly feeds. Development in the eye takes place without further migration.

***Thelazia* species**

Species	Hosts	Site	Intermediate hosts
<i>Thelazia rhodesi</i>	Cattle, buffalo, occasionally sheep, goat, camel	Eye, conjunctival sac, lacrimal duct	Muscid flies, particularly <i>Fannia</i> spp.
<i>Thelazia gulosa</i> (syn. <i>Thelazia alfortensis</i>)	Cattle, sheep, wild ruminants	Eye, conjunctival sac, lacrimal duct	Muscid flies (<i>Musca</i> spp.)
<i>Thelazia skrjabini</i>	Cattle, sheep, wild ruminants	Eye, conjunctival sac, lacrimal duct	Muscid flies (<i>Musca</i> spp.)
<i>Thelazia callipaeda</i>	Dog, cat, human, primates, rabbit	Eye, conjunctival sac, lacrimal duct	Muscid flies, fruit flies
<i>Thelazia californiensis</i>	Dog, cat, sheep, deer, human	Eye, conjunctival sac, lacrimal duct	Muscid flies
<i>Thelazia lacrymalis</i>	Horse, cattle	Eye, conjunctival sac, lacrimal duct	Face flies (<i>Musca</i> spp.)
<i>Thelazia leesi</i>	Camel	Conjunctival sac	Muscid flies

Thelazia rhodesi

Description: Small, thin, yellowish-white worms 1.0–2.0 cm long. Males are 8–12 mm and females are 12–20 mm in length. The cuticle has prominent striations at the anterior end. The male worms have about 14 pairs of pre-cloacal and three pairs of post-cloacal papillae.

Life cycle: The prepatent period is 20–25 days.

Thelazia gulosa

Synonym: *Thelazia alfortensis*

Description: *Thelazia gulosa* are milky-white worms, with thin transverse cuticular striations (less evident in rear part of the body), and a large deep cup-shaped buccal cavity. Males are 4.8–10.9 mm long and have a variable number of pre-cloacal papillae (from 8 to 33 pairs) and three pairs of post-cloacal papillae. There are two asymmetric spicules. The females are 4.8–18.8 mm long with a tapered caudal extremity.

Thelazia skrjabini

Description: Adult worms are whitish in colour, with transverse fine cuticular striations. The buccal cavity is small and shallow. Males are 5–11.5 mm long and curved posteriorly, with 16–32 pairs of pre-cloacal and three pairs of post-cloacal papillae. The spicules are unequal in length. The females are 7.5–21 mm long with a truncated caudal extremity.

Thelazia callipaeda

Description: Small thin white worms 1.0–1.7 cm long; males are 7–11.5 mm and females 7–17 mm in length. The cuticle bears fine transverse striations. The male has one single and five pairs of pre-cloacal papillae and two pairs of post-cloacal papillae. The left

spicule is much longer (about 10 times) than the right. In the female the vulva is in the oesophageal region.

Thelazia californiensis

Description: Small thin white worms 1.0–1.5 cm long. A mouth capsule is present and the cuticle has prominent striations at the anterior end. The male has 10 pairs of caudal papillae. The left spicule is long and slender and the right spicule short and stout.

Thelazia lacrymalis

Description: Small thin yellowish-white worms 1.0–2.0 cm long. Males are 8–12 mm and females 14–18 mm. A mouth capsule is present and the cuticle has prominent striations at the anterior end. In the male, the tail is blunt and recurved with caudal alae.

Life cycle: The prepatent period is about 3–6 weeks.

Oxyuris

Eyeworms of birds found on the conjunctiva, under the nictitating membrane, or in the nasal–lacrimal ducts.

Life cycle: The life cycle is indirect. Eggs pass through the lacrimal duct, are swallowed and shed in the faeces. These are ingested by an intermediate host and development to the infective stage occurs. Following consumption of the intermediate host by the definitive host the larvae migrate from the oesophagus and pharynx to the eye via the lacrimal duct.

***Oxyuris* species**

Species	Hosts	Site	Intermediate hosts
<i>Oxyuris mansoni</i> (syn. <i>Oxyuris parvorum</i>)	Chicken, turkey, guinea fowl, peafowl	Eye, conjunctiva, lacrimal ducts	Cockroaches, mayfly (Ephemeroptera)

Oxyuris mansoni

Synonym: *Oxyuris parvorum*

Description: These are slender worms with a smooth cuticle and a globular-shaped pharynx; in the female, the vulva is near the tail. The males measure around 10–15 mm and the females 14–20 mm. The tail is finely pointed in both sexes. The tail of the male is curved ventrally and alae are absent. Spicules are uneven, the right being short and stubby, the left long (about 15 times that of the right spicule) and slender.

FAMILY GNATHOSTOMATIDAE***Gnathostoma***

These are parasites of the stomach of carnivores. The presence of the worms in gastric nodules is sufficient for generic diagnosis.

Gnathostoma species

Species	Hosts	Site	Intermediate hosts
<i>Gnathostoma spinigerum</i>	Cat, dog, human, mink, polecat and several wild carnivores	Stomach	Freshwater crustaceans, copepods
<i>Gnathostoma hispidum</i>	Pig, rarely human	Stomach	Freshwater crustaceans, <i>Cyclops</i> spp.
<i>Gnathostoma doloresi</i>	Pig, wild boar	Stomach	Freshwater crustaceans

Gnathostoma spinigerum

Description: Thick-bodied short worms, reddish at the front, and greyish posteriorly. The males are 1–2.5 cm and the females up to 3–4 cm long. The head is swollen and is covered with transverse rows of 6–11 small hooks, and contains four sub-medial cavities that each communicate with a cervical sac. The anterior section of the body is covered with flat cuticular spines and the ventral caudal region of the male has small spines, and four pairs of large pedunculate papillae. Several smaller sessile papillae are also present. The left spicule is about three times longer than the right spicule.

Life cycle: The adult worms live in tunnels in the gastric nodules, and the eggs pass from there into the lumen and are dropped into the water in the faeces where they hatch after several days. The crustaceans (first intermediate hosts) ingest L₁ and development to L₂ takes place. The crustaceans are themselves ingested by vertebrates (second intermediate hosts), such as fish, frogs and reptiles, and development to L₃ occurs and the larvae become encysted. The L₃ can also encyst in many mammals such as mice, rats and dogs. The final host is infected by ingestion of the vertebrate vector and further development occurs in the stomach wall, where the worms provoke the growth of fibrous lesions.

Gnathostoma hispidum

Description: Thick-bodied worms; the males are 1.5–2.5 cm and the females 2–4.5 cm long. Spiny scales cover the whole body of the worm. The left spicule is about three times longer than the right spicule.

Life cycle: The young worms migrate in the abdominal organs of the host, particularly the liver. Adult worms live in tunnels in the gastric nodules, and the eggs pass from there into the lumen and are dropped into the water in the faeces where they develop to L₂ before hatching after several days. Crustaceans ingest L₂ and development to L₃ takes place within about 10 days. The final host is infected by ingestion of the crustacean intermediate host and further development occurs in the stomach wall, where the deeply embedded worms provoke the growth of fibrous lesions. A second intermediate host is not required with *G. hispidum*.

Gnathostoma doloresi

Description: Adult male worms are 2.6–2.8 cm long and female worms 3–4 cm long. The entire body surface has numerous transverse rows of backwardly directed cuticular spines. Anteriorly the

spines are broad and short, with several unequal teeth, becoming gradually smaller, with single-pointed spines posteriorly. The spicules are unequal, stout, curved, tapering evenly from root to tip.

Life cycle: As for *G. hispidum*.

FAMILY GONGYLONEMATIDAE***Gongylonema***

Thread-like parasitic worms of mammals and birds often referred to as 'gullet worms', with over 30 species described. Both sexes have cervical alae and the males possess caudal alae which are often asymmetrical.

Life cycle: The life cycle is typically spiruroid. Eggs are passed in faeces and when eaten by an intermediate host they hatch and develop to the infective stage within about 4 weeks. Infection of the definitive host is through the ingestion of infected coprophagous beetles or cockroaches. The adult worms live spirally (in a zipper fashion) embedded in the mucosa or submucosa with their anterior and/or posterior ends protruding into the lumen. The prepatent period is about 8 weeks.

***Gongylonema* species**

Species	Hosts	Site	Intermediate hosts
<i>Gongylonema ingluvicola</i>	Chicken, turkey, partridge, pheasant, quail	Crop, oesophagus	Coprophagous beetles, cockroaches
<i>Gongylonema monnigi</i>	Sheep, goat	Rumen	Coprophagous beetles, cockroaches
<i>Gongylonema pulchrum</i> (syn. <i>Gongylonema scutatatum</i>)	Sheep, goat, cattle, pig, zebu, buffalo, horse, donkey, deer, camel, human, primates	Oesophagus, rumen	Coprophagous beetles, cockroaches
<i>Gongylonema verrucosum</i>	Cattle, sheep, goat, deer, zebu	Rumen, reticulum, omasum	Coprophagous beetles, cockroaches
<i>Gongylonema macrogubernaculum</i>	Old and New World Monkeys	Oesophagus, tongue, buccal cavity	Coprophagous beetles, cockroaches

Gongylonema ingluvicola

Description: These are long slender worms. The female worm is about 32–55 mm and the males around 18 mm long. The anterior end of the body has a number of longitudinal rows of round or oval, wart-like cuticular plaques.

Gongylonema monnigi

Description: A long, slender, whitish worm, the males being about 4 cm and the females up to about 11 cm in length. Similar to *G. verrucosum* except the cervical ala is not festooned and the shape of the gubernaculum differs.

Gongylonema pulchrum

Synonym: *Gongylonema scutatatum*

Description: A long, slender, whitish worm, the males being about 5.0 cm and the females up to about 14.0 cm in length. Asymmetrical cervical alae are prominent and the anterior end has longitudinal rows of cuticular plaques. The tail of the male has asymmetrical alae with 10 pairs of papillae. The left spicule is long and slender whereas the right spicule is short and stout. The male has a gubernaculum.

Gongylonema verrucosum

Description: Long slender worms, reddish when fresh. The males are about 3.5 cm and the females 7.0–9.5 cm in length. The adult worms have a festooned cervical ala and cuticular bosses only on the left side of the body. The males' spicules are unequal in length with the left spicule considerably longer than the right.

Gongylonema macrogubernaculum

Description: These are long thin whitish worms, the males measuring about 5 cm and the females around 14 cm in length. The anterior of the worm possesses longitudinal rows of cuticular bosses.

FAMILY PHYSALOPTERIDAE

Physaloptera

The genus *Physaloptera* includes a number of species that are parasites of the stomach of mammals and other vertebrates.

Life cycle: The life cycle is typically spiruroid. Eggs passed in the faeces of the infected host develop into infective larvae if ingested by coprophagous beetles, crickets and other insects. The life cycle is completed when cats ingest the intermediate hosts. Various cold-blooded transport hosts may also be involved in transmission of infection. The prepatent period is around 8–10 weeks.

Physaloptera species

Species	Hosts	Site	Intermediate hosts
<i>Physaloptera praeputialis</i>	Cat and wild felids; rarely dog	Stomach	Beetles, cockroaches, crickets
<i>Physaloptera rara</i>	Cat, dog	Stomach	Beetles, cockroaches, crickets

Physaloptera praeputialis

Description: Adult worms are larger than most spiruroids, being stout and resembling ascarids. Males measure 1.0–4.5 cm and females 2–6 cm in length. The cuticle in both sexes extends posteriorly as a sheath beyond the end of the body. The mouth is surrounded by a cuticular collar and possesses pseudolabia. The lips are simple and triangular in shape and bear a set of three small flattened internal teeth and a single conical external tooth. The posterior of the male bears asymmetrical lateral alae, joined anteriorly across the

ventral surface. The spicules are slightly unequal in length. In the female the vulva is slightly anterior to the mid-body.

Physaloptera rara

Description: Adult male worms are 2.5–3 cm and females 3–6 cm long. This species differs from *P. praeputialis* in that there is no sheath over the posterior portion of the body in both sexes. The female vulva is anterior to the middle of the body.

FAMILY SPIRURIDAE

Nematodes of the family Spiruridae are found in the upper digestive tract of mammals and birds.

Spirura/Odontospirura

Life cycle: The life cycle is typically spiruroid. Eggs develop into infective larvae within an intermediate host. Larvae may be ingested by paratenic hosts, such as rodents and lizards, in which they become encapsulated. The final host becomes infected by ingesting the insects or their transport hosts.

Spirura species

Species	Hosts	Site	Intermediate hosts
<i>Spirura ritypleurites</i>	Cat; rarely dog, fox	Stomach	Beetles, cockroaches
<i>Spirura uncinipenis</i> (syn. <i>Sicarius uncinipenis</i>)	Rhea	Proventriculus	Beetles, cockroaches
<i>Spirura zschokkei</i> (syn. <i>Vaznema zschokkei</i>)	Rhea	Proventriculus	Beetles, cockroaches
<i>Odontospirura cetiopenis</i>	Rhea	Proventriculus, gizzard	Beetles, cockroaches

Spirura ritypleurites

Description: Thick, short, white worms with the posterior region thicker than the anterior of the worm and twisted in a spiral. Male worms measure up to 26 mm and females can be 30 mm in length. The anterior area of the cuticle is inflated on the underside and the transverse striations are prominent.

Spirura uncinipenis

Synonym: *Sicarius uncinipenis*

Description: Males measure 15–20 mm and females 16–26 mm. The spicules are short and unequal in length.

Spirura zschokkei

Synonym: *Vaznema zschokkei*

Description: Males measure 16–17 mm and female worms 17–25 mm in length. The spicules are long and filiform.

Odontospirura cetiopenis

Description: The body is spirally-coiled, with males measuring 15–17 mm and female worms 20–23 mm. Four pairs of cephalic papillae are present at the base of the lips. Males have caudal alae and long spicules of equal length.

FAMILY TETRAMERIDAE

Tetrameres

Parasites of this genus show sexual dimorphism. The male worms are pale white, small, and slender and lie in the lumen of the proventriculus of birds. The females are bright red and almost spherical, and lie embedded in the proventricular glands. Cordons are absent.

Life cycle: Eggs are shed with the faeces and hatch when eaten by an intermediate host. The final host becomes infected following ingestion of the intermediate host and the males and females locate in the glands of the proventriculus. Males inhabit the mucosal surface and upper regions of the glands but after mating the males leave the glands and die. The females are embedded deep in the mucosal glands.

Tetrameres species

Species	Hosts	Site	Intermediate hosts
<i>Tetrameres americana</i> (syn. <i>Tropisurus americana</i>)	Chicken, turkey, duck, goose, grouse, quail, pigeon	Proventriculus	Cockroaches, grasshoppers, beetles
<i>Tetrameres fissispina</i> (syn. <i>Tropisurus fissispina</i>)	Duck, goose, chicken, turkey, pigeon and wild aquatic birds	Proventriculus	Crustaceans (<i>Daphnia</i> and <i>Gammarus</i>), grasshoppers, earthworms
<i>Tetrameres crami</i>	Domestic and wild ducks	Proventriculus	Crustaceans (<i>Gammarus</i> and <i>Hyalella</i>)
<i>Tetrameres confusa</i>	Chicken	Proventriculus	?
<i>Tetrameres mohtedai</i>	Chicken	Proventriculus	?
<i>Tetrameres pattersoni</i>	Quail	Proventriculus	?

Tetrameres americana

Synonym: *Tropisurus americana*

Description: Males are 5–6 mm long and females are subspherical, measuring 3.5–5.0 mm long by 3 mm wide (see Fig. 13.1). Males have spiny cuticles and no cordons; females have four longitudinal deep furrows on the surface.

Tetrameres fissispina

Synonym: *Tropisurus fissispina*

Description: Males are 5–6 mm long and females 2.5–6.0 mm long by 1–3.5 mm in width.

Tetrameres crami

Description: Males are white, slender and about 4 mm long. The red ovoid/spherical females measure around 2 mm by 1.5 mm.

FAMILY HARTERTIIDAE

Hartertia

Hartertia species

Species	Hosts	Site	Intermediate hosts
<i>Hartertia gallinarum</i>	Chicken, bustards	Small intestine	Termites

Hartertia gallinarum

Description: Slender worms and exceptionally long for a spiruroid. The males measure up to around 40 mm and the females up to 110 mm in length. The gross appearance of the worms closely resembles that of *Ascaridia galli* and they have two lateral lips, each divided medially into three lobes. The posterior of the male has lateral alae, ventral cuticular bosses, and four pairs of pre-cloacal and two pairs of post-cloacal papillae. The left spicule has a barbed expansion at its tip and is about four times larger than the blunt-ended right spicule.

Life cycle: Eggs are passed in faeces and, when ingested by a termite, develop to the infective stage in the body cavity. Following ingestion of an infected intermediate host the larvae develop to maturity in the final host in about 3 weeks.

FAMILY PNEUMOSPIRIDAE

Members of this family are lungworms of wild felids and include species within the genera *Metathelazia* and *Vogeloides*.

SUPERFAMILY SUBULUROIDEA

Members of this superfamily are parasites mainly of rodents and are characterised by weakly developed lips with sensilla and a thick-walled stoma that is armed with three teeth. The only genus of veterinary importance is *Subulura*, species of which are parasites of poultry.

FAMILY SUBULIRIDAE

Subulura

Species of this genus, found in birds, are small worms located in the caecae. They are similar to *Heterakis*, although the tail is not as pointed. The males measure around 8–10 mm and the females up to 14–18 mm in length.

Life cycle: Eggs passed in faeces are ingested by the intermediate host where they develop to the infective L₃ stage after about 2 weeks. Following ingestion by the final host the larvae migrate to the lumen of the caeca. The prepatent period is 6–8 weeks.

Subulura species

Species	Hosts	Site	Intermediate hosts
<i>Subulura suctorica</i> (syn. <i>Subulura brumpti</i> , <i>Subulura differens</i> , <i>Allodapa suctorica</i>)	Chicken, turkey, guinea fowl, quail, grouse, pheasant, duck	Caeca	Beetles, cockroaches

Subulura suctoría

Synonyms: *Subulura brumpti*, *Subulura differens*, *Allodapa suctoría*

Description: The buccal capsule is small and possesses three teeth at its base. The oesophagus is dilated posteriorly, followed by a bulb. The tail of the male has large lateral alae and is curved ventrad. Two long thin curved spicules are present. A slit-like pre-cloacal sucker is present, surrounded by radiating muscle fibres. In the female, the vulva is situated just anterior to the middle of the body.

SUPERFAMILY DRACUNCULOIDEA

Members of this superfamily are parasites of the subcutaneous tissues. The two genera of veterinary significance are *Dracunculus* and *Avioserpens*. The life cycle involves development in a species of *Cyclops* before becoming infective to the final host.

FAMILY DRACUNULIDAE

Dracunculus

This genus includes the 'guinea worm', an important parasite affecting humans, and the North American guinea worm found in carnivores. The male worms are very much smaller than the females and the latter are one of the longest of the common nematodes in human and animals.

Life cycle: This is indirect. Adult worms mature in deep connective tissue and then migrate to peripheral subcutaneous tissue about 9 months after initial infection. A cutaneous blister develops around the head end of the worm, and when this makes contact with water the uterus of the worm ruptures and liberates large numbers of L₁ larvae. Release of larvae can continue over several weeks if the lesion is repeatedly immersed in water. These larvae develop to the infective stage in a species of *Cyclops*. Infection of the final host is through ingestion of infected copepods with drinking water or within paratenic hosts.

Dracunculus species

Species	Hosts	Site	Intermediate HOSTS
<i>Dracunculus medinensis</i>	Human; occasionally cattle, horse, dog, cat and other mammals	Subcutaneous connective tissue	Copepod crustaceans (<i>Cyclops</i> spp.)
<i>Dracunculus insignis</i>	Mink, raccoon, otter, wild carnivores; occasionally dog and cat	Subcutaneous connective tissue	Copepod crustaceans (<i>Cyclops</i> spp.) Frogs

Dracunculus medinensis

Description: Males measure about 2–3 cm; females are much larger, being around 100 cm long and 1.5–2.0 mm in width, but they can reach up to 300 cm in length. The anterior of the worms possess a 'helmet'. Females have no vulva.

Life cycle: Infection is caused by drinking water containing copepods, which are infected with larvae of *D. medinensis*. Following ingestion, the copepods die and release the larvae, which penetrate the host stomach and intestinal wall and enter the abdominal cavity. After maturation into adults and copulation, the male worms die and the females migrate in the subcutaneous tissues near the skin surface, where the female worm induces a blister on the skin that ruptures. When this

lesion comes into contact with water, the female worm emerges and releases larvae, which if ingested by a copepod develop into infective larvae after about 2 weeks. The prepatent period is around 12 months.

Dracunculus insignis

Description: Adults are white cylindrical worms 17.6–23.0 cm in length and 3–4 mm at maximum width. The females are much larger than the males and are filled with first-stage larvae. This species can be differentiated from *D. medinensis* by the number of pre-anal papillae and also the length of the gubernaculum.

Life cycle: Similar to *D. medinensis*. Development in the copepod is around 3 weeks. Frogs can also act as paratenic intermediate hosts.

Avioserpens

Avioserpens are parasites of ducks and are found in subcutaneous swellings.

Life cycle: Larvae are released into water and infective stages have been shown to occur in *Cyclops*. Infection of the final host occurs through ingestion of the intermediate host.

Avioserpens species

Species	Hosts	Site	Intermediate hosts
<i>Avioserpens taiwana</i>	Duck	Subcutaneous tissue	Copepods (<i>Cyclops</i>)
<i>Avioserpens mosgovoyi</i>	Duck	Subcutaneous tissue	Copepods (<i>Cyclops</i>)

Avioserpens taiwana

Synonyms: *Filaria taiwana*, *Oshimaia taiwana*, *Avioserpens denticulophasma*, *Petroviprocta vigissi*

Description: The female measures up to about 25 cm in length by 0.8 mm in width. The anterior end is blunt and a chitinous rim, carrying two prominent lateral papillae, surrounds the mouth. Four smaller papillae are found further back on the head. The large uterus contains larvae. The anus, vagina and vulva are atrophied. A conical papilla is sited at the termination of the tail. The male worm is unknown.

SUPERFAMILY ACUARIOIDEA

Members of the Acuarioidea (formerly Spiruroidea) are small to medium-sized nematodes inhabiting the upper alimentary tract of birds. The species are characterised by the presence of peculiar cuticular cephalic structures (cordons) extending posteriorly, and sometimes recur forwards.

FAMILY ACURIDAE

Echinuria

Echinuria species

Species	Hosts	Site	Intermediate hosts
<i>Echinuria uncinata</i> (syn. <i>Acuaria uncinata</i>)	Duck, goose, swan and various aquatic birds	Oesophagus, proventriculus, gizzard	<i>Daphnia</i> and <i>Gammarus</i>

Echinuria uncinata

Synonym: *Acuaria uncinata*

Description: These are small whitish worms with a slender body. Males measure 8–10 mm and females 12–18.5 mm long. The cuticle is ornamented with four wavy cordons that are non-recurrent and they anastomose in pairs and do not extend beyond the oesophagus section. Four rows of longitudinal spines are present on the cuticle. In the male, there are four pairs of pre-cloacal papillae in two groups of two either side, and four pairs of post-cloacal papillae. The left spicule is about three to four times longer than the right spicule.

Life cycle: Eggs are passed in the faeces and ingested by water fleas in which they hatch and develop to infective larvae. The parasites continue development when the intermediate host is ingested by an aquatic bird.

Dispharynx

Dispharynx species

Species	Hosts	Site	Intermediate hosts
<i>Dispharynx nasuta</i> (syn. <i>Dispharynx spiralis</i> , <i>Acuaria spiralis</i> , <i>Acuaria nasuta</i>)	Chicken, turkey, pigeon, guinea fowl, grouse, pheasant and other birds	Oesophagus, proventriculus	Isopods: sowbugs (<i>Porcellio</i>) and pillbugs (<i>Armadillidium</i>)

Dispharynx nasuta

Synonym: *Dispharynx spiralis*, *Acuaria spiralis*, *Acuaria nasuta*

Description: The body is slender and coiled, particularly the posterior of the male. Males measure up to around 8 mm and the females 10–12 mm long. The cuticle is ornamented with four wavy cordons that recurve anteriorly and do not fuse. The male has four pairs of pre-cloacal and five pairs of post-cloacal papillae. The left spicule is slender and the right spicule shorter and oval-shaped.

Life cycle: The intermediate host ingests embryonated eggs and development to the L₃ takes place in the body cavity. When the isopod is consumed by the final host, the worms develop to the final stage in the proventriculus or oesophagus.

Cheilospirura

Cheilospirura species

Species	Hosts	Site	Intermediate hosts
<i>Cheilospirura hamulosa</i> (syn. <i>Acuaria hamulosa</i>)	Chicken, turkey	Gizzard	Grasshoppers (<i>Melanoplus</i>), weevils and beetles

Cheilospirura hamulosa

Synonym: *Acuaria hamulosa*

Description: The worms have four, double-wavy, irregular, cuticular ridged cordons that extend to more than half the length of the body. These cordons do not anastomose or recur anteriorly. Male worms measure up to 15 mm and females 30 mm. The males have four pairs of pre-cloacal and six pairs of post-cloacal papillae, a short flattened spicule on the right and a longer slender spicule on the left side.

Life cycle: Eggs shed in the faeces are ingested by the intermediate host where they develop to the infective stage in about 3 weeks. The final host becomes infected after consuming this intermediate host and the prepatent period is about 3 weeks.

Streptocara

These worms are of minor importance in domestic livestock.

Streptocara species

Species	Hosts	Site	Intermediate hosts
<i>Streptocara crassicauda</i>	Duck, chicken	Gizzard	Crustacea (<i>Gammarus</i>)

Streptocara crassicauda

Description: Males are about 5 mm and females up to 10 mm in length. The cervical alae are well developed and possess small teeth on the posterior margin.

Life cycle: Little is known of the life cycle.

SUPERFAMILY FILARIOIDEA

This superfamily is closely related to the Spiruroidea and, as in the latter, all its genera have indirect life cycles. None of them inhabits the alimentary tract, and they depend on insect vectors for transmission.

Within the superfamily, differences in biological behaviour are seen, the more primitive forms laying eggs, which are available to the vectors in dermal exudates, and the more highly evolved forms laying larvae, termed microfilariae. The latter, which may be enclosed in a flexible sheath-like 'eggshell', are taken up by parasitic insects feeding on blood and tissue fluids. In some species, the microfilariae only appear in the peripheral blood and tissues at regular intervals, some appearing in the daytime and others at night; this behaviour is termed diurnal or nocturnal periodicity.

Genera of interest in veterinary medicine include the Filariidae: *Parafilaria*, *Stephanofilaria*, *Suifilaria*; and the Onchocercidae: *Onchocerca*, *Dirofilaria*, *Acanthocheilonema*, *Pelecitus*, *Chandlerella*, *Setaria*, *Elaeophora*, *Splendidofilaria* and *Paronchocerca*.

FAMILY FILARIIDAE

Parafilaria

Adults of this genus of primitive filarioids live under the skin where they produce inflammatory lesions or nodules.

Parafilaria species

Species	Hosts	Site	Intermediate hosts
<i>Parafilaria bovicola</i>	Cattle, buffalo	Subcutaneous and intermuscular connective tissue	Muscid flies; <i>Musca autumnalis</i> in Europe
<i>Parafilaria multipapillosa</i> (syn. <i>Filaria haemorrhagica</i>)	Horse, donkey, other equids	Subcutaneous and intermuscular connective tissue	Horn flies; <i>Haematobia</i> spp. in Europe

Parafilaria bovicola

Description: Small slender white worms about 3.0–6.0 cm in length. Males are 2–3 cm and females 4–6 cm long. Anteriorly, there

are numerous papillae and circular ridges in the cuticle. The rest of the cuticle is striated transversely. In the female the vulva is situated anteriorly near the simple mouth opening and the tail is blunt with no papillae. The tail of the male is blunt and short. The caudal alae are supported by pre-cloacal and post-cloacal papillae.

Life cycle: Eggs or free L₁ present in exudates from bleeding points in the skin surface are ingested by muscid flies (e.g. *Musca autumnalis* in Europe, *M. lusoria* and *M. xanthomelas* in Africa) in which they develop to L₃ within several weeks to months, depending on air temperature. Transmission occurs when infected flies feed on lacrimal secretions or skin wounds in other cattle and the L₃ deposited then migrate in the subcutaneous tissue and develop to the adult stage under the skin in 5–7 months. Bleeding points develop 7–9 months after infection, which is about the same duration as patency.

Parafilaria multipapillosa

Synonym: *Filaria haemorrhagica*

Description: Slender white worms 3.0–7.0 cm in length. Adult males are 28 mm and females 40–70 mm in length. The anterior end of the worm bears a large number of papilliform thickenings.

Life cycle: Eggs or free L₁ larvae present in exudates from bleeding points in the skin surface are ingested by horn flies (*Haematobia*), in which they develop to L₃ within several weeks to months, depending on air temperature. Transmission occurs when infected flies feed on lacrimal secretions or skin wounds in other horses and the L₃ deposited then migrate in the subcutaneous tissue and develop to the adult stage under the skin in 9–12 months.

Stephanofilaria

Worms of this genus inhabit the dermis and cause chronic dermatitis in cattle, buffalo, rhinoceros and elephants in the tropics and subtropics. The genus is readily recognised because the worms are small, and the oral opening is surrounded by numerous spines.

Life cycle: The fly vectors are attracted to the open lesions in the skin caused by the adult parasites, and ingest the microfilariae in the exudate. Development to L₃ takes about 3 weeks, and the final host is infected when the flies deposit larvae on normal skin.

Stephanofilaria species

Species	Hosts	Site	Intermediate hosts
<i>Stephanofilaria assamensis</i>	Cattle, goat, buffalo	Skin, back	Muscid flies
<i>Stephanofilaria kaeli</i>	Cattle	Skin, head, legs, teats	Muscid flies
<i>Stephanofilaria dedoesi</i>	Cattle	Skin, head, legs, teats	Muscid flies
<i>Stephanofilaria okinawaensis</i>	Cattle	Skin, face and teats	Muscid flies
<i>Stephanofilaria stilesi</i>	Cattle	Skin lower abdomen	Horn flies (<i>Haematobia</i> spp.)
<i>Stephanofilaria zaheeri</i>	Buffalo, cattle	Skin, ears, legs, teats	Muscid flies

Stephanofilaria dedoesi

Description: Small nematodes; males are 2.3–3.2 mm and females 6.1–8.5 mm in length. A protruding cuticular rim, with a

denticulate edge, surrounds the oral aperture. The anterior of the worms has a circular thickening, which possesses a number of small cuticular spines. An anus is absent in female worms. The male spicules are of unequal length.

Stephanofilaria stilesi

Description: Small nematodes; males are 2.6–3.7 mm and females 3.7–6.9 mm in length. There are four to five cephalic spines and 18–19 peribuccal spines. The male spicules are unequal and the female worms have no anus.

Stephanofilaria okinawaensis

Description: The parasites are small, rounded, whitish and slender bodied. Females are 7.0–8.5 mm and males 2.7–3.5 mm in length.

Suifilaria

These worms can be associated with dermal abscesses but are generally of little veterinary significance.

Life cycle: Not known. The females appear to lay their eggs in the skin of the pig.

Suifilaria species

Species	Hosts	Site	Intermediate hosts
<i>Suifilaria suis</i>	Pig	Subcutaneous connective tissue	Not known

Suifilaria suis

Description: These are slender worms. Male are 17–25 mm and females 34–40 mm in length. The posterior of the male is coiled in a spiral and the spicules are uneven, the left being about six to eight times as long as the right spicule. The male only has one caudal ala and this is on the left. The female tail bears a number of small tubercles.

FAMILY ONCHOCERCIDAE

Dirofilaria

Of the two species occurring in domestic carnivores, *Dirofilaria immitis* is by far the more important. The adults, found in the right side of the heart and adjacent blood vessels of dogs, are responsible for canine heartworm disease.

Dirofilaria species

Species	Hosts	Site	Intermediate hosts
<i>Dirofilaria immitis</i> (syn. <i>Nochtiella immitis</i>)	Dog, fox, wild canids; occasionally cat and rarely human, primates	Cardiovascular system: right ventricle, right atrium, pulmonary artery and posterior vena cava	Mosquitoes of the genera <i>Aedes</i> , <i>Anopheles</i> and <i>Culex</i>
<i>Dirofilaria repens</i> (syn. <i>Nochtiella repens</i>)	Dog, cat, fox, bear, occasionally human, primates	Subcutaneous, intermuscular tissues	Mosquitoes of the genera <i>Aedes</i> , <i>Anopheles</i> and <i>Culex</i>

Dirofilaria immitis

Synonym: *Nochtiella immitis*

Description: Long slender white/grey worms measuring 15–30 cm in length with a tough cuticle. Adult females measure 25–30 cm, with the males about half as long. Many worms are usually found together in a tangled mass (Fig. 1.60). The size and site are diagnostic for *D. immitis*. The male tail has the typical loose spiral, and the tail bears small lateral alae. There are four to six pairs of ovoid papillae. The left spicule is long and pointed; the right spicule is smaller (about half as long) and ends bluntly. In the female the vulva is situated just to the rear of the end of the oesophagus.

Life cycle: The adults live in the heart and adjacent blood vessels and the females release microfilariae directly into the bloodstream. These microfilariae can live for several months in the visceral blood vessels. Microfilariae are ingested by female mosquitoes during feeding. Development to infective L₃ in the malpighian tubules of the mosquito takes about 2 weeks. The infective L₃ then migrate to the mouthparts and the final host is infected when the mosquito takes a further blood meal. In the dog the L₃ migrate to the subcutaneous or subserosal tissues in the thorax or abdomen and undergo two moults over the next few months; only after the final moult do the young *D. immitis* pass to the heart via the venous circulation. The minimum prepatent period is about 6 months. The adult worms survive for several years and patency has been recorded for over 5 years.

Dirofilaria repens

Synonym: *Nochtiella repens*

Description: The adults are long slender worms measuring from around 5 cm up to 17 cm in length. Males are 5–7 cm and females 13–17 cm.

Life cycle: The adults live in subcutaneous nodules and the females release microfilariae, which migrate to the blood and are ingested by female mosquitoes during feeding. Development to L₃ takes place in the mosquito and the final host is infected when the mosquito

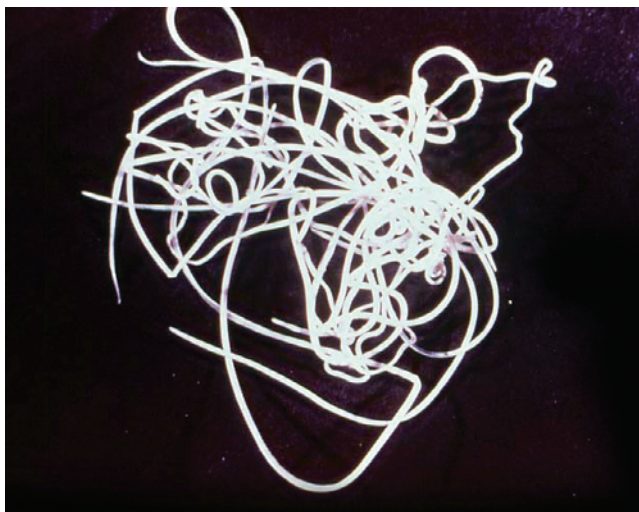


Fig. 1.60 Adult *Dirofilaria immitis* heartworms.

takes a further blood meal. In the dog the L₃ migrate to the subcutaneous or subserosal tissues and undergo two moults over the next few months. The prepatent period is 27–34 weeks.

Acanthocheilonema

Several species of *Acanthocheilonema* (formerly *Dipetalonema*), transmitted mainly by ticks and fleas, occur in the subcutis of dogs in tropical and subtropical zones.

Acanthocheilonema species

Species	Hosts	Site	Intermediate hosts
<i>Acanthocheilonema reconditum</i> (syn. <i>Dipetalonema reconditum</i>)	Dog and various canids	Subcutaneous tissues, kidney and body cavity	Fleas, ticks, lice, mosquitoes
<i>Acanthocheilonema dracunculoides</i> (syn. <i>Dipetalonema dracunculoides</i>)	Dog, hyena	Peritoneum	Ticks, louse fly and fleas
<i>Acanthocheilonema grassi</i> (syn. <i>Dipetalonema grassi</i> , <i>Cercopithifilaria grassi</i>)	Dog	Subcutaneous and intramuscular tissue	Ticks and fleas

Acanthocheilonema reconditum

Synonym: *Dipetalonema reconditum*

Description: The slender male worms measure on average 1.5 cm and females about 2.5 cm. The male spicules are unequal.

Life cycle: Following ingestion of a blood meal the microfilariae develop to the infective third stage in about 7–14 days and then migrate to the head. Larvae pass to the host when the intermediate host next feeds. The prepatent period in the dog is 8–10 weeks. *Acanthocheilonema reconditum* shows a diurnal periodicity.

Acanthocheilonema dracunculoides

Synonym: *Dipetalonema dracunculoides*

Description: The adult worms are small; male worms are 2.4–3 cm, females 3.2–6 cm in length. Males have broad unequal spicules.

Acanthocheilonema grassi

Synonym: *Dipetalonema grassi*, *Cercopithifilaria grassi*

Description: The adult worms are small, the females measuring about 2.5 cm in length.

Life cycle: The life cycle has not been described in detail. Following ingestion of a blood meal, the microfilariae develop to infective larvae in the intermediate hosts, which are ticks and fleas. Larvae pass to the host when the intermediate host next feeds.

Dipetalonema

Several species of *Dipetalonema*, transmitted mainly by mosquitoes, occur in the subcutis, peritoneum, pleura or blood vessels of mammals in tropical and subtropical zones.

Dipetalonema species

Species	Hosts	Site	Intermediate hosts
<i>Dipetalonema evansi</i> (syn. <i>Deraiphoronema evansi</i>)	Camel	Heart, arteries and veins, pulmonary arteries, spermatic arteries, lymph nodes	Mosquitoes of the genus <i>Aedes</i>

Dipetalonema evansi

Synonym: *Deraiphoronema evansi*

Description: These are fairly large filarial worms; adult male worms are 8–11 cm, adult females 14.5–18.5 cm.

Onchocerca

Though onchocercosis is an important filarial infection in human medicine (*Onchocerca volvulus* causing river blindness), most species in domestic animals are relatively harmless.

Life cycle: The life cycle of *Onchocerca* is typically filarioid, with the exception that the microfilariae occur in the tissue spaces of the skin rather than in the peripheral bloodstream. Microfilariae migrate in subdermal connective tissue in the skin of the back, sometimes ears and neck, where biting flies, feeding in this area, ingest microfilariae, which then develop to the infective stage in around 3 weeks. When these infected insects feed on another animal, host transmission of L₃ occurs.

***Onchocerca* species**

Species	Hosts	Site	Intermediate hosts
<i>Onchocerca gutturosa</i> (syn. <i>Onchocerca lienalis</i>)	Cattle, camel	Connective tissue, ligamentum nuchae, gastrosplenic ligament	Blackflies (<i>Simulium</i>)
<i>Onchocerca gibsoni</i>	Cattle	Connective tissue	Midges (<i>Culicoides</i>)
<i>Onchocerca ochengi</i> (syn. <i>Onchocerca dermati</i>)	Cattle	Connective tissue, scrotum and udder	Unknown
<i>Onchocerca armillata</i>	Cattle, buffalo, sheep, goat, occasionally camel	Thoracic aorta	Midges (<i>Culicoides</i>), blackflies (<i>Simulium</i>)
<i>Onchocerca dukei</i>	Cattle	Abdomen, thorax, thighs	Unknown but probably blackflies
<i>Onchocerca cebei</i> (syn. <i>Onchocerca sweetae</i>)	Buffalo	Abdomen, thorax, thighs	Midges (<i>Culicoides</i>)
<i>Onchocerca cervicalis</i>	Horse	Cervical ligament	Midges (<i>Culicoides</i>)
<i>Onchocerca fasciata</i>	Camel	Connective tissue, ligamentum nuchae	Unknown
<i>Onchocerca tarsicola</i>	Deer	Legs	Blackflies (<i>Simulium</i>)
<i>Onchocerca reticulata</i>	Horse, donkey	Connective tissue, flexor tendons	Midges (<i>Culicoides</i>)
<i>Onchocerca volvulus</i>	Human	Dermis, eye	Blackflies (<i>Simulium</i>)

Onchocerca gutturosa

Synonym: *Onchocerca lienalis*

Description: Slender whitish worms; males range from 2 to 6 cm, while females are up to 60 cm in length or longer and are coiled in fibrous tissues. The cuticle possesses spiral thickenings to aid attachment.

Onchocerca gibsoni

Description: The slender worms range from 2 cm to over 20 cm in length and lie tightly coiled in tissue nodules. Males are 3–5 cm and females 14–20 cm although there have been reports of worms up to 50 cm in length. The tail of the male is ventrally curved and bears lateral alae and six to nine papillae at either side. The spicules are unequal in size.

Onchocerca armillata

Description: Slender whitish worms. Male worms are about 7 cm and female worms up to 70 cm long.

Onchocerca cervicalis

Description: The male is 6–7 cm in length and the female up to 30 cm long.

Onchocerca reticulata

Description: Slender whitish worms; males are 15–20 cm and females over 50 cm long.

Life cycle: The prepatent period is around 12–16 months.

Pelecitus

The members of this genus are filarioid worms of birds and mammals.

***Pelecitus* species**

Species	Hosts	Site	Intermediate hosts
<i>Pelecitus clavus</i> (syn. <i>Eulimdana clava</i>)	Pigeon, wild birds	Subcutaneous, connective tissue	Unknown
<i>Pelecitus mazzanti</i>	Pigeon	Subcutaneous, connective tissue	Unknown
<i>Pelecitus scapiceps</i> (syn. <i>Dirofilaria scapiceps</i> , <i>Loaina scapiceps</i>)	Rabbit, hare	Synovial sheaths of the feet	Species of mosquitoes

Pelecitus clavus

Synonym: *Eulimdana clava*

Description: Small to medium-sized worms which have helical turns. Male worms are 6–7 mm and female worms 17–20 mm long. The male spicules are unequal in length, the left being larger than the right.

Life cycle: Microfilariae are present in the blood or subcutaneous space of infected birds and are ingested by biting ectoparasite vectors when they feed.

Pelecitus scapiceps

Synonyms: *Dirofilaria scapiceps*, *Loaina scapiceps*

Description: Male worms are 11–16 mm in length with spicules of unequal length. Female worms are 25–30 mm long.

Life cycle: Microfilariae circulate in the blood of infected lagomorph hosts (there is no circadian periodicity). Microfilariae ingested by a mosquito develop into infective third-stage larvae and these are then injected into the definitive host during feeding. These larvae migrate in the subcutaneous tissue to a maturation site, such as the main body, and develop to the early fifth stage before migrating to the hocks where they develop into mature adult worms. The prepatent period can vary around 130–220 days.

Chandlerella

Members of this genus are filarioid worms of birds.

Chandlerella species

Species	Hosts	Site	Intermediate hosts
<i>Chandlerella quisquali</i>	Emus, wild birds	Brain	Midges (<i>Culicoides</i> spp.)

Chandlerella quisquali

Description: Slender worms, with males 8–15 mm and female worms 17–24 mm in length. In the male, the spicules are thick and equal in length and there are three to four pairs of post-anal papillae.

Setaria

The members of this genus are usually harmless inhabitants of the peritoneal and pleural cavities. The worms are slender whitish worms, up to 12 cm long, and the posterior end is spirally coiled. The mouth is surrounded by a cuticular ring with dorsal, ventral and frequently lateral prominences, which give the worms a characteristic appearance. The tail of the male has four pairs of pre-cloacal and usually four pairs of post-cloacal papillae. The spicules are dissimilar and unequal in length. The tail of female worms usually has spines of several large conical projections. The site and gross appearance are sufficient for generic identification (Fig. 1.61).

Setaria species

Species	Hosts	Site	Intermediate hosts
<i>Setaria congolensis</i> (syn. <i>Setaria bernardi</i>)	Pig	Peritoneum, pleural cavity	Mosquitoes
<i>Setaria equina</i>	Horse, donkey, other equids	Peritoneum, pleural cavity	Mosquitoes
<i>Setaria labiato-papillosa</i> (syn. <i>Setaria digitata</i> , <i>Setaria altaica</i> , <i>Setaria cervi</i>)	Cattle, buffalo, bison, yak, deer, antelope, rarely sheep	Peritoneum, pleural cavity	Mosquitoes
<i>Setaria digitatus</i>	Cattle, buffalo	Peritoneum, pleural cavity	Mosquitoes

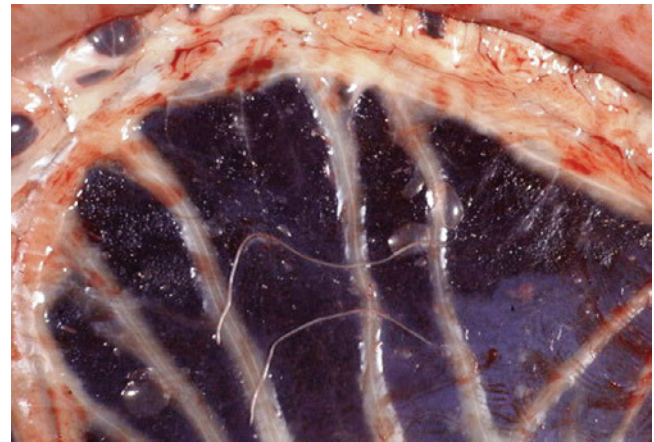


Fig. 1.61 *Setaria labiato-papillosa* in bovine mesentery.

Setaria congolensis

Synonym: *Setaria bernardi*

Description: Male worms are 8 cm and female worms 11–14 cm in length. The male worm has three pairs of small pre-cloacal papillae and four pairs of large post-cloacal papillae. The right spicule is spiny, and the left spicule is comparatively long with a flagellated end.

Setaria equina

Description: The adults are long and slender with cephalic papillae. Males measure 8–10 cm and females 13–15 cm in length. Worms have an elevated chitinous peribuccal ring. The spiral tail of the female terminates in a point. Male spicules are unequal, the left being about three times longer than the right.

Life cycle: Larvae produced by adult worms in the body cavity circulate in the blood and are taken up by culicine mosquitoes, including *Aedes* and *Culex* species. Infective larvae develop in the mosquito muscles in 2 weeks, and are reinjected into horses when the mosquitoes feed. The prepatent period is 8–10 months.

Setaria labiato-papillosa

Synonyms: *Setaria digitata*, *Setaria altaica*, *Setaria cervi*

Description: Males are 40–60 mm and females 60–120 mm in length. The dorsal and ventral prominences and the peribuccal ring are clearly perceptible. The tail of the female ends in a marked button, which is divided into a number of papillae. The male spicules are of unequal length, the left being around 2.5 times longer than the right.

Life cycle: Larvae produced by adult worms in the body cavity circulate in the blood and are taken up by culicine mosquitoes, including *Aedes* and *Culex* species. Infective larvae develop in the mosquito muscles in 12–16 days, and are reinjected into the final host when the mosquitoes feed. The prepatent period is 8–10 months.

Elaeophora

These long slender worms inhabit large blood vessels, but are generally of local importance causing filarial dermatosis caused by circulating microfilariae.

Elaeophora species

Species	Hosts	Site	Intermediate hosts
<i>Elaeophora poeli</i>	Cattle, buffalo, zebu	Aorta	Unknown
<i>Elaeophora schneideri</i>	Deer, sheep, goat	Blood vessels	Tabanid flies
<i>Elaeophora bohmi</i>	Horse	Blood vessels	Unknown

Elaeophora poeli

Description: Slender worms, males measuring around 4–7 cm and females up to 30 cm in length. The oesophagus is very long and lips are absent. The tail of the male possesses five to seven pairs of papillae, of which two pairs are pre-cloacal. Spicules are short and robust.

Life cycle: The life cycle is indirect. The microfilariae are ingested by the intermediate host and the L₃, when developed, are released into the wound made when the insect next feeds. The male occurs in nodules in the wall of the aorta, while the female is fixed in nodules by its anterior extremity with the rest of the body free in the lumen of the aorta. Microfilariae occur in the blood and in subcutaneous connective tissue.

Elaeophora schneideri

Description: Slender worms; males are around 5–8 cm and females up to 12 cm long with a very long oesophagus. The tail of the male is coiled and the spicules are long, slender and unequal.

Life cycle: Similar to *E. poeli*. Early development in the host appears to be in the meningeal arteries, then the worms migrate to the carotid arteries and are mature and producing microfilariae about 4.5 months after infection. The adult worms are embedded in the arterial intima of the carotid, mesenteric and iliac arteries; occasionally they are found in the digital and tibial arteries with only the anterior part of the female free in the lumen. The prepatent period is around 4–5 months.

Elaeophora bohmi

Description: These are slender worms, the males measuring 4.5–6 cm and females 4–20 cm in length.

Life cycle: The microfilariae are ingested by the intermediate host (tabanid flies) when blood feeding and the L₃, when developed, are released into the wound made when the insect next feeds. Microfilariae occur in the blood and in subcutaneous connective tissue.

Splendidofilaria

Parasites of birds, characterised by a relatively long tail and sub-equal spicules.

Splendidofilaria species

Species	Hosts	Site	Intermediate hosts
<i>Splendidofilaria fallisensis</i> (syn. <i>Ornithofilaria fallisensis</i>)	Duck	Subcutaneous tissue	Blackflies (<i>Simulium</i>)

Splendidofilaria fallisensis

Synonym: *Ornithofilaria fallisensis*

Description: These are delicate transparent nematodes, with male worms measuring 9–15 mm and female worms 24–40 mm in length.

Paronchocerca

This genus of filarial heartworms is of little veterinary importance. *Paronchocerca struthionis* has been reported in ostriches; *Paronchocerca ciconarum* has been reported to cause myocardial degeneration in storks.

Paronchocerca species

Species	Hosts	Site	Intermediate hosts
<i>Paronchocerca struthionis</i>	Ostrich, rhea	Pulmonary arteries, lungs	Unknown
<i>Paronchocerca ciconarum</i>	Stork	Heart, pulmonary vessels	Unknown

Paronchocerca struthionis

Description: Long abursate nematodes, 3–5 cm in length with bluntly rounded extremities. Male spicules are dissimilar in length; a gubernaculum is absent.

Filariosis in humans

Filarioid worms are probably the most important group of helminth infections in humans, but are of only marginal concern to the veterinarian, since domestic animals are of little significance in their epidemiology. Of greatest importance in human medicine are the genera *Onchocerca*, *Brugia*, *Loa*, *Wuchereria* and *Mansonella*.

1 *Onchocerca volvulus*. Human onchocercosis, due to *O. volvulus*, occurs around the world in the equatorial zone, and is transmitted by *Simulium* spp. (blackflies). The adult worms live in subcutaneous nodules, and almost the entire pathogenic effect is caused by the microfilariae; dermatitis and elephantiasis are common, but the most important effect is ocular onchocercosis ('river blindness'), so-called because of its distribution along the habitats of *Simulium* spp. Dying microfilariae cause a sclerosing keratitis in the cornea that leads to corneal opacification and retinochoroiditis. It has been estimated that in Africa there are about 20 million people affected by onchocercosis. The only other animals to which it is transmissible are the higher primates, chimpanzee and gorilla. Ivermectin is effective in reducing skin microfilarial counts in *O. volvulus* infection and repeated treatment should help reduce transmission. The onchocercosis-associated pathology in the eye and skin has also been shown to be reduced with ivermectin treatment.

- 2 *Brugia* spp. are carried by many species of mosquito and occur in Southeast Asia, notably in Malaysia, causing elephantiasis. The most important species, *B. malayi*, is also infective for monkeys and domestic and wild carnivores, and has been transmitted experimentally to the cat and dog. The lesser species occurring in human, *B. pahangi*, has a reservoir in many species of domestic and wild animals, including the dog and cat. Adult parasites inhabit lymph nodes and afferent lymphatic vessels.
- 3 *Wuchereria bancrofti* is also mosquito-borne and affects the lymphatic system, causing elephantiasis in Africa, Asia and South America. It is exclusive to humans. As with *Brugia* spp., the main pathogenic effects are associated with adult worms rather than with microfilariae.
- 4 *Loa loa* is transmitted by *Chrysops* spp. (tabanid flies), and occurs in West, Central and East Africa, where it causes the transient subcutaneous enlargements known as 'Calabar swellings'. It is confined to human, apes and monkeys. Longevity can be up to 20 years.
- 5 *Mansonella ozzardi*, carried by *Culicoides* spp. and *Simulium* spp., occurs in the Caribbean and in Central and South America. It lives in the fat and on the mesentery or pleural cavity, and is usually considered to be non-pathogenic, though recently it has been associated with allergic signs. The prevalence is extremely high in endemic areas, where parasites closely resembling *M. ozzardi* are commonly found in monkeys and in horses and cattle. However, there is reluctance to presume that these animals may be reservoir hosts until positive identification is made.

SUPERFAMILY TRICHUROIDEA

The members of this superfamily are found in a wide variety of domestic animals. A common morphological feature is the 'stichosome' oesophagus that is composed of a capillary-like tube surrounded by a single column of cells. The male has only one spicule within a sheath, or it may be completely absent (e.g. *Trichinella*).

There are several genera of veterinary interest in the family Trichuridae. The Trichuridae includes species of *Trichuris*, which are found in the caecum and colon of mammals; *Capillaria* (*Eucoleus*) species are most commonly present in the alimentary or respiratory tract of mammals or birds. Both lay eggs with plugs at both poles. *Trichosomoides* species are of minor interest, and are bladder worms found in rodents. *Anatrichosoma* are parasites of primates, and occasionally reported in humans, and are found in the skin and nasal passages.

FAMILY TRICHURIDAE

Trichuris

Worms belonging to this genus are commonly known as 'whipworms' because the thick broad posterior end tapers rapidly to a long filamentous anterior end (about twice as long as the posterior region) that is characteristically embedded in the mucosa (Fig. 1.62). The anterior of the worm bears a small point. The male tail is tightly coiled and possesses a single spicule in a protrusible sheath.



Fig. 1.62 *Trichuris suis* adult worms.

Trichuris trichiura, the whipworm of human and simian primates, is morphologically indistinguishable from *T. suis*. However, it is generally considered that these two parasites are strictly host-specific. Worldwide the number of cases in humans is several hundred million, with around 10,000 deaths per year attributed to trichuriasis. It is more common in children.

The taxonomic status of *Trichuris* species is very confused because many described species may be synonymous, reflecting the fact that an accepted species has been found in a different host and determined as a new species.

Life cycle: The infective stage is the L₁ within the egg, which develops within 1 or 2 months of being passed in the faeces depending on the temperature. Under optimal conditions, these larvated eggs may subsequently survive and remain viable for several years. After ingestion, the plugs are digested and the released L₁ penetrate the mucosal glands of the distal ileum, caecum and colon. Subsequently, all four moults occur within these glands, the adults emerging to lie on the mucosal surface with their anterior ends embedded in the mucosa. The prepatent period is about 7–10 weeks.

Trichuris species

Species	Hosts	Site
<i>Trichuris campanula</i>	Cat	Large intestine
<i>Trichuris capreoli</i>	Deer	Large intestine
<i>Trichuris discolor</i>	Cattle, buffalo, occasionally sheep, goat	Large intestine
<i>Trichuris globulosa</i>	Cattle, occasionally sheep, goat, camel, other ruminants	Large intestine
<i>Trichuris leporis</i>	Rabbit, hare, coypu	Large intestine
<i>Trichuris muris</i>	Rat, mouse	Large intestine
<i>Trichuris ovis</i>	Sheep, goat, occasionally cattle and other ruminants	Large intestine
<i>Trichuris serrata</i>	Cat	Large intestine
<i>Trichuris skrjabini</i>	Sheep, goat, camel	Large intestine
<i>Trichuris suis</i>	Pig, wild boar	Large intestine
<i>Trichuris trichiura</i>	Human, primates	Large intestine
<i>Trichuris vulpis</i>	Dog, fox, cat	Large intestine
<i>Trichuris cameli</i>	Camel	Large intestine
<i>Trichuris tenuis</i>	Llama, alpaca	Large intestine

Trichuris discolor

Description: Worms are similar to *T. globulosa* but the females are yellow-orange in colour.

Trichuris globulosa

Description: The adults are long white worms, with males measuring 4–7 cm and females 4–6 cm in length. The single spicule sheath bears a terminal spherical expansion, on which are spines larger than on the rest of the sheath.

Trichuris leporis

Description: Adult males measure 1.9–2.1 cm and adult females 1.7–2.1 cm in length.

Trichuris ovis

Description: The adults are long white worms about 4–8 cm in length (males 5–8 cm, females 3.5–7 cm). Only one spicule is present in the male. The spicule sheath is equipped with an oblong swelling near its distal extremity and is covered with very small spines, the size of which decrease towards the distal end.

Trichuris skrjabini

Description: Males of *T. skrjabini* have one short spicule (0.82 mm) with a rounded tip that is always fully covered by the spicule sheath and large conical caudal papillae.

Trichuris suis

Description: The adults are whitish and about 3–5 cm long. The spicule has a blunt tip and the sheath is variable in shape and in the number of spines on its surface.

Trichuris trichiura

Description: Females are slightly larger than male worms (approximately 3.5–5.0 cm compared to 3.0–4.5 cm). The females have a bluntly round posterior compared to their male counterparts with a coiled posterior end.

Trichuris vulpis

Description: The adults are whitish and about 4.5–7.5 cm long. Only one spicule is present and the sheath bears small spines only on its anterior portion.

Trichosomoides

These are permanent hyperparasites that inhabit the urinary bladder of rats.

Life cycle: Infection is by ingestion of embryonated eggs voided in the urine. Eggs hatch in the stomach, penetrate the stomach wall and are carried in the blood to the lungs and other parts of the body. Only those larvae that reach the kidneys or urinary bladder survive. The life cycle takes 8–9 weeks and the prepatent period is 8–12 weeks.

***Trichosomoides* species**

Species	Hosts	Site
<i>Trichosomoides crassicauda</i>	Rat	Bladder

Trichosomoides crassicauda

Description: Males measure 1.5–3.5 mm and females 10–19 mm in length. The small male lives within the uterus of the female worm.

Anatrichosoma

Members of this genus have been reported from the skin and nasal mucosa of primates and the skin and mucosa of wild rodents and marsupials. There have been some reports of infections with species of these parasites in dogs, cats and humans.

Capillaria

Worms belonging to this genus, commonly known as ‘hair-worms’ or ‘threadworms’, are very fine whitish filamentous worms, the narrow stichosome oesophagus occupying about one-third to half the body length. There is a simple mouth and a buccal capsule is absent. The males have a long thin colourless single spicule and often possess a primitive bursa-like structure. The females contain eggs that resemble those of *Trichuris* in possessing bipolar plugs.

Life cycle: The life cycles are generally direct but some species found in birds have indirect life cycles, with earthworms acting as intermediate hosts. The infective L₁ develops within the egg in about 3–4 weeks. Infection of the final host is through ingestion of this embryonated infective stage and development to adult worms occurs usually without a migration phase.

The taxonomy and systematics of these parasites have been changed many times because of a difficulty in designation of particular species’ features and there are many synonyms in this group. Some species of *Capillaria* are now listed under the generic name *Eucoleus*, although they may universally still be referred to as *Capillaria*.

***Capillaria/Eucoleus* species**

Species	Hosts	Site
<i>Capillaria anatis</i> (syn. <i>Capillaria brevicollis</i> , <i>Capillaria collaris</i> , <i>Capillaria mergi</i> , <i>Thormix anatis</i>)	Chicken, turkey, gallinaceous birds (pheasant, partridge), pigeon, duck, goose	Caeca
<i>Capillaria anseris</i> (syn. <i>Baruscapillaria anseris</i>)	Goose, duck	Small intestine
<i>Capillaria bovis</i> (syn. <i>Capillaria brevipes</i>)	Cattle	Small intestine

Species	Hosts	Site
<i>Capillaria bilobata</i>	Zebu	Abomasum
<i>Capillaria bursata</i>	Chicken, turkey, pheasant, duck and wild birds Intermediate hosts: earthworms	Small intestine
<i>Capillaria caudinflata</i> (syn. <i>Aonchotheca caudinflata</i>)	Chicken, turkey, goose, pigeon and wild birds Intermediate hosts: earthworms	Small intestine
<i>Capillaria feliscati</i> (syn. <i>Pearsonema feliscati</i>)	Cat	Bladder
<i>Capillaria hepatica</i> (syn. <i>Callodium hepatica</i> , <i>Hepaticola hepatica</i>)	Rat, mouse, squirrel, rabbit and farmed mustelids; occasionally dog, cat, human, primates	Liver
<i>Capillaria longipes</i>	Sheep, goat, cattle	Small intestine
<i>Capillaria obsignata</i> (syn. <i>Baruscapillaria obsignata</i> , <i>Capillaria columbae</i>)	Pigeon, chicken, turkey, pheasant and wild birds	Small intestine
<i>Capillaria phasianina</i> (syn. <i>Thornix phasianina</i>)	Pheasant, grey partridge	Small intestine, caecae
<i>Capillaria philippinensis</i>	Human	Small intestine
<i>Capillaria plica</i> (syn. <i>Pearsonema plica</i>)	Dog, cat, fox, wolf	Bladder
<i>Capillaria putorii</i> (syn. <i>Aonchotheca putorii</i>)	Cat, dog, mustelids, hedgehog, bear, raccoon	Stomach, small intestine
<i>Capillaria uropapillata</i>	Pheasant	Oesophagus, crop
<i>Eucoleus aerophila</i> (syn. <i>Capillaria aerophila</i>)	Fox, mustelids, occasionally dog, coyote, cat and human	Trachea, bronchi
<i>Eucoleus boehmi</i> (syn. <i>Capillaria boehmi</i>)	Fox, dog	Nasal, frontal and maxillary sinuses
<i>Eucoleus annulata</i> (syn. <i>Capillaria annulata</i>)	Chicken, turkey, duck and wild birds Intermediate hosts: earthworms	Oesophagus, crop
<i>Eucoleus contorta</i> (syn. <i>Capillaria contorta</i>)	Chicken, turkey, pheasant, duck and wild birds Intermediate hosts: earthworms	Oesophagus, crop
<i>Eucoleus perforans</i> (syn. <i>Capillaria perforans</i>)	Pheasant, guinea fowl	Oesophagus, crop

Capillaria anatis

Synonyms: *Capillaria brevicollis*, *Capillaria collaris*, *Capillaria mergi*, *Thornix anatis*

Description: Males measure around 16–24 mm and females 28–38 mm in length.

Life cycle: The life cycle is direct. The infective L₁ develops within the egg in about 3–4 weeks. Infection of the final host is through ingestion of this embryonated infective stage, and development to adult worms occurs without a migration phase. The prepatent period is 3–4 weeks.

Capillaria bursata

Description: Males measure around 6–12 mm and females up to 25 mm.

Life cycle: The life cycle of this species is indirect.

Capillaria bovis

Synonym: *Capillaria brevipes*

Description: Males measure around 8–9 mm and females up to 12 mm.

Capillaria caudinflata

Synonym: *Aonchotheca caudinflata*

Description: Males measure around 6–12 mm and females up to 25 mm in length. Females have a characteristic projecting vulval appendage and a cylindrical tail that does not taper significantly.

Life cycle: The life cycle of this species is indirect.

Capillaria hepatica

Synonyms: *Callodium hepatica*, *Hepaticola hepatica*

Description: These are very fine filamentous worms generally measuring 10–50 mm in length.

Life cycle: The life cycle is direct and differs from that of other *Capillaria* species. Adult *C. hepatica* worms reproduce in the liver and females lay groups of eggs in the parenchyma where they become encapsulated by the host's reaction. These eggs are therefore not released directly from the host. Infection is acquired by ingestion of either the liver, following predation, cannibalism or carrion feeding, or eggs on the ground, which have been freed by decomposition of the host. Eggs in the soil will embryonate and be infective in about 4 weeks. When infective eggs are ingested by the host, they hatch in the intestine and the larvae penetrate the intestinal wall and are carried to the liver via the lymphatics and the bloodstream.

Capillaria longipes

Description: Males measure around 10–13 mm and females up to 20 mm.

Life cycle: The prepatent period is 3–4 weeks.

Capillaria obsignata

Synonyms: *Baruscapillaria obsignata*, *Capillaria columbae*

Description: Males measure around 10–12 mm and females are up to 15 mm in length. The tail of the female worm tapers posteriorly.

Life cycle: This species has a direct life cycle. The infective L₁ develops within the egg in about 7–10 days. Infection of the final host is through ingestion of this embryonated infective stage, and development to adult worms occurs without a migration phase. The prepatent period is around 3 weeks.

Capillaria plica

Synonym: *Pearsonema plica*

Description: Adult males are 13–30 mm and females are 30–60 mm long.

Life cycle: This parasite requires an earthworm intermediate host, ingested eggs developing to the infective L₃ within 30 days. The prepatent period is around 8 weeks.

Capillaria feliscati

Synonym: *Pearsonema feliscati*

Description: Adult males are 13–30 mm and females 30–60 mm long.

Capillaria putorii

Synonym: *Aonchotheca putorii*

Description: Thin filamentous worms, about 10 mm long; males are 5–8 mm and females 9–15 mm.

Eucoleus aerophila

Synonym: *Capillaria aerophila*

Description: Males measure around 24 mm and females 32 mm in length. The male possesses only one spicule and the spicule sheath is covered with spines.

Eucoleus boehmi

Synonym: *Capillaria boehmi*

Description: These are fine whitish filamentous worms, with adults 15–40 mm long. The male has a long thin single spicule.

Eucoleus annulata

Synonym: *Capillaria annulata*

Description: Males measure around 15–25 mm and females 37–80 mm. This species has a cuticular swelling at the back of the head.

Life cycle: The life cycle is indirect. Eggs passed in faeces are ingested by earthworms and develop to the infective stage in 2–3 weeks. The prepatent period is about 3–4 weeks in the final host.

Eucoleus contorta

Synonym: *Capillaria contorta*

Description: Males measure around 12–17 mm and females 27–38 mm.

Life cycle: *Eucoleus contorta* appears to be able to develop both directly and indirectly. In the direct life cycle, the infective L₁ develops within the egg in about 3–4 weeks. Infection of the final host is through ingestion of this embryonated infective stage, and development to adult worms occurs without a migration phase. In the

indirect life cycle, the egg needs to be ingested by an earthworm in which it hatches, the final host being infected by ingestion of the earthworm. The prepatent period is about 3–4 weeks in the final host.

Capillariosis in humans

Three species of *Capillaria*, *C. philippinensis*, *C. hepatica* and *Eucoleus (Capillaria) aerophila*, can infect humans. Humans acquire *C. hepatica* infection through ingestion of soil containing embryonated eggs or by consuming contaminated food or water. Heavy infections in human induce similar hepatic lesions to those seen in other mammalian hosts and hepatic capillariosis is usually fatal.

Capillaria philippinensis infects the small intestine and causes a severe enteropathy that can be fatal. It occurs mainly in the Philippines and Thailand, with sporadic outbreaks in other parts of Southeast Asia, India, the Middle East and southern Europe. Eggs shed into water embryonate and are ingested by freshwater or brackish-water fish and develop to the infective stage in the intestinal mucosa. Infection is acquired through the consumption of raw or undercooked fish. Large infections can accumulate through autoinfection. Fish-eating birds are thought to be the reservoir host. Clinical signs include intermittent diarrhoea, followed by anorexia, abdominal distension and weight loss. There is a protein-losing enteropathy. Human capillariosis resulting from *E. aerophila* is very rare.

SUPERFAMILY TRICHINELLOIDEA

FAMILY TRICHINELLIDAE

Trichinella are found in the small intestine of mammals and produce larvae that immediately invade the tissues of the same host.

Trichinella

The taxonomy of the genus has been controversial until very recently. It is composed of several sibling species that cannot be differentiated morphologically but molecular typing, and other criteria, have now identified eight species of *Trichinella* (Table 1.7).

In the very small adult worms (males 1.4–1.6 mm, females 3–4 mm in length) the oesophagus is at least one-third of the total body length, and the tail in the male has two small knob-shaped conical cloacal flaps, but no copulatory spicule nor a spicule sheath. In the female, the uterus contains developing larvae. The vulva is sited in the mid-oesophageal region of the worm. *Trichinella* infection is most easily identified by the presence of coiled larvae in striated muscle (Fig. 1.63) and adult worms are unlikely to be encountered during gross examination of intestinal digesta.

Life cycle: The life cycle is indirect. The adult parasites and infective larvae (muscle trichinae) are unusual in being present within a single host (i.e. development from larva to adult to larva in a single host). *Trichinella* does not have a free-living stage. The very small developing adults lie between the villi of the small intestine. After fertilisation, the males die while the females burrow deeper into the intestinal mucosa. About a week later, they produce L₁ which enter the lymphatic vessels and travel via the bloodstream to the skeletal

Table 1.7 *Trichinella* species.

Species	Distribution	Principal hosts	Resistance to freezing
Capsule forming			
<i>T. spiralis</i>	Cosmopolitan	Pig, rat, horse, wide range of mammals, human	No
<i>T. nativa</i>	Arctic and subarctic zones: North America, Finland, Sweden	Wild carnivores, seal, polar bear, walrus	High
<i>T. nelsoni</i>	Tropical Africa	Wild carnivores and omnivores	No
<i>T. britovi</i>	Temperate zone of Palaearctic region	Wild carnivores, fox, wild boar, horse, human	Low
<i>T. murrelli</i>	North America	Wildlife, horse, human	No
Non-capsule forming			
<i>T. pseudospiralis</i>	Cosmopolitan	Mammals, birds	No
<i>T. papuae</i>	Papua New Guinea	Wild pig, human	No
<i>T. zimbabwensis</i>	Zimbabwe	Crocodiles	No


Fig. 1.63 Coiled infective larvae of *Trichinella spiralis* in striated muscle.

muscles. There, still as L₁, they penetrate striated muscle cells where they are encapsulated by the host, grow and assume a characteristic coiled position; the parasitised muscle cell is transformed by microvascularisation into a ‘nurse cell’. This process is complete within about 3–4 weeks, by which time the larvae are infective and may remain so for many years. Development is resumed when muscle, containing the encysted trichinae, is ingested by another host, usually as a result of predation or carrion feeding. The L₁ is liberated in the stomach and in the intestine undergoes four moults to become sexually mature within about a week. Patent infections persist for only a few weeks at the most.

PHYLUM ACANTHOCEPHALA

This is a separate phylum, closely related to the Nematoda, that contains a few genera of veterinary importance. They are generally referred to as ‘thorny-headed worms’ due to the presence of a hook-covered proboscis anteriorly (Fig. 1.64), and most are parasites of the alimentary tract of vertebrates. The body is usually cylindrical, although some are flattened. The hollow proboscis armed with recurved hooks, which aid in attachment, is retractable and lies in a sac. There is no alimentary canal, with absorption taking place through the thick cuticle, which is often folded and invaginated to


Fig. 1.64 Head of *Macracanthorhynchus hirudinaceus* showing the retractable proboscis.

increase the absorptive surface. The sexes are separate, males being much smaller than females. Posteriorly, the male has a muscular bursa and penis. After copulation, eggs, discharged by ovaries into the body cavity of the female, are fertilised and taken up by a complex structure called the uterine bell, which only allows mature eggs to pass out. These are spindle-shaped, thick-shelled and contain a larva which has an anterior circlet of hooks and spines on its surface and is called an **acanthor**.

Life cycle: The life cycle is indirect, involving either an aquatic or terrestrial arthropod intermediate host. On ingestion by the intermediate host, the egg hatches and the acanthor migrates to the haemocoel of the arthropod where it develops to become a **cystacanth** after 1–3 months. The definitive host is infected by ingestion of the arthropod intermediate host, and the cystacanth, which is really a young adult, attaches and grows to maturity in the alimentary canal. The prepatent period varies from 5 to 12 weeks.

FAMILY OLIGACANTHORHYNCHIDAE

The major genera of veterinary significance are *Macracanthorhynchus*, which is found in pigs, *Oncicola* found in dogs and other canids, and *Prosthenorchis* (*Oncicola*) which is found in primates.

Macracanthorhynchus

Macracanthorhynchus species

Species	Hosts	Site	Intermediate hosts
<i>Macracanthorhynchus hirudinaceus</i>	Pig, wild boar	Small intestine	Various dung beetles and water beetles

Macracanthorhynchus hirudinaceus

Description: Male worms are up to 10 cm long and the females around 40–60 cm in length and are slightly curved and white/pinkish in colour when fresh. The worms are thick (5–10 mm in width) and flattened and the cuticle is transversely wrinkled. This

pseudo-segmentation can sometimes cause misidentification as a tapeworm. There is no alimentary canal. The anterior of the worm possesses a small retractable proboscis, which is covered with about six transverse rows of recurved hooks. The size of the hooks decreases posteriorly.

Life cycle: The prepatent period is 2–3 months and longevity can be around 1 year.

Oncicola

Oncicola species

Species	Hosts	Site	Intermediate hosts
<i>Oncicola canis</i>	Dog, coyote, occasionally cat	Small intestine	Beetles

Oncicola canis

Description: These are thick worms (around 2–4 mm in width). Males are 6–13 mm and females 7–14 mm in length. The body is conical tapering backwards and is dark grey in colour. The proboscis bears six transverse rows, each with six hooks. The shapes of the hooks are taenioid in the anterior region and more like a rose thorn in the posterior section.

FAMILY POLYMORPHIDAE

A few genera are parasites of rodents (*Moniliformis*), aquatic birds (*Polymorphus*, *Filicollis*) and fishes (*Echinorhynchus*, *Acanthocephalus*). These are frequently small worms with a cylindrical body, although *Moniliformis* species can be very large, up to 30 cm in length.

Life cycle: The definitive host is infected following ingestion of an intermediate host that contains an infective cystacanth. The adult worm establishes in the posterior small intestine. The prepatent period is 3–4 weeks.

Polymorphus

Polymorphus species

Species	Hosts	Site	Intermediate hosts
<i>Polymorphus boschadis</i> (syn. <i>Polymorphus minutus</i> , <i>Echinorhynchus polymorphus</i>)	Duck, goose, chicken, swan and various wild aquatic birds	Small intestine	Crustaceans: <i>Gammarus pulex</i> , freshwater shrimp and sometimes the crayfish <i>Potamobius astacus</i>

Polymorphus boschadis

Synonyms: *Polymorphus minutus*, *Echinorhynchus polymorphus*

Description: Males measure around 3 mm and females up to 10 mm in length and are orange-coloured when fresh. The anterior region possesses small spines and the cylindrical body has a constriction along its length, about one-third from the head. The proboscis has 16 rows of small hooks, their size increasing anteriorly.

Filicollis

Filicollis species

Species	Hosts	Site	Intermediate hosts
<i>Filicollis anatis</i>	Duck, goose, swan and wild aquatic birds	Small intestine	Crustaceans, isopods such as <i>Asellus aquaticus</i>

Filicollis anatis

Description: The whitish male is about 7 mm in length and the anterior region possesses many small spines. The ovoid proboscis is armed with 18 longitudinal rows of small hooks. The neck of the female worm is elongate, slender and bears a globular-shaped proboscis, the crown of which is armed with 18 rows of minute hooks in a star-shaped pattern.

PHYLUM PLATYHELMINTHES

This phylum contains the two classes of parasitic flatworms, the **Trematoda** and the **Cestoda**. A third class, the **Turbellaria** (planarians), which are mainly free-living carnivorous flatworms, are of no veterinary significance.

CLASS TREMATODA

The class Trematoda falls into two main subclasses, the **Monogenea**, which have a direct life cycle, and the **Digenea**, which require an intermediate host. The Digenea are found exclusively in vertebrates and are of considerable veterinary importance. The adult digenetic trematodes (commonly called ‘flukes’) occur primarily in the bile ducts, alimentary tract and vascular system. Most flukes are flattened dorsoventrally, have a blind alimentary tract, suckers for attachment and are hermaphrodite (except Schistosomatidae where the sexes are separate). Depending on the predilection site, the eggs pass out of the final host, usually in faeces or urine, and the larval stages develop in a molluscan intermediate host. For a few species, a second intermediate host is involved, but the mollusc is essential for all members of the group.

The subclass Monogenea will not be considered further in this book as they are primarily external parasites of fish and other amphibious animals. There are many families in the subclass Digenea, and those which contain parasites of major veterinary importance include the Fasciolidae, Dicrocoeliidae, Paramphistomatidae and Schistosomatidae. Of lesser importance are the Echinostomidae, Gastrodiscidae, Cyclocoelidae, Opisthorchiidae, Brachylaemiidae, Heterophyidae, Diplostomatidae, Strigeidae and Lecithodendriidae. The most important family by far is the Fasciolidae and our discussion of structure, function and life cycle is largely oriented towards this group (Table 1.8).

SUBCLASS DIGENEA

STRUCTURE AND FUNCTION OF DIGENETIC TREMATODES

The adult is usually flat and leaf-like and possesses two muscular suckers for attachment. The oral sucker at the anterior end surrounds

Table 1.8 Classification of trematodes of veterinary importance.

Kingdom	Phylum	Class Subclass	Order	Family	Genus	
Animalia	Platyhelminthes	Trematoda Digenea	Echinostomatida	Fasciolidae	<i>Fasciola</i> <i>Fascioloides</i> <i>Fasciolopsis</i>	
				Paramphistomatidae	<i>Paramphistomum</i> <i>Orthocoelium</i> <i>Cotylophoron</i> <i>Calicophoron</i> <i>Gigantocotyle</i> <i>Bothriophoron</i> <i>Pseudodiscus</i>	
				Gastrodiscidae	<i>Gastrodiscus</i> <i>Homologaster</i>	
				Gastrothylacidae	<i>Gastrothylax</i> <i>Fischoederius</i> <i>Carmyerius</i>	
				Echinostomatidae	<i>Echinostoma</i> <i>Echinoparyphium</i> <i>Hypoderaeum</i> <i>Echinochasmus</i> <i>Euparyphium</i> <i>Isthmiophora</i>	
				Philophthalmidae	<i>Philophthalmus</i>	
				Cyclocoelidae	<i>Typhlocoelum</i> <i>Hypitasmus</i>	
				Notocotylidae	<i>Notocotylus</i> <i>Catatropis</i> <i>Cymbiforma</i> <i>Paramonostomum</i> <i>Ogmcotyle</i>	
				Plagiorchida	Dicrocoeliidae	<i>Dicrocoelium</i> <i>Eurytrema</i> <i>Platynosomum</i>
					Paragonimidae	<i>Paragonimus</i>
					Nanophyetidae	<i>Nanophyetus</i>
					Collyriclidae	<i>Collyriclum</i>
					Prosthogonimidae	<i>Prosthogonimus</i>
			Plagiorchidae		<i>Plagiorchis</i>	
			Lecithodendriidae		<i>Novetrema</i> <i>Odeningotrema</i> <i>Phaneropsolus</i> <i>Primatotrema</i>	
			Opisthorchida	Opisthorchiidae	<i>Clonorchis</i> <i>Opisthorchis</i> <i>Metorchis</i> <i>Parametorchis</i> <i>Pseudamphistomum</i>	
				Brachylaemidae	<i>Brachylaemus</i> <i>Skrjabinotrema</i> <i>Postharmostomum</i>	
				Heterophyidae	<i>Heterophyes</i> <i>Metagonimus</i> <i>Apophallus</i> <i>Cryptocotyle</i> <i>Haplorchis</i> <i>Pygidiopsis</i>	
			Strigeidida	Schistosomatidae	<i>Schistosoma</i> <i>Bilharziella</i> <i>Trichobilharzia</i> <i>Orientobilharzia</i> <i>Ornithobilharzia</i> <i>Heterobilharzia</i> <i>Austroilharzia</i>	
				Diplostomatidae	<i>Alaria</i>	
				Strigeidae	<i>Apatemon</i> <i>Parastrigea</i> <i>Cotylurus</i>	

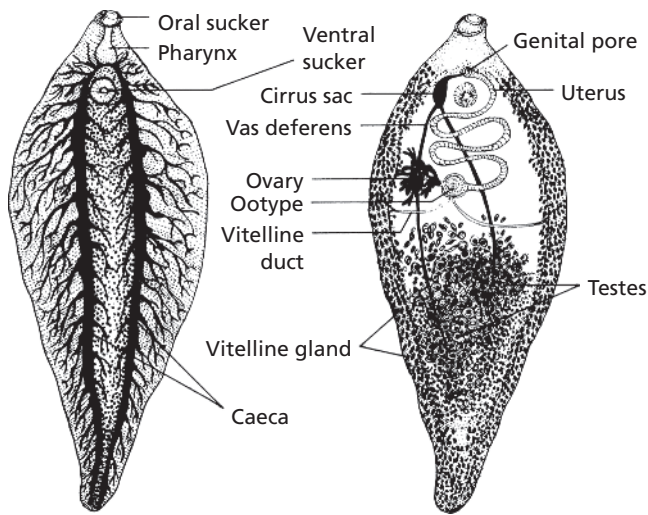


Fig. 1.65 Internal structure of a generalised digenetic trematode.

the mouth, and the ventral sucker (called the acetabulum), as the name indicates, is on that surface. The body surface is a tegument, which is absorptive and is often covered with spines or scales. The muscles lie immediately below the tegument. There is no body cavity and the organs are packed in a parenchyma (Fig. 1.65).

The digestive system is simple, the oral opening leading into a pharynx, oesophagus and a pair of branched intestinal caeca, which end blindly. Undigested material is presumably regurgitated as flukes lack an anus. The excretory system consists of a large number of ciliated flame cells, which impel waste metabolic products along a system of tubules that ultimately join and open to the exterior, or to an excretory bladder. The nervous system is simple, consisting of a pair of longitudinal trunks connecting anteriorly with two ganglia.

The trematodes are usually hermaphrodite and both cross- and self-fertilisation may occur. The male reproductive system consists of a pair of testes, simple or branched, each leading into a vas deferens; these join to enter the cirrus sac containing a seminal vesicle and the cirrus, a primitive penis which terminates at the common genital opening (Fig. 1.65). In some flukes there is a cirrus sac surrounding these terminal organs. The female system has a single ovary leading into an oviduct (where eggs are fertilised), which is expanded distally to form the ootype. There the ovum acquires a yolk from the secretion of the vitelline glands and ultimately a shell. As the egg passes along the uterus, the shell becomes hardened and toughened and is finally extruded through the genital opening adjacent to the ventral sucker. The mature egg is usually yellow because of the tanned protein shell and most species have an operculum. The eggs of many species of fluke develop in the uterus and are therefore able to hatch once they are expelled.

Food, generally blood or tissue debris, is ingested and passed into the caeca where it is digested and absorbed. Metabolism appears to be primarily anaerobic.

LIFE CYCLE OF DIGENETIC TREMATODES

There is wide variation on the complex digenetic life cycle. In general, the life cycle may have two or more obligate hosts, sometimes with transport or paratenic hosts. In most species, the first intermediate host is a mollusc in which further development of hatched larvae takes place (Fig. 1.66). The essential point of the life cycle is that whereas one nematode egg can develop into only one adult, one trematode egg may eventually develop into hundreds of adults. This is due to the phenomenon of asexual multiplication, **parthenogony**, in the molluscan intermediate host, i.e. the production of new individuals by single larval forms.

The adult flukes are always oviparous and lay eggs with an operculum or lid at one pole. In the egg the embryo develops into a

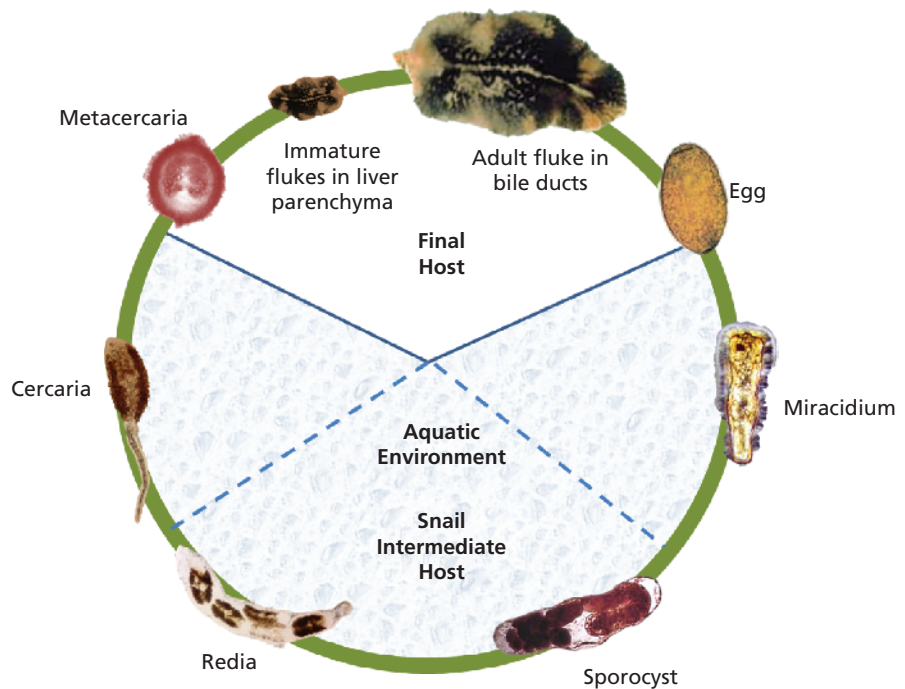


Fig. 1.66 Digenetic trematode life cycle stages (*Fasciola hepatica*).



Fig. 1.67 Miracidium of *Fasciola hepatica*.

pyriform (pear-shaped) ciliated larva called a **miracidium** (Fig. 1.67). The eggs of some digenean flukes may be passively eaten by snails, in which they hatch. In many species of digenean flukes (e.g. *Fasciola hepatica*) the egg hatches in water, and under the stimulus of light and temperature the miracidium releases an enzyme that attacks the proteinaceous cement holding the operculum in place. The latter springs open like a hinged lid and the miracidium emerges within a few minutes.

The miracidium, propelled through the water by its cilia, does not feed and must, for its further development, find a suitable snail within a few hours before it exhausts its energy reserves. It is believed to use chemotactic responses to 'home in' on the snail and, on contact, it adheres by suction to the snail and penetrates its soft tissues using its conical papilla and aided by a cytolytic enzyme. The entire process of penetration takes about 30 minutes, after which the cilia are lost and the miracidium develops into an elongated sac, the **sporocyst**, containing a number of undifferentiated germinal cells. These cells develop into **rediae**, which migrate to the hepatopancreas of the snail; rediae are also larval forms possessing an oral sucker, some flame cells and a simple gut. From the germinal cells of the rediae arise the final stages, the **cercariae** (Fig. 1.68), although if environmental conditions for the snail are unsuitable, a second or daughter generation of rediae is often produced instead. The



Fig. 1.68 Cercaria of *Fasciola hepatica*.



Fig. 1.69 Metacercariae of *Fasciola hepatica*.

cercariae, in essence young flukes with long tails, emerge actively from the snail, usually in considerable numbers. The actual stimulus for emergence depends on the species, but is most commonly a change in temperature or light intensity. Once a snail is infected, cercariae continue to be produced indefinitely, although the majority of infected snails die prematurely from gross destruction of the hepato-pancreas.

Typically the cercariae swim for some time, utilising a film of water, and within an hour or so attach themselves to vegetation, shed their tails and encyst. This stage is called a **metacercaria** (Fig. 1.69), which is the infective stage for grazing animals.

Encysted metacercariae have great potential for survival extending to months. Once ingested, the outer cyst wall is removed mechanically during mastication. Rupture of the inner cyst occurs in the intestine and depends on a hatching mechanism, enzymatic in origin, triggered by a suitable oxidation-reduction potential and a carbon dioxide system provided by the intestinal environment. The emergent juvenile fluke, often called a **marita**, then penetrates the intestine and migrates to the predilection site where it becomes adult after several weeks and commences to lay eggs thus completing the cycle.

The location of the metacercariae varies between different flukes but in general they have a pattern. Those from fasciolids and paramphistomatids encyst on herbage. The metacercariae from troglotrematids, opisthorchiids and heterophyids encyst in fish, crab or crayfish intermediate hosts, whereas those from diplostomatids prefer amphibian or other vertebrate paratenic hosts. Schistosomatids do not have a metacercarial stage; the cercariae are able to penetrate the definitive host percutaneously.

ORDER ECHINOSTOMATIDA

FAMILY FASCIOLIDAE

These are large flat leaf-shaped flukes. The anterior end is usually elongated into the shape of a cone and the anterior sucker is located at the end of the cone. The ventral sucker is placed at the level of the 'shoulders' of the fluke. The internal organs are branched while the cuticle is covered in spines. There are three important genera: *Fasciola*, *Fascioloides* and *Fasciolopsis*.

Fasciola

The members of this genus are commonly known as liver flukes. They are responsible for widespread morbidity and mortality in sheep and cattle. The two most important species are *F. hepatica* found in temperate areas and in cooler areas of high altitude in the tropics and subtropics, and *F. gigantica* which predominates in tropical areas.

Fasciola species

Species	Hosts	Site	Intermediate hosts
<i>Fasciola hepatica</i>	Sheep, cattle, goat, horse, deer, rabbit, human and other mammals	Liver	Lymnaeid snails (<i>Galba</i> , <i>Lymnaea</i> , <i>Radix</i> , <i>Stagnicola</i>)
<i>Fasciola gigantica</i>	Cattle, buffalo, sheep, goat, pig, camel, deer, human	Liver	Lymnaeid snails (<i>Lymnaea</i> , <i>Radix</i> , <i>Austropelea</i>)

Fasciola hepatica

Description: Adult flukes are leaf-shaped (being broader anteriorly than posteriorly), grey-brown in colour and are around 2.5–3.5 cm in length and 1.0 cm in width (Fig. 1.70a). The anterior end is conical and marked off by distinct shoulders from the body. The tegument is covered with backwardly projecting spines. An oral and ventral sucker, situated at the level of the shoulders, may be readily seen. The intestinal caeca have many branches and extend a considerable distance posteriorly. The testes and ovary are multi-branched. The uterus is positioned anterior to the testes. The cirrus is well developed. Immature flukes at the time of entry into the liver are 1.0–2.0 mm in length and lancet-like.

Life cycle: Adult flukes in the bile ducts shed eggs into the bile and these enter the intestine. Eggs passed in the faeces of the mammalian

host develop and hatch, releasing motile ciliated miracidia. This takes 9–10 days at optimal temperatures of 22–26°C and little development occurs below 10°C. The liberated miracidium has a short lifespan and must locate a suitable snail within about 3 hours if successful penetration of the latter is to occur. In infected snails, development proceeds through the sporocyst and redial stages to the final stage in the intermediate host, the cercaria; these are shed from the snail as motile forms, which attach themselves to firm surfaces, such as grass blades, and encyst there to form the infective metacercariae. It takes a minimum of 6–7 weeks for completion of development from miracidium to metacercaria, although under unfavourable circumstances a period of several months is required. Infection of a snail with one miracidium can produce over 600 metacercariae. Metacercariae ingested by the final host excyst in the small intestine, migrate through the gut wall, cross the peritoneum and penetrate the liver capsule. The young flukes tunnel through the liver parenchyma for 6–8 weeks and then enter the small bile ducts where they migrate to the larger ducts and occasionally the gallbladder and reach sexual maturity. The prepatent period is 10–12 weeks. The minimal period for completion of one entire life cycle of *F. hepatica* is therefore 17–18 weeks (Fig. 1.71). The longevity of *F. hepatica* in untreated sheep may be years; in cattle it is usually less than 1 year.

Fasciola gigantica

Description: The adult fluke is larger than *F. hepatica*, reaching 7.5 cm in length and 1.5 cm in breadth, and the body is more transparent. The shape is more leaf-like, the conical anterior end is very short and the shoulders, characteristic of *F. hepatica*, are barely perceptible (Fig. 1.70b). The gut caeca are more highly branched than in *F. hepatica*.

Life cycle: This is similar to *F. hepatica*, the main differences being in the time scale of the cycle. The immature stages migrate through the liver parenchyma, the adults reaching the bile ducts about 12 weeks after infection. Most parasitic phases are longer and the prepatent period is 13–16 weeks.

Fascioloides

The genus comprises a single species, *Fascioloides magna*, also known as the giant liver fluke, large American liver fluke or deer fluke. It is one of the largest of the trematodes and is easily identified.

Life cycle: The life cycle is similar to that of *F. hepatica*. The eggs hatch to miracidia after 4 weeks or longer. Development in the snail takes 7–8 weeks. The prepatent period in deer is around 30 weeks.

Fascioloides species

Species	Hosts	Site	Intermediate hosts
<i>Fascioloides magna</i>	Deer, cattle, sheep, goat, pig, horse, llama	Liver, occasionally bile duct	Lymnaeid snails (<i>Fossaria</i> spp., <i>Lymnaea</i> spp., <i>Stagnicola</i> spp.)

Fascioloides magna

Description: Flukes are large and thick and measure up to 10 cm long by 2.5 cm broad and around 3–4 mm in depth. The flukes are oval, with a rounded posterior end. They possess no anterior cone projection and when fresh are flesh-coloured (Fig. 1.72).

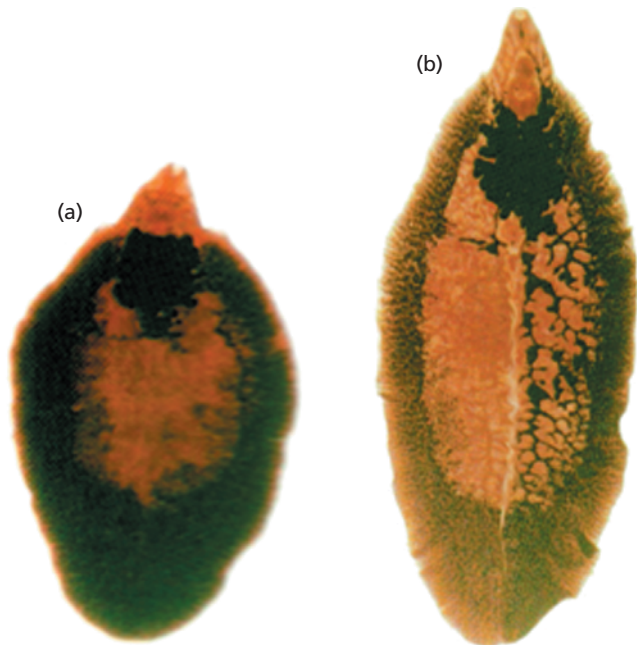


Fig. 1.70 Outline of (a) *Fasciola hepatica* and (b) *F. gigantica*. The former has broader shoulders and is shorter in length.

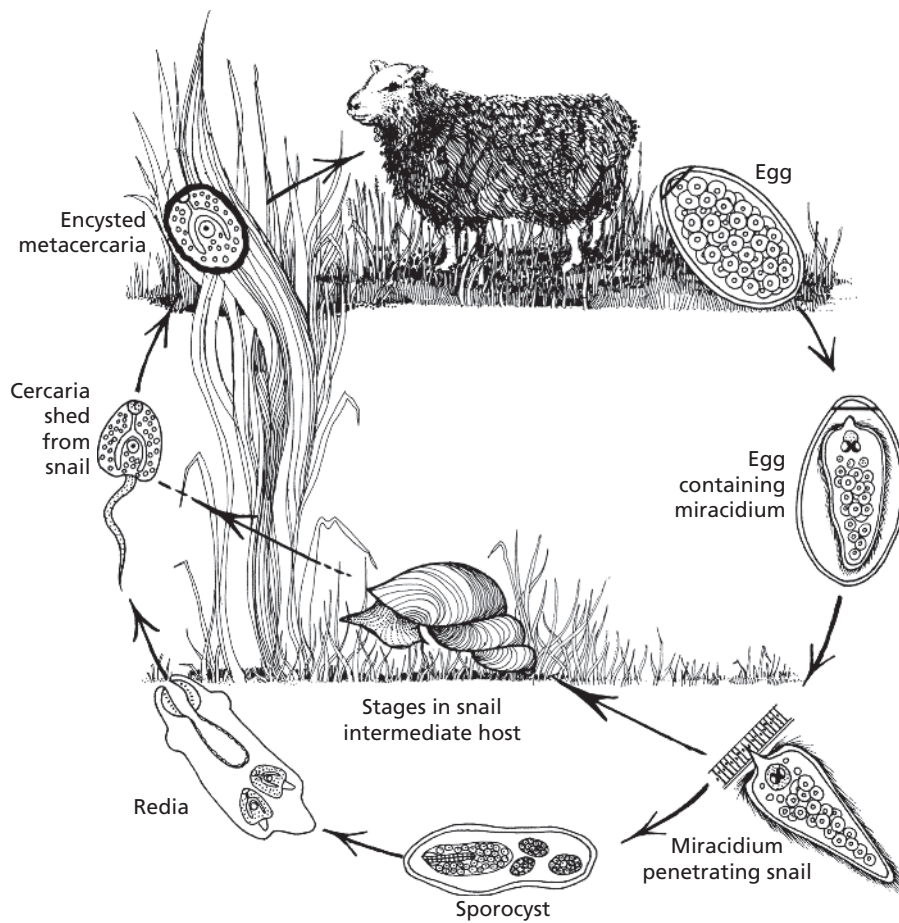


Fig. 1.71 Life cycle of the liver fluke *Fasciola hepatica*.

Fasciolosis

The single species of this genus is primarily a parasite of humans in India, Pakistan, Southeast Asia and China, but can occur in the pig which may act as a reservoir host.



Fig. 1.72 *Fascioloides magna*.

Life cycle: The life cycle is similar to that of *F. hepatica*. The final host is infected through ingestion of metacercariae that encyst on aquatic plants. The prepatent period is 9–13 weeks.

Fasciolosis species

Species	Hosts	Site	Intermediate hosts
<i>Fasciolopsis buski</i>	Humans, pig, occasionally dog	Small intestine	Freshwater snails (<i>Planorbis</i> , <i>Segmentina</i> , <i>Hippeutis</i>)

Fasciolopsis buski

Description: Large, thick, elongate-oval, fleshy pink flukes without shoulders, broader posteriorly, and variable in size but usually measuring 30–75 mm long by 8–20 mm wide. The ventral sucker is located near the anterior extremity and is much larger than the oral sucker. The cuticle is covered in spines that are frequently lost as adults. The intestinal caeca are unbranched and extend to near the posterior of the fluke. The testes are branched and tandem; the ovary is also branched.

FAMILY PARAMPHISTOMATIDAE

Adult paramphistomes (amphistomes) are mainly parasitic in the forestomachs of ruminants, although *Gigantocotyle* is found in the liver and duodenum. Their shape is not typical of the trematodes, being conical and thick and fleshy rather than flat. All require a

water snail as an intermediate host. There are several genera: *Paramphistomum*, *Cotylophoron*, *Bothriophoron*, *Orthocoelium* and *Gigantocotyle*, of which *Paramphistomum* is the most common and widespread in ruminants. The taxonomy of the paramphistomes is complex and unresolved and many of the species described may be synonymous, being differentiated mainly on size and shape of the suckers.

Paramphistomum

Members of this genus (rumen fluke) are found in the rumen and reticulum of ruminants. The adults are small, conical (pear-shaped), maggot-like flukes about 1.0 cm long and 3–5 mm wide and light red in colour when fresh. Unlike other flukes, the large ventral sucker is located at the posterior extremity of the body and is well developed.

Life cycle: Eggs shed in the faeces are undeveloped. In an aquatic environment miracidia develop and hatch to penetrate water snails in which they develop to cercaria, following sporocyst and redial stages. The cercariae encyst (metacercariae) on vegetation in, or bordering, watercourses and ponds. Development in the snail intermediate host is similar to that of *Fasciola* and under favourable conditions (26–30°C) can be completed in 4 weeks. Following ingestion by a definitive host the metacercariae excyst in the duodenum, where the young flukes attach and feed for about 6 weeks, before migrating forward to the forestomachs where they mature. The prepatent period is between 7 and 10 weeks.

Paramphistomum (*Calicophoron*, *Cotylophoron*, *Bothriophoron*) species

Species	Hosts	Site	Intermediate hosts
<i>Paramphistomum cervi</i> (syn. <i>Paramphistomum explanatum</i>)	Cattle, sheep, goat, deer, buffalo, antelope	Rumen	Freshwater snails (<i>Bulinus</i> spp., <i>Planorbis</i> spp.)
<i>Calicophoron daubneyi</i> (syn. <i>Paramphistomum daubnei</i> , <i>Paramphistomum daubneyi</i>)	Cattle, goat	Rumen	Freshwater snails (<i>Omphiscola</i> spp.)
<i>Paramphistomum microbothrium</i>	Cattle, sheep, goat, deer, buffalo, antelope	Rumen	Freshwater snails (<i>Fossaria</i> spp., <i>Bulinus</i> spp.)
<i>Paramphistomum ichikawa</i>	Sheep, cattle	Rumen	Planorbid snails (<i>Gyraulus</i> , <i>Helicorbis</i> , <i>Segnetilia</i>)
<i>Cotylophoron cotylophorum</i> (syn. <i>Paramphistomum cotylophorum</i>)	Sheep, goat, cattle and wild ruminants	Rumen, reticulum	Freshwater snails (<i>Bulinus</i> spp.)
<i>Paramphistomum bothriophoron</i> (syn. <i>Bothriophoron bothriophoron</i>)	Zebu	Rumen	Freshwater snails (<i>Bulinus</i> spp., <i>Planorbis</i> spp.)
<i>Paramphistomum streptocoelium</i> (syn. <i>Ceylonocotyle streptocoelium</i> , <i>Orthocoelium streptocoelium</i>)	Cattle, sheep, goat and wild ruminants	Rumen	Freshwater snails (<i>Glyptanisis</i> spp.)
<i>Calicophoron calicophorum</i> (syn. <i>Paramphistomum calicophorum</i>)	Cattle, sheep, other ruminants	Rumen, reticulum	Water snails

Paramphistomum cervi

Synonym: *Paramphistomum explanatum*

Description: Adult flukes measure about 6–13 mm by 3–5 mm. One sucker is visible at the tip of the cone and the other at the base. The tegument has no spines. The testes are located anteriorly to the ovary and are lightly lobed. The larval stages are less than 5.0 mm, fresh specimens having a pink colour.

Cotylophoron cotylophorum

Synonym: *Paramphistomum cotylophoron*

Description: Resembles *P. cervi*, but there is a genital sucker surrounding the genital pore.

Gigantocotyle

Gigantocotyle is found in the liver and duodenum of cattle and other ruminants. The life cycle is similar to that of *F. hepatica* and requires species of snails of the genus *Galba* as intermediate hosts.

Gigantocotyle species

Species	Hosts	Site	Intermediate hosts
<i>Gigantocotyle explanatum</i> (syn. <i>Explanatum explanatum</i> , <i>Paramphistomum explanatum</i>)	Cattle, buffalo, other ruminants	Liver, bile ducts, gallbladder, duodenum	Freshwater snails

Gigantocotyle explanatum

Synonyms: *Paramphistomum explanatum*, *Paramphistomum fraturum*, *Explanatum explanatum*

Description: Adult fluke are 8–10 mm long and 4.7–5.7 mm wide. The body tapers anteriorly and is curved ventrally with no tegumental papillae.

Pseudodiscus

Adult flukes have a conical anterior end widening gradually to an oval leaf-like shape.

Pseudodiscus species

Species	Hosts	Site	Intermediate hosts
<i>Pseudodiscus collinsi</i>	Horse	Caecum, colon	Freshwater snails (<i>Indoplanorbis</i> spp.)

Pseudodiscus collinsi

Description: Adult flukes are 6–12 mm by 3–7 mm in size. The conical body has conspicuous serrations along the anterior lateral margins. There is a ventral sucker and the oral sucker has paired pouch-like diverticula.

FAMILY GASTRODISCIDAE

Gastrodiscus spp. are found in the large intestines of horses and pigs. *Homalogaster* is found in the large intestine of cattle and buffalo.

Gastrodiscus

Intestinal flukes with a short conical anterior end, and a large posterior discoid body covered ventrally with large papillae.

Life cycle: The life cycle of the different species is generally similar. Eggs are passed in the faeces and, following development, release miracidia into water where they enter a species of water snail. Development in the snail proceeds through sporocyst and redial stages leading to the release of cercariae, which encyst to form metacercariae. Infection of the final host is by ingestion of metacercariae with herbage. Excystation occurs in the intestine where the immature paramphistomes develop to reach maturity.

Gastrodiscus species

Species	Hosts	Site	Intermediate hosts
<i>Gastrodiscus aegyptiacus</i>	Horse, donkey, pig, warthog	Large and small intestine	Freshwater snails (<i>Bulinus</i> spp., <i>Cleopatra</i> spp.)
<i>Gastrodiscus hominis</i> (syn. <i>Gastrodiscoides hominis</i>)	Pig, human	Caecum, colon	Planorbid snails (<i>Helicorbis</i> spp.)
<i>Gastrodiscus secundus</i>	Horse, elephant	Large intestine	Freshwater snails (<i>Bulinus</i> spp.)

Gastrodiscus aegyptiacus

Description: Adult flukes are reddy-pink in colour when fresh and measure 9–17 mm by 8–11 mm. The anterior region measures up to 4 mm by 2.5 mm and is cylindrical, while the remainder of the body is saucer-shaped, with the margins curved inwards (Fig. 1.73).

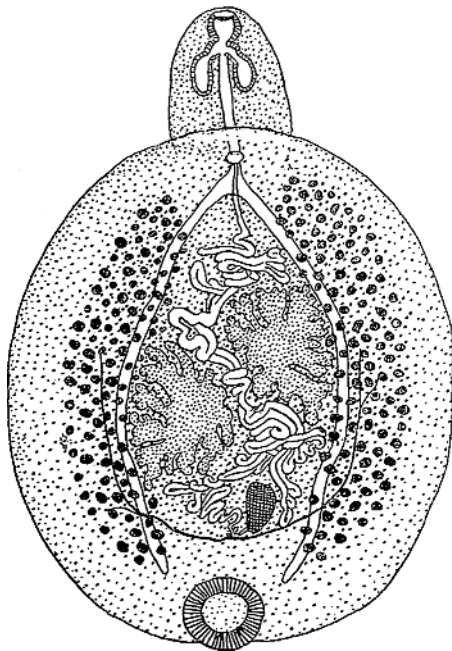


Fig. 1.73 *Gastrodiscus aegyptiacus*. (Redrawn from Mönning, 1934.)

A large number of regularly arranged papillae cover the ventral surface. The oral sucker has two posterolateral pouches; the posterior sucker is small and subterminal.

Gastrodiscus hominis

Synonym: *Gastrodiscoides hominis*

Description: Adult flukes are pink in colour when fresh and measure 8–14 mm by 5–8 mm, with a conical anterior body and a large discoidal posterior body lacking tegumental papillae.

Gastrodiscus secundus

Description: Identical to *G. aegyptiacus* but the genital pore is located posterior to the level of the caecal origin and the vitelline glands are distributed all over the discoidal posterior body.

Homalogaster

These are intestinal flukes in which the body is divided into two, with a large anterior region and a small cylindrical posterior region.

Life cycle: The life cycle is presumed to be similar to other paramphistomes of the rumen.

Homalogaster species

Species	Hosts	Site	Intermediate hosts
<i>Homalogaster paloniæ</i>	Cattle, buffalo	Large intestine	Freshwater snails (<i>Hippeutis</i> spp., <i>Polypylis</i> spp.)

Homalogaster paloniæ

Description: Adult flukes are 8–15 mm long and 4.5–7.5 mm wide. The anterior body is large, flat, ellipsoidal and bluntly pointed anteriorly with large numbers of papillae present on the ventral tegument. The posterior body is small and spherical.

FAMILY GASTROTHYLACIDAE

Pouched amphistomes are similar in appearance to the paramphistomes, with a number of species belonging to the genera *Gastrothylax*, *Fischoederius* and *Carmyerius* parasitic in ruminants throughout Africa and Asia. These flukes differ in having an extremely large ventral pouch that opens anteriorly and which covers the ventral surface of the fluke as far as the large ventral sucker.

Gastrothylax

Gastrothylax species

Species	Hosts	Site	Intermediate hosts
<i>Gastrothylax crumenifer</i>	Cattle, buffalo, zebu, sheep and other ruminants	Rumen, reticulum	Freshwater snails

Gastrothylax crumenifer

Description: This is an elongated fluke, being circular in transverse section and reddish in colour when fresh. The body is 10–16 mm long and 5–8 mm wide. The ventral pouch is normally triangular in cross-section with a dorsally directed apex. The terminal genitalium opens into the ventral pouch about halfway between the intestinal bifurcation and the pharynx. The terminal oval sucker is small.

Fischoederius

Fischoederius species

Species	Hosts	Site	Intermediate hosts
<i>Fischoederius elongatus</i>	Cattle, buffalo, zebu, sheep and other ruminants; rarely human	Rumen, duodenum	Freshwater snails
<i>Fischoederius cobboldi</i>	Cattle, buffalo, zebu, sheep and other ruminants	Rumen, duodenum	Freshwater snails

Fischoederius elongatus

Description: The flukes are reddish when fresh. The body is 10–20 mm long and 3–5 mm wide. The terminal genitalium is within the ventral pouch. The uterus is situated along the mid-line. The testes are lobed and one is sited dorsally to the other.

Fischoederius cobboldi

Description: The flukes are reddish in colour when fresh. The body measures 8–10 mm in length.

Carmyerius

Carmyerius species

Species	Hosts	Site	Intermediate hosts
<i>Carmyerius spatiosus</i> (syn. <i>Gastrothylax spatiosus</i>)	Cattle, zebu, antelope	Rumen	Freshwater snails
<i>Carmyerius gregarius</i>	Cattle, buffalo	Rumen	Freshwater snails

Carmyerius spatiosus

Synonym: *Gastrothylax spatiosus*

Description: Flukes measure 8.5–12 mm in length and 2.5–3.0 mm in width. The posterior sucker is quite small and is spherical. The intestinal caeca extend down into the last quarter of the body. The ventral pouch is either circular or slightly triangular with blunt angles and the terminal genitalium lies within the pouch. The testes lie horizontally, one on each side of the median line, which differs from the position in *Fischoederius*.

Carmyerius gregarius

Description: The flukes are 7–10 mm in length. The intestinal caeca extend only a short distance below the middle of the body.

FAMILY ECHINOSTOMATIDAE

The family Echinostomatidae includes the genera *Echinostoma*, *Echinoparyphium* and *Hypoderaeum*, which are parasites of birds, and *Echinochasmus*, *Isthmiophora* and *Euparyphium*, which are parasites of fish-eating mammals.

Life cycle: The life cycle involves two intermediate hosts, namely freshwater snails and fish or frogs. Eggs passed in the faeces of infected birds hatch to produce a miracidium, which infects the first intermediate snail host. Subsequently, cercariae encyst within the snail or are shed and migrate to infect other snails. Cercariae can also encyst in the kidneys of tadpoles and adult frogs. The definitive host is infected through eating the second intermediate host containing encysted metacercariae (mesocercariae). The prepatent period is 1–2 weeks.

Echinostoma

Echinostoma species

Species	Hosts	Site	Intermediate hosts
<i>Echinostoma revolutum</i>	Duck, goose, fowl, partridge, pigeon, occasionally human	Caecum, cloaca, rectum	Snails Frogs
<i>Echinostoma paraulum</i> (syn. <i>Echinoparyphium paraulum</i>)	Duck, pigeon, human	Small intestine	Snails Fish

Echinostoma revolutum

Description: The fluke is about 10–20 mm long and up to 2 mm in width. The head-collar is armed with around 37 spines, some forming groups of ‘corner’ spines. The anterior of the cuticle is covered in spines. The ovary is anterior to the tandem testes.

Echinostoma paraulum

Synonym: *Echinoparyphium paraulum*

Description: The fluke measures 6.0–10.5 mm in length by 0.8–1.5 mm in width. The tegument is usually almost completely covered in spines, but in some instances these can be absent. The head-collar is armed with 37 spines, some forming a double dorsolateral row. The tandem testes are located in the third quarter of the body.

Echinoparyphium

Echinoparyphium species

Species	Hosts	Site	Intermediate hosts
<i>Echinoparyphium recurvatum</i>	Duck, goose, chicken, pigeon, wild birds, human	Small intestine	Snails, fish, shellfish, tadpoles

Echinoparyphium recurvatum

Description: The fluke is about 4 mm long by 0.7 mm wide and curved ventrally. Spines are present anterior to the ventral sucker and the head-crown is armed with spines.

Hypoderaeum

Hypoderaeum species

Species	Hosts	Site	Intermediate hosts
<i>Hypoderaeum conoideum</i>	Chicken, turkey, duck, goose, swan, pigeon and other aquatic birds	Small intestine	Snails, fish, shellfish, tadpoles

Hypoderaeum conoideum

Description: Adult fluke have an elongate body 5–12 mm long and tapering posteriorly. The anterior body is armed with about 50 small spines and bears a large ventral sucker. The testes are elongate and slightly lobed, and situated just beyond the midline.

Echinochasmus

Echinochasmus species

Species	Hosts	Site	Intermediate hosts
<i>Echinochasmus perfoliatus</i>	Dog, cat, fox, pig	Small intestine	Snails, fish

Echinochasmus perfoliatus

Description: Adult flukes are 2–4 mm long with a head-crown bearing 24 spines arranged in a single row. The testes are large and situated just beyond the midline, with the ovaries to the right and anterior to the testes.

Euparyphium

Euparyphium species

Species	Hosts	Site	Intermediate hosts
<i>Euparyphium melis</i>	Cat, fox, polecat, mink, badger, otter, hedgehog	Small intestine	Snails, amphibian tadpoles
<i>Euparyphium ilocanum</i>	Human, dog, rat	Small intestine	Snails

Euparyphium melis

Description: Adult flukes have an elongate body 3.5–12 mm long that bears a large ventral sucker and a dorsal head-collar with 27 spines. The whole ventral surface is covered with small spines. The testes are situated midline, with one lying posterior to the other. The ovary lies anterior to the testes and to the right of the midline.

FAMILY PHILOPHTHALMIDAE

Philophthalmus are eye flukes of birds.

Life cycle: Embryonated eggs are shed from the eyes, mouth and nostrils, and hatch immediately on contact with water. After penetrating a snail intermediate host, a single redia is released. The mother redia penetrates the heart of the snail, releasing daughter rediae that migrate to the digestive glands and after about 95 days produce cercariae, which are released from the snail and encyst on aquatic vegetation.

Following ingestion, metacercariae excyst in the mouth or crop and young flukes may be found in the oesophagus, nasal passages, orbit and lacrimal gland within a few hours following ingestion.

Philophthalmus

Philophthalmus gralli (the oriental avian eye fluke) are small flukes found in the conjunctival sac of many species of birds.

Philophthalmus species

Species	Hosts	Site	Intermediate hosts
<i>Philophthalmus gralli</i>	Ostrich, chicken, wild birds	Conjunctival sac	Freshwater snails

Philophthalmus gralli

Description: Adult flukes are very small (2–3 mm) and fusiform shaped. The body surface is covered by small spines and the two suckers are orally and subterminally located. The pharynx is located immediately posterior to the oral sucker.

FAMILY CYCLOCOELIDAE

These are medium-sized to large slightly flattened flukes, parasites of aquatic birds in the body cavity, air sacs or nasal cavities. They do not possess an oral sucker and often the ventral sucker is absent. The intestinal caeca are joined together posteriorly and their structure is simple or branched. The lateral vitellaria similarly meet posteriorly. Genera include *Typhlocoelum* in the respiratory tract of ducks, and *Hyptiasmus* in the nasal and orbital sinuses of ducks and geese.

Typhlocoelum

Life cycle: Eggs are coughed up and swallowed in the faeces. A miracidium, containing a single redia, hatches from the egg. The redia, not the miracidium, enters a snail and after 11 days produces small numbers of cercariae. There is no sporocyst stage. The cercariae are retained within the snail and encyst. Birds are infected by eating infected snails. The larval fluke reaches the bronchi via the bloodstream.

Typhlocoelum species

Species	Hosts	Site	Intermediate hosts
<i>Typhlocoelum cucumerinum</i> (syn. <i>Distoma cucumerinum</i> , <i>Typhlocoelum obovulae</i>)	Duck	Trachea, air sacs, oesophagus	Snails of the genera <i>Helisoma</i> and <i>Planorbis</i>
<i>Typhlocoelum cymbium</i> (syn. <i>Tracheophilus sisowi</i>)	Duck	Trachea, bronchi	Snails of the genera <i>Helisoma</i> and <i>Planorbis</i>

Typhlocoelum cucumerinum

Synonyms: *Distoma cucumerinum*, *Typhlocoelum obovulae*

Description: Adult flukes are 6–12 mm long by 2–5 mm broad. The body is oval and blunter anteriorly than posteriorly. The testes are deeply lobed and lie diagonally one behind the other with the unlobed ovary situated in front of the posterior testis.

Typhlocoelum cymbium

Synonym: *Tracheophilus sisowi*

Description: Adult flukes are 6–11.5 mm long by 3 mm broad. The body has rounded ends and is wide in the middle. The testes are rounded, not lobed, and lie in a diagonal position in the posterior part of the body with the unlobed ovary situated in front of the anterior testis.

Hyptiasmus

Hyptiasmus species

Species	Hosts	Site	Intermediate hosts
<i>Hyptiasmus tumidus</i> (syn. <i>Hyptiasmus arcuatus</i> , <i>Cyclocoelum arcuatum</i>)	Duck, goose	Nasal and orbital sinuses	Water snails

Hyptiasmus tumidus

Synonyms: *Hyptiasmus arcuatus*, *Cyclocoelum arcuatum*

Description: Adult flukes are 7–20 mm long by 2–5 mm wide. The body is pyriform and more rounded posteriorly. The gonads are arranged in a straight line.

FAMILY NOTOCOTYLIDAE

The family Notocotylidae includes the genera *Notocotylus*, *Paramonostomum* and *Catatropis*, which are parasites of birds, and *Cymbiforma*, which occur in sheep, goats and cattle. The small eggs are characterised by long filaments at the poles. The intermediate hosts are water snails.

Notocotylus

Notocotylus species

Species	Hosts	Site	Intermediate hosts
<i>Notocotylus attenuatus</i>	Chicken, duck, goose, wild aquatic birds	Caeca, rectum	Snails

Notocotylus attenuatus

Description: The adult flukes are 2–5 mm long by 0.7–1.5 mm wide, narrow anteriorly and have no ventral sucker. The testes are situated posteriorly and the ovary lies between them. The uterus forms regular transverse coils extending from the posterior ovary to the elongate cirrus sac, situated anteriorly.

Catatropis

Catatropis species

Species	Hosts	Site	Intermediate hosts
<i>Catatropis verrucosa</i>	Chicken, duck, goose, other aquatic birds	Caeca	Snails

Catatropis verrucosa

Description: The fluke is 2–6 mm long and rounded anteriorly and posteriorly and has no ventral sucker. The testes are situated posteriorly and the ovary lies between them.

Cymbiforma

Cymbiforma species

Species	Hosts	Site	Intermediate hosts
<i>Cymbiforma indica</i> (syn. <i>Ogmocotyle indica</i>)	Sheep, goat, cattle	Small intestine	Snails

Cymbiforma indica

Synonym: *Ogmocotyle indica*

Description: Adult flukes are pear-shaped, concave ventrally and measure 0.8–2.7 cm in length and 0.3–0.9 mm in width. There is no ventral sucker and the cuticle is armed with fine spines ventrally and anteriorly. The ovary has four demarcated lobes. The fluke lacks a pharynx and the oesophagus is short.

ORDER PLAGIORCHIDA

FAMILY DICROCOELIIDAE

These trematodes are small lancet-like flukes occurring in the biliary and pancreatic ducts of vertebrates. Miracidia are present in the eggs when they are passed in the faeces; there is no redial stage during development in the snail and two to three intermediate hosts may be involved in the life cycle. Members of this family are found in ruminants (*Dicrocoelium*, *Eurytrema*), cats and birds (*Platynosomum*).

Dicrocoelium

The single species of this genus is found in the bile ducts of the liver of ruminants. There is no possibility of confusion with other flukes in the bile ducts of ruminants due to their small size and distinct laceolate shape.

Life cycle: The egg does not hatch until ingested by the first intermediate host, a terrestrial snail, in which two generations of sporocysts develop which then produce cercariae. The latter are extruded in masses cemented together by slime and adhere to vegetation. This phase of development takes at least 3 months. The slime balls of cercariae are ingested by ants in which they develop to metacercariae mainly in the body cavity and occasionally the brain. The presence of a brain lesion in the ant, induced by metacercariae, impels the ant to climb up and remain on the tips of the herbage, thus increasing the chance of ingestion by the final host. This phase in the ant is completed in just over 1 month in summer temperatures. Infection of the final host is by passive ingestion of ants containing metacercariae. The metacercariae hatch in the small intestine and the young flukes migrate up the main bile duct and thence to the smaller ducts in the liver. There is no parenchymal migration and the prepatent period is 10–12 weeks. The total life cycle takes

approximately 6 months. The flukes are long-lived and can survive in the final host for several years.

Dicrocoelium species

Species	Hosts	Site	Intermediate hosts
<i>Dicrocoelium dendriticum</i> (syn. <i>Dicrocoelium lanceolatum</i>)	Sheep, goat, cattle, buffalo, deer, camel, rabbit, occasionally horse, pig, dog, human	Liver	Land snails of many genera: <i>Cionella</i> spp., <i>Zebrina</i> spp. Brown ants (<i>Formica</i> , frequently <i>F. fusca</i>)
<i>Dicrocoelium hospes</i>	Cattle, ox, occasionally sheep, goat	Liver	Land snails Ants

Dicrocoelium dendriticum

Synonym: *Dicrocoelium lanceolatum*

Description: Adult flukes are 6–12 mm long and 1.5–2.5 mm wide, distinctly lanceolate and semi-transparent/translucent allowing the internal organs to be readily seen (Fig. 1.74). They are almost symmetrical in shape and the cuticle is smooth. The oral sucker is smaller than the ventral sucker and is located in close proximity. The gut is simple, consisting of two branches and resembles a tuning fork. Behind the ventral sucker the lobed testes lie in tandem with the ovary immediately posterior. The uterus is usually dark brown and convoluted, filling the space behind the genital gland. The cirrus is small. There are no spines on the cuticle (cf. *Fasciola*).

Dicrocoelium hospes

Description: Details are essentially similar to *D. dendriticum* and the flukes are usually found in the liver and gallbladder of cattle, ox and occasionally sheep and goats in parts of Africa.



Fig. 1.74 *Dicrocoelium dendriticum*.

Eurytrema

This genus inhabits the pancreatic ducts and sometimes the bile ducts of ruminants.

Eurytrema species

Species	Hosts	Site	Intermediate hosts
<i>Eurytrema pancreaticum</i> (syn. <i>Distoma pancreaticum</i> , <i>Eurytrema ovis</i>)	Cattle, buffalo, sheep, goat, pig, camel, human, primates	Pancreas; rarely bile ducts Perirenal fat	Land snails, particularly of the genus <i>Bradybaena</i> Grasshoppers of the genus <i>Conocephalus</i> or tree crickets (<i>Oecanthus</i>)
<i>Eurytrema coelomaticum</i> (syn. <i>Distoma coelomaticum</i>)	Cattle, sheep	Pancreas; rarely bile ducts	Land snails, particularly of the genus <i>Bradybaena</i> Grasshoppers of the genus <i>Conocephalus</i> or tree crickets (<i>Oecanthus</i>)
<i>Eurytrema procyonis</i>	Cat, fox, raccoon	Pancreas	Snails of the genus <i>Mesodon</i> Grasshoppers

Eurytrema pancreaticum

Synonyms: *Distoma pancreaticum*, *Eurytrema ovis*

Description: Oval, leaf-shaped, reddish-brown flukes measuring around 8–16 mm long by 5–8.5 mm wide (Fig. 1.75). The body is thick and the juvenile flukes are armed with spines which are often absent by the adult stage. The oral sucker is larger than the ventral sucker and the pharynx and oesophagus are short. The testes are positioned horizontally just behind the ventral sucker. A tubular cirrus sac is present. The uterus completely occupies the posterior body.

Life cycle: Eggs passed in faeces are ingested by a snail where two generations of sporocysts occur. Cercariae are released onto the herbage

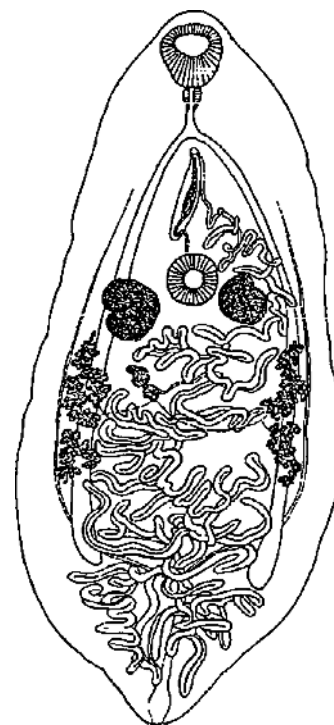


Fig. 1.75 *Eurytrema pancreaticum*. (Redrawn from Soulsby, 1971. Reproduced with permission from Lord Soulsby of Swaffham Prior.)

about 5 months after initial infection and these are ingested by grasshoppers. Infective metacercariae are produced in about 3 weeks. The final host becomes infected by accidentally eating the second intermediate host. Metacercariae encyst in the duodenum and migrate to the pancreas via the pancreatic duct and reside in the small ducts of the pancreas. The prepatent period in cattle is 3–4 months.

Eurytrema coelomaticum

Synonym: *Distoma coelomaticum*

Description: A leaf-shaped reddish brown fluke with adults measuring around 8–12 by 6–7 mm.

Eurytrema procyonis

Description: The adult measures about 2.9 mm long by 1.2 mm wide. The oral sucker is subterminal with a dorsal lip-like projection.

Life cycle: The life cycle is unknown but is thought to involve snail intermediate hosts of the genus *Mesodon*. Animals are likely to become infected by ingestion of the snail intermediate host.

Platynosomum

Flukes of this genus are found in wild birds, but some species are also found in the liver of cats.

***Platynosomum* species**

Species	Hosts	Site	Intermediate hosts
<i>Platynosomum fastosum</i> (syn. <i>Eurytrema fastosum</i>)	Cat	Bile and pancreatic ducts	Land snail (<i>Sublima</i>) and woodlice Lizards are obligate paratenic hosts
<i>Platynosomum concinnum</i>	Cat	Bile and pancreatic ducts	Land snail (<i>Sublima</i>) and woodlice Lizards are obligate paratenic hosts
<i>Platynosomum illiiciens</i>	Cat	Bile and pancreatic ducts	Land snail (<i>Sublima</i>) and woodlice Lizards are obligate paratenic hosts

Platynosomum fastosum

Description: The adult fluke is lanceolate and measures 4–8 mm by 1.5–2.5 mm in size. The testes lie obliquely horizontal.

Life cycle: Eggs passed in the faeces develop in a land snail (*Sublima*) and a crustacean (woodlouse). Cercariae encyst when a lizard, gecko, skink or toad eats the woodlouse. The cat is infected by ingesting a lizard or other host containing metacercariae, which acts as an obligate paratenic host. The prepatent period is around 2–3 months.

FAMILY PARAGONIMIDAE

Trematodes in this family mainly have a flattened fleshy body and a tegument covered with spines. The oral sucker is subterminal and the ventral sucker is located around the middle of the body. The

genital pore is situated just below the ventral sucker. Several genera are of local veterinary interest. *Paragonimus*, commonly referred to as the 'lung fluke', is found in cats, dogs and other carnivores and in humans in North America and Asia. Pulmonary signs are comparatively rare in cats or dogs and the veterinary interest is in the potential reservoir of infection for humans.

Life cycle: The life cycle involves an amphibious or water snail, and a crayfish or freshwater crab. Snails of the genera *Melania*, *Ampullaria* or *Pomatiopsis* are infected by miracidia in which further development through sporocyst, redia and cercaria takes place. After escaping the snail, the cercariae swim about and, on contact with a freshwater crab or crayfish, penetrate it and encyst. Crabs and crayfish can also eat cercaria-infected snails. Infection of the final host occurs by ingestion of the metacercariae in the liver or muscles of the crustacean. Infection can also be acquired through consumption of paratenic hosts which have eaten infected crabs or crayfish. The young flukes migrate to the lungs where they are encapsulated by fibrous cysts connected by fistulae to the bronchioles to facilitate egg excretion. Eggs pass up from the lung in the sputum, which the animal usually swallows such that eggs are passed in the faeces. The prepatent period is 5–6 weeks.

Paragonimus

***Paragonimus* species**

Species	Hosts	Site	Intermediate hosts
<i>Paragonimus westermani</i>	Dog, cat, pig, goat, cattle, fox, other carnivores, human and primates	Lung	Snails of the genera <i>Melania</i> , <i>Ampullaria</i> , <i>Pomatiopsis</i> Crabs and crayfish
<i>Paragonimus kellicotti</i>	Cat, pig, dog	Lung	Snails of the genera <i>Melania</i> , <i>Ampullaria</i> , <i>Pomatiopsis</i> Crabs and crayfish

Paragonimus westermani

Description: The parasite is rounded (lemon-shaped) and thick (7.5–16 mm by 4–8 mm), reddish-brown in colour, and covered in very small scale-like spines. The oral and ventral suckers are similar in size with the ventral sucker situated slightly anterior to the middle of the fluke (Fig. 1.76). The testes are located in the posterior half of the body. Species differentiation is based on the shape of the spines. Those in *P. westermani* are large and have bifid points.

Paragonimus kellicotti

Description: Adult flukes are usually located in pairs in cysts in the lungs of the final host. The spines in *P. kellicotti* are very large and have a number of points.

FAMILY NANOPHYETIDAE

The genus *Nanophyetus* is a fluke found mainly in the small intestine of dogs, mink and other fish-eating mammals. It occurs in the northwest USA and parts of Siberia and is of importance because the flukes are vectors of the rickettsial organism *Neorickettsia helminthoeca*, which causes severe haemorrhagic enteritis of dogs, so-called 'salmon poisoning'. This name is derived from the cycle of the

Prosthogonimus pellucidus

Synonyms: *Prosthogonimus intercalandus*, *Prosthogonimus cuneatus*

Description: Adult flukes are pear-shaped, semi-transparent, pale orange when fresh and measure around 9–12 mm in length, being broader towards the posterior. Two suckers are present. The irregular oval testes lie midline and horizontally. The lobed ovary lies dorsal and midline to the testes.

Prosthogonimus macrorchis

Description: These flukes are very similar to *P. pellucidus* but possess larger testes.

Prosthogonimus ovatus

Description: Adult flukes are smaller than the other two species, measuring 3–6 mm. The testes are slightly elongate and lie side by side midline.

FAMILY PLAGIORCHIIDAE

Plagiorchis are parasites of birds and are mainly located in the gut. One species, *P. arcuatus*, has a similar pathogenesis to *Prosthogonimus*, affecting the bursa of Fabricius in young birds and the oviduct in older birds.

Life cycle: The life cycle involves two intermediate hosts, namely freshwater snails and larvae of dragonflies. The definitive host is infected through eating the dragonflies or their nymphs containing encysted metacercariae.

Plagiorchis

Plagiorchis species

Species	Hosts	Site	Intermediate hosts
<i>Plagiorchis arcuatus</i>	Chicken, other poultry	Oviduct and bursa of Fabricius	Snails Crustacea, insects

Plagiorchis arcuatus

Description: The fluke is oval, about 4–5 mm in length and 1.5 mm in breadth, and tapers to a point at both ends. The cuticle possesses small spines, which are more numerous in the anterior region. The testes are rounded or oval and lie obliquely behind each other. The ovary is rounded, situated near the end of the cirrus sac, and to the right of the ventral sucker.

FAMILY LECITHODENDRIIDAE

The Lecithodendriidae includes the genera *Novotrema*, *Odeningotrema*, *Phaneropsolus* and *Primatotrema*, which are intestinal flukes of primates.

ORDER OPISTHORCHIDA

FAMILY OPISTHORCHIIDAE

The members of this family require two intermediate hosts, the first being water snails and the second a wide variety of fish, in which the metacercariae are encysted. The final hosts are fish-eating mammals in which they inhabit the bile ducts. These oval or fusiform flukes are of medium size and possess suckers which are small and weak and located fairly close together. The ovary and uterus are anterior to the testes. This feature avoids confusion with the similarly sized and shaped microcoeliid flukes where they are positioned posteriorly to the testis.

Clonorchis is by far the most important genus, with *Opisthorchis*, *Metorchis*, *Parametorchis* and *Pseudamphistomum* being of lesser importance.

Clonorchis

Clonorchis species

Species	Hosts	Site	Intermediate hosts
<i>Clonorchis sinensis</i> (syn. <i>Opisthorchis sinensis</i>)	Human, dog, cat, pig, mink, weasel, badger	Bile ducts, pancreatic ducts, occasionally small intestine	Operculated snails (<i>Parafossalurus</i> , <i>Bulimus</i> spp., <i>Bithynia</i> , <i>Melania</i> and <i>Vivipara</i>) Cyprinid fishes

Clonorchis sinensis

Synonym: *Opisthorchis sinensis*

Description: The adult fluke is flat, transparent–pinkish, wide posteriorly and tapering anteriorly, and may reach a size of 25 mm long by 5 mm wide (Fig. 1.77). The cuticle bears spines in the young fluke but is smooth in the adult. The testes are multi-branched and lie posteriorly in the body. There is no cirrus sac.

Life cycle: The eggs normally hatch only after they have been swallowed by the snail first intermediate host. In the snails the miracidium develops into a sporocyst, which produces rediae and these in turn produce cercariae, which have fairly long tails and elongate bodies with pigmented eye-spots. After breaking out of the snail the cercaria swims about, and on meeting a suitable fish it penetrates partly or completely into the tissues of the fish and, losing its tail, becomes encysted in the fish. Infection of the final host occurs through eating raw infected fish. The metacercariae are liberated in the duodenum of the final host and reach the liver by way of the bile duct. The prepatent period is 16 days.

Opisthorchis

Opisthorchis species

Species	Hosts	Site	Intermediate hosts
<i>Opisthorchis felineus</i> (syn. <i>Opisthorchis tenuicollis</i> , <i>Opisthorchis viverrini</i>)	Cat, dog, fox, pig, human, cetaceans	Liver, bile ducts, occasionally pancreatic ducts	Freshwater snails (<i>Bithynia</i> spp.) Freshwater fish

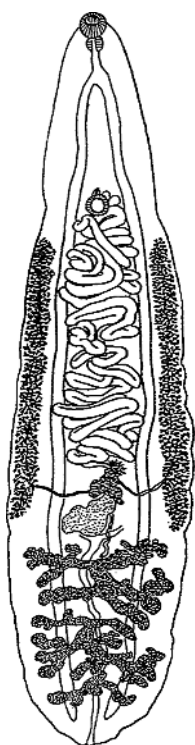


Fig. 1.77 *Clonorchis sinensis*. (Redrawn from Soulsby, 1971. Reproduced with permission from Lord Soulsby of Swaffham Prior.)

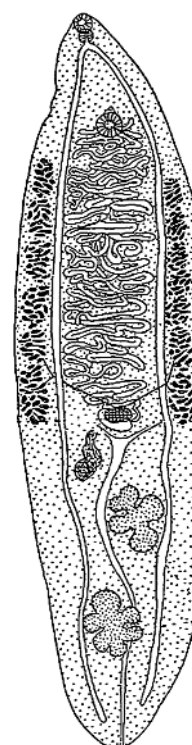


Fig. 1.78 *Opisthorchis felinus*. (Redrawn from Mönning, 1934.)

Opisthorchis felinus

Synonyms: *Opisthorchis tenuicollis*, *Opisthorchis viverrini*

Description: Adult flukes are reddish in colour when fresh, with a smooth cuticle and measure 7–12 mm long by 1.5–2.5 mm broad (Fig. 1.78). The testes are lobed and not branched and a cirrus sac and cirrus are absent. The ovary is small. The intestinal caeca reach to almost the end of the body.

Life cycle: The prepatent period is 2–3 weeks and deposited eggs are ingested by a snail in which cercariae develop in rediae. The cercariae encyst in fish as metacercariae and infect the definitive host when ingested.

Metorchis

***Metorchis* species**

Species	Hosts	Site	Intermediate hosts
<i>Metorchis albidus</i> (syn. <i>Distoma albidum</i> , <i>Opisthorchis albidus</i>)	Dog, cat, fox, seal, some poultry, occasionally human	Liver, bile ducts, gallbladder	Freshwater snails Fishes (<i>Blicca</i>)
<i>Metorchis conjunctus</i>	Dog, cat, fox, mink, raccoon	Liver, bile ducts	Freshwater snails (<i>Amnicola</i>) Fishes (<i>Catostomus</i>)

Metorchis albidus

Synonyms: *Distoma albidum*, *Opisthorchis albidus*

Description: The fluke is spatulate, pointed anteriorly, rounded and flat posteriorly, 2.5–6.5 mm long by 1.0–1.6 mm broad with

a spinous cuticle in the young fluke. The genital pore is in front of the ventral sucker. The testes are located diagonally in the posterior region of the body and they are lobed. The ovary is fairly circular and lies just in front of the anterior testis.

Metorchis conjunctus

Description: Adults measure 1–6.5 mm long by 0.6–2.6 mm broad. The suckers are equal in diameter. The genital pore lies at the anterior margin of the acetabulum. The cuticle of the young fluke possesses spines.

Parametorchis

***Parametorchis* species**

Species	Hosts	Site	Intermediate hosts
<i>Parametorchis complexus</i>	Cat, dog	Liver, bile ducts	Not known, but probably freshwater snails

Parametorchis complexus

Description: The fluke is 5–10 mm long by 1.5–2 mm broad. The uterus forms a rosette around the ventral sucker. The testes are lobed and lie together in the posterior part of the body. The vitelline glands are restricted to the anterior third of the fluke.

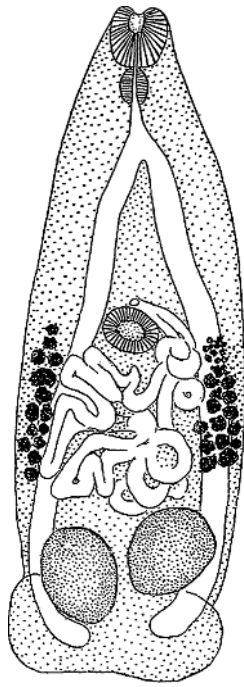


Fig. 1.79 *Pseudamphistomum truncatum*. (Redrawn from Mönnig, 1934.)

Pseudamphistomum

Pseudamphistomum species

Species	Hosts	Site	Intermediate hosts
<i>Pseudamphistomum truncatum</i>	Dog, cat, fox, rarely human	Liver, bile ducts	Snails Fish

Pseudamphistomum truncatum

Description: Adult flukes are small, measuring 2–2.5 mm, with a spiny body that is truncate posteriorly. The testes are spherical and lie horizontally at the posterior end of the body (Fig. 1.79).

FAMILY BRACHYLAEMIDAE

Members of this family are parasites of birds (*Brachylaemus*), sheep (*Skrjabinotrema*) and pigs (*Postharmostomum*). The intermediate hosts are snails. They are of only minor veterinary importance.

Skrjabinotrema

Skrjabinotrema species

Species	Hosts	Site	Intermediate hosts
<i>Skrjabinotrema ovis</i>	Sheep	Small intestine	Snails

Skrjabinotrema ovis

Description: Adult flukes are small with smooth bodies and measure about 1 mm long by 0.3–0.7 mm wide.

Postharmostomum

Postharmostomum species

Species	Hosts	Site	Intermediate hosts
<i>Postharmostomum suis</i>	Pig	Small intestine	Snails

Postharmostomum suis

Description: The body is smooth, elongate and around 4–8 mm in length.

FAMILY HETEROPHYIDAE

These are small trematodes found in the intestines of mammals and birds. The genital pore and the ventral sucker are located in a ventro-genital sac. More than 10 species of the family Heterophyidae have been reported in humans and fish-eating mammals. The life cycle generally involves two intermediate hosts, namely freshwater snails and fishes or frogs. Genera of veterinary interest are *Heterophyes* found in dogs, cats, foxes and humans; *Metagonimus* in the small intestines of dogs, cats, pigs and humans; *Cryptocotyle* of seabirds, reported in dogs and cats; and *Apophallus* (*Rossicotrema*) normally found in seabirds or seals but also reported in cats, dogs and foxes.

Heterophyes

Heterophyes species

Species	Hosts	Site	Intermediate hosts
<i>Heterophyes heterophyes</i>	Dog, cat, fox, human	Small intestine	Snails (<i>Pirenella</i> spp., <i>Cerithida</i> spp.) Fish
<i>Heterophyes nocens</i>	Dog, cat, fox, human	Small intestine	Snails (<i>Pirenella</i> spp.) Fish

Heterophyes heterophyes

Description: This is a small pear-shaped fluke that is wider posteriorly than anteriorly and measuring 1–1.7 mm by 0.3–0.7 mm. The ventral sucker is anterior to the middle of the body and the genital sucker lies immediately behind it and to one side and bears an incomplete circle of 70–80 small rods. The testes are located horizontally and are oval in shape (Fig. 1.80).

Heterophyes nocens

Description: Small ovoid fluke measuring 0.8–1 mm in length by 0.5–0.6 mm in width. The genital sucker is armed with 50–60 small rods and is located close to the ventral sucker.

Metagonimus

Metagonimus species

Species	Hosts	Site	Intermediate hosts
<i>Metagonimus yokagawai</i>	Dog, cat, pig, human	Small intestine	Snails (<i>Semisulcospira</i> spp.) Cyprinid fish, mullet, trout

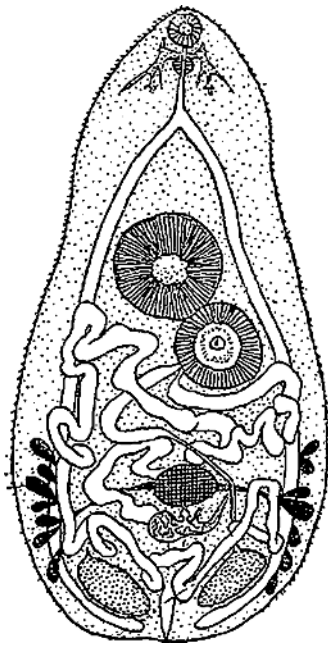


Fig. 1.80 *Heterophyes heterophyes*. (Redrawn from Neveu-Lemaire, 1936. Reproduced with permission from Editions Vigot.)

Metagonimus yokagawai

Description: Small flukes that are wider posteriorly than anteriorly and measuring 1–2.5 mm by 0.4–0.7 mm. The cuticle bears spines over its whole surface. The ventral sucker is right of the median line and close to the genital pore, which opens anteriorly. The testes are slightly oblique and the ovary is median in position.

Apophallus

Apophallus species

Species	Hosts	Site	Intermediate hosts
<i>Apophallus muhlingi</i> (syn. <i>Cotylophallus muhlingi</i>)	Gulls, cormorants, dog, cat	Small intestine	Unknown Fish
<i>Apophallus donicum</i> (syn. <i>Rossicotrema donicum</i>)	Cat, dog, fox, seal	Small intestine	Unknown Fish

Apophallus muhlingi

Synonym: *Cotylophallus muhlingi*

Description: Adult flukes are small and measure 1.2–1.6 mm by 0.2 mm. The cuticle is covered in fine spines. The suckers are small, equal in size and located in the mid-body. The testes are rounded and lie diagonally one behind the other. The ovary is rounded and is opposite the anterior testis.

Apophallus donicum

Synonym: *Rossicotrema donicum*

Description: Flukes are small, measuring 0.5–1.15 mm by 0.2–0.4 mm. The cuticle is covered in spines and the testes are round and large and located in the posterior section of the body.

Cryptocotyle

Cryptocotyle species

Species	Hosts	Site	Intermediate hosts
<i>Cryptocotyle lingua</i>	Gulls, terns, kittiwake, seal, mink, dog, cat, human	Small intestine	Shellfish, snails Fish

Cryptocotyle lingua

Description: Spatula-shaped body, 0.5–2 mm long by 0.2–0.9 mm wide. The cuticle is armed with spines and the suckers are small, with the anterior larger than the ventral sucker. The testes are slightly lobed and lie side by side or diagonally at the posterior end of the body. The ovary is trilobed and lies in front of the testes.

ORDER STRIGEIDIDA

FAMILY SCHISTOSOMATIDAE

This family is primarily parasitic in the blood vessels of the alimentary tract and bladder. In humans, schistosomes are often responsible for severe and debilitating disease and veterinary interest lies in the fact that they can cause a similar disease in animals, some of which may act as reservoirs of infection for humans. The schistosomes differ from other flukes in that the sexes are separate, the small adult female lying permanently in a longitudinal groove, the gynaecophoric canal, in the body of the male (Fig. 1.81). The most important genus is *Schistosoma*, with *Bilharziella*, *Trichobilharzia*, *Orientobilharzia*, *Ornithobilharzia*, *Heterobilharzia* and *Austrobilharzia* other genera of lesser importance.

Schistosoma

The sexes are separate, with the male, which is broad and flat and about 2.0 cm long, carrying the slender female in the hollow of its inwardly curved body. This characteristic and the vascular predilection site are sufficient for generic identification. Suckers are either absent or weak and there is no pharynx. The genus, as currently defined, is paraphyletic so revisions are likely. The genus has been divided into four groups: *haematobium*, *indicum*, *mansoni* and

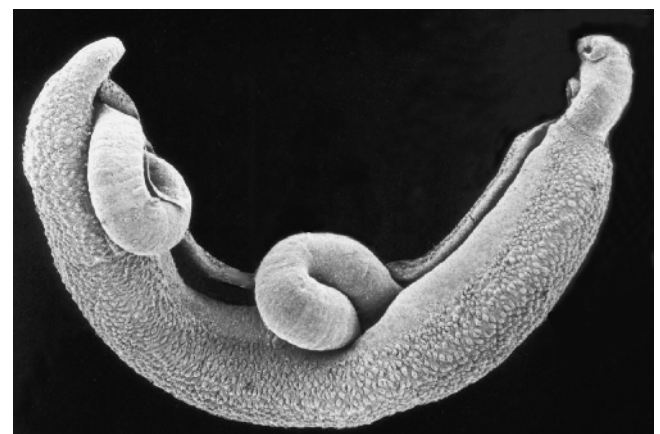


Fig. 1.81 Male and female *Schistosoma* in copula.

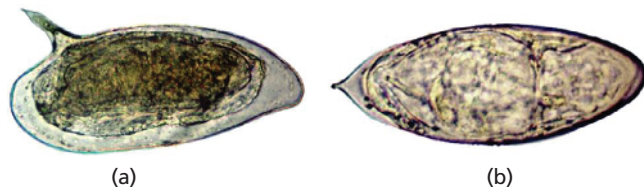


Fig. 1.82 *Schistosoma* egg morphology: (a) *mansoni* group; (b) *haematobium* group.

japonicum. Species found in Africa are divided into two groups: those with a lateral spine on the egg (*mansoni* group) and those with a terminal spine (*haematobium* group) (Fig. 1.82).

Schistosoma species

Species	Hosts	Site	Intermediate hosts
Haematobium group			
<i>Schistosoma bovis</i>	Cattle, sheep, goat, camel	Portal, mesenteric, and urogenital veins	Snails (<i>Bulinus</i> spp., <i>Physopsis</i> spp.)
<i>Schistosoma haematobium</i>	Human, primates	Bladder veins and urethra	Snails (<i>Bulinus</i> spp.)
<i>Schistosoma mattheei</i>	Cattle, sheep, goat, camel, human, primates	Portal, mesenteric and bladder veins	Snails (<i>Physopsis</i> spp.)
<i>Schistosoma leiperi</i>	Cattle, antelope	Mesenteric veins	Snails (<i>Bulinus</i> spp.)
Indicum group			
<i>Schistosoma indicum</i>	Cattle, buffalo, sheep, goat, horse, donkey, camel	Portal, pancreatic, hepatic and mesenteric veins	Snails (<i>Indoplanorbis</i>)
<i>Schistosoma nasalis</i> (syn. <i>Schistosoma nasale</i>)	Cattle, goat, sheep, buffalo, horse	Nasal mucosa veins	Snails (<i>Lymnaea</i> spp., <i>Indoplanorbis</i> spp.)
<i>Schistosoma spindale</i>	Cattle, buffalo, horse, pig and rarely dog	Mesenteric veins	Snails (<i>Planorbis</i> , <i>Indoplanorbis</i> spp., <i>Lymnaea</i> spp.)
Mansoni group			
<i>Schistosoma mansoni</i>	Human, primates, wild animals	Mesenteric veins	Snails (<i>Biomphalaria</i> spp.)
Japonicum group			
<i>Schistosoma japonicum</i>	Cattle, horse, sheep, goat, dog, cat, rabbit, rodents, pig, human	Portal and mesenteric veins	Snails (<i>Oncomelania</i> spp.)
Others			
<i>Schistosoma incognitum</i> (syn. <i>Schistosoma suis</i>)	Pig, dog	Mesenteric veins	Snails (<i>Radix</i> spp.)
<i>Schistosoma turkestanica</i> (syn. <i>Orientobilharzia turkestanicum</i>)	Cattle, buffalo, sheep, goat, camel, horse, donkey, cat	Mesenteric veins and small veins of the pancreas and liver	Snails (<i>Lymnaea</i> spp.)

Schistosoma bovis

Description: The male is 9–22 mm long and 1–2 mm wide, and the female 12–28 mm long. In the male the suckers and the tegument behind the suckers are armed with minute spines, while the dorsal

surface of the tegument bears small cuticular tubercles. The slender female worm lies permanently in a ventral groove in the broad flat body of the male.

Life cycle: The ovigerous female penetrates deeply into the small vessels of the mucosa or submucosa of the intestine and inserts her tail into a small venule. Since the genital pore is terminal, the eggs are deposited, or even pushed, into the venule. There, aided by their spines and by proteolytic enzymes secreted by the unhatched miracidia, they penetrate the endothelium to enter the intestinal submucosa and ultimately the gut lumen; they are then passed out in the faeces. Worms present in the vesical veins penetrate the endothelial lining of the bladder where eggs may be passed in the urine. Some eggs are carried away in the bloodstream and locate in other organs such as the liver. The eggs hatch in water and the miracidia penetrate appropriate snails. Cercariae develop from daughter sporocysts, which replace the redia stage and there is no metacercarial phase; penetration of the final host by the motile cercariae occurs via the skin or by ingestion in drinking water. After penetration or ingestion the cercariae lose their forked tails, transform to schistosomula or young flukes, and travel via the bloodstream through the heart and lungs to the systemic circulation. In the liver they locate in the portal veins and become sexually mature before migrating to their final site, the mesenteric veins. The prepatent period is 6–7 weeks.

Schistosoma mattheei

Description: The male flukes measure around 9–22 mm in length and about 1–2 mm wide. Females range from 12 to 28 mm in length. The body of the male behind the suckers is armed with very long spines, as are the suckers. The dorsal surface possesses small cuticular tubercles.

Schistosoma indicum

Description: The sexes are separate; the males are 5–19 mm and the females 6–22 mm in length.

Schistosoma spindale

Description: The male measures 5–16 mm and the female 7.2–16.2 mm long.

Schistosoma nasalis

Synonym: *Schistosoma nasale*

Description: The male is 6.3–11 mm and the female 5–11 mm long.

Life cycle: Details of the life cycle are not completely known. The female in the veins of the nasal mucosa lays her eggs, which presumably enter the nasal sinuses and are sneezed out. The eggs hatch in minutes in water and the miracidia penetrate appropriate snails. Development to the cercarial stage occurs without a redial form and there is no metacercarial phase. After penetration or ingestion the cercariae transform to schistosomula, or young flukes, and travel to their final site, the nasal veins.

Schistosoma mansoni

Description: The male *S. mansoni* is approximately 1 cm long with a funnel-shaped oral sucker at its anterior end followed by a second pediculated sucker. The female worm has a cylindrical body that is darker, longer and thinner than that of the male (12–16 mm long).

Schistosoma japonicum

Description: The male is broad and flat and 9.5–20 mm long, carrying the female (12–26 mm long) in the hollow of the inwardly curved body. The suckers lie close together near the anterior end. The cuticle is spiny on the suckers and in the gynaecophoric canal. This characteristic and the vascular predilection site are sufficient for generic identification.

Life cycle: This is similar to that of *S. bovis*. Development to the cercarial stage occurs through two generations of sporocyst without a redial form and there is no metacercarial phase, penetration of the final host by the motile cercariae occurring via the skin. The developmental period in the snail can be as short as 5 weeks. Schistosomula, or young flukes, that reach the abdominal vessels and pass to the portal veins become sexually mature in about 4 weeks.

Schistosoma turkestanica

Synonym: *Orientobilharzia turkstanicum*

Description: This is a small species; the male is 4.2–8 mm and the female 3.4–8 mm in length. The female uterus contains only one egg at a time.

Other schistosomes

Other schistosome species

Species	Hosts	Site	Intermediate hosts
<i>Bilharziella polonica</i>	Duck	Mesenteric and pelvic veins	Snails of the genus <i>Planorbis</i>

Bilharziella polonica

Description: The body is lancet-shaped posteriorly and the sexes are separate. Males are about 4 mm and females 2 mm in size. The female genital pore is just behind the ventral sucker and the short uterus contains one egg at a time.

Life cycle: Eggs are laid in the small vessels of the intestinal wall through which they penetrate and are passed out in the faeces. Development takes place in the snail intermediate host and leads to the release of cercariae, which infect the intermediate host either percutaneously or following ingestion.

FAMILY DIPLOSTOMATIDAE

The family Diplostomatidae includes the genera *Alaria* and *Diplostomum*, which are flukes of mammals and birds. Only the former genus is of veterinary significance. The life cycle involves two

intermediate hosts, namely freshwater snails and frogs. The definitive host is infected through eating frogs containing encysted metacercariae (mesocercariae).

Alaria

Alaria are found in the small intestine of dogs, cats, foxes and mink. The anterior forebody of the fluke is flattened or spoon-shaped, and the posterior hindbody is conical and contains the reproductive organs. The oral and ventral suckers are located in the forebody. The life cycle involves freshwater snails as first intermediate hosts, and amphibian or reptile second intermediate hosts.

Life cycle: Unembryonated eggs are passed in the faeces from which miracidia eventually hatch and enter freshwater snails (*Planorbis*). Sporocysts produce cercariae with bifurcated tails. These leave the snail and infect tadpoles or frogs where the cercariae encyst in the muscles forming mesocercariae. If a frog, snake or mouse eats the tadpole, the mesocercariae become encysted, these animals acting as paratenic hosts. Dogs and foxes may be infected by eating rodents infected with mesocercariae. Once infected the mesocercariae migrate extensively, including passage through the lungs and diaphragm, becoming metacercariae before returning to the small intestine and maturing into flukes. The prepatent period is 2–4 weeks.

Alaria species

Species	Hosts	Site	Intermediate hosts
<i>Alaria alata</i>	Dog, cat, fox, mink, wild carnivores and rarely human	Small intestine	Snails (<i>Planorbis</i> spp.) Frogs, toads Paratenic: snakes, rodents
<i>Alaria americana</i>	Dog, fox and other canids	Small intestine	Snails (<i>Planorbis</i> spp.) Frogs, toads
<i>Alaria canis</i>	Dog, fox	Small intestine	Snails (<i>Heliosoma</i> spp.) Frogs, toads
<i>Alaria marcianae</i>	Cat, raccoon	Small intestine	Snails (<i>Heliosoma</i> spp.) Frogs, toads Paratenic: snakes, rodents
<i>Alaria michiganensis</i>	Dog, fox, coyote	Small intestine	Snails (<i>Planorbis</i> spp.) Frogs, toads

Alaria alata

Description: Adult flukes are 2–6 mm in length and the flat spatulate forebody is much longer than the posterior cylindrical hindbody. At the anterior lateral corners of the anterior section there are two tentacle-like processes (Fig. 1.83). The suckers are very small and the adhesive organ comprises two long tubular folds with lateral margins that are distinct.

Alaria americana

Description: Adult flukes range from 2.5 to 4.0 mm in length. The genital pore is located posteriorly on the mid-hindbody. This species is additionally characterised by the presence of pointed processes flanking the oral sucker.

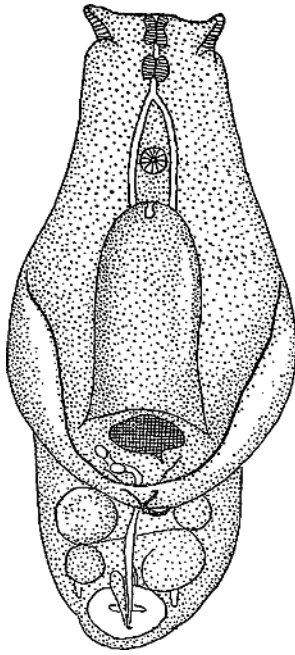


Fig. 1.83 *Alaria alata*. (Adapted from Baylis, 1929.)

Alaria canis

Description: Adult flukes are 2.5–4.2 mm long. There is a conical tentacle-like appendage on each side of the oral sucker. There is an oval holdfast organ with a longitudinal median depression extending from the ventral sucker to the constriction between the anterior and posterior parts of the body. Testes are lobed, with the posterior one much larger.

FAMILY STRIGEIDAE

These flukes are characterised by a constriction dividing the body into an anterior flattened adhesive organ and a posterior cylindrical or oval part, which contains the reproductive system. A cup-shaped adhesive organ is present in the anterior region. They are parasites of the alimentary tract of birds. The life cycle involves two intermediate hosts, freshwater snails of many genera and a second host that may be a fish or leech. Genera include *Apatemon* and *Cotylurus* in the intestine of pigeons and ducks, and *Parastrigea* in ducks.

Apatemon

Apatemon species

Species	Hosts	Site	Intermediate hosts
<i>Apatemon gracilis</i>	Duck, pigeon, wild birds	Intestine	Snails Leeches

Apatemon gracilis

Description: Adult flukes have a cup-like anterior region, containing an adhesive organ, and a posterior cylindrical region and measure 1.5–2.5 mm by 0.4 mm. The suckers are fairly well developed

and the testes and ovary are arranged one behind the other with the ovary foremost. Vitellaria are limited to the posterior region of the body.

Parastrigea

Parastrigea species

Species	Hosts	Site	Intermediate hosts
<i>Parastrigea robusta</i>	Duck	Intestine	Unknown

Parastrigea robusta

Description: The flukes are 2–2.5 mm long and broader in the anterior region (1.5 mm) than the posterior region (1 mm). The genital papilla is large and oviform and the testes are compact and only slightly lobed. The vitellaria are mainly located in the adhesive organ and the lateral expansions, although some extend into the posterior part of the body.

Cotylurus

Cotylurus species

Species	Hosts	Site	Intermediate hosts
<i>Cotylurus cornutus</i>	Duck, pigeon, wild birds	Intestine	Snails

Cotylurus cornutus

Description: The adult flukes are around 1.2–1.5 mm long and 0.5 mm wide with a rounded anterior region and an ovoid posterior region. The oral sucker is smaller than the ventral sucker and the testes and ovary are arranged one behind the other. They are similar to *Apatemon* species but a strong copulatory organ is located in the bursa.

CLASS CESTODA

This class differs from the Trematoda in having a tape-like body with no body cavity or alimentary canal. There is a wide variation in length, ranging from a few millimetres to several metres. The body is segmented, each segment containing one and sometimes two sets of male and female reproductive organs. Almost all the tapeworms of veterinary importance are in the order Cyclophyllidea, the two exceptions being in the order Pseudophyllidea (Table 1.9).

ORDER CYCLOPHYLLIDEA

STRUCTURE AND FUNCTION

The adult cestode (Fig. 1.84) consists of a globular head or **scolex** bearing attachment organs, a short unsegmented neck and a chain of segments. The chain is known as a **strobila** and each segment as a **proglottid**.

The organs of attachment are four suckers on the sides of the scolex and these may bear hooks. The scolex usually bears anteriorly a

Table 1.9 Classification of cestodes of veterinary importance.

Kingdom	Phylum	Class Subclass	Order	Family	Genus	
Animalia	Platyhelminthes	Cestoda	Cyclophyllidea	Taeniidae	<i>Taenia</i> <i>Echinococcus</i>	
				Anoplocephalidae	<i>Anoplocephala</i> <i>Paranoplocephala</i> <i>Moniezia</i> <i>Cittotaenia</i> <i>Thysanosoma</i> <i>Thysaniezia</i> <i>Stilesia</i> <i>Avitellina</i>	
				Dilepididae	<i>Dipylidium</i> <i>Amoebotaenia</i> <i>Choanotaenia</i> <i>Joyeuxiella</i> <i>Diplopylidium</i>	
				Paruterinidae	<i>Metroliasthes</i>	
				Davaineidae	<i>Davainea</i> <i>Raillietina</i> <i>Cotugnia</i> <i>Houttuynia</i>	
				Hymenolepididae	<i>Hymenolepis</i> <i>Fimbriaria</i> <i>Rodentolepis</i>	
				Mesocestoididae	<i>Mesocestoides</i>	
				Pseudophyllidea	Diphyllobothridae	<i>Diphyllobothrium</i> <i>Spirometra</i>

mobile protrusible cone or rostellum and in some species this may be also armed with one or more concentric rows of hooks, which aid in attachment.

The proglottids are continuously budded from the neck region and become sexually mature as they pass down the strobila to the distal end of the tapeworm. Each proglottid is hermaphrodite with one or two sets of reproductive organs, the genital pores usually opening on the lateral margin or margins of the segment (Fig. 1.85);

both self-fertilisation and cross-fertilisation between proglottids may occur. The structure of the genital system is generally similar to that of the trematodes. As the segment matures, its internal structure largely disappears and the fully ripe or gravid proglottid eventually contains only remnants of the branched uterus packed with

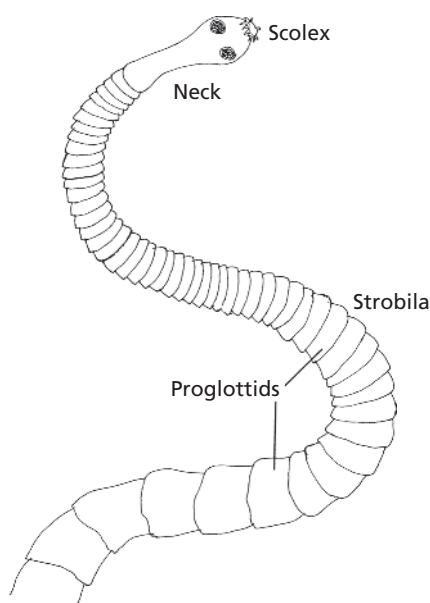


Fig. 1.84 Structure of a typical cyclophyllidean cestode.

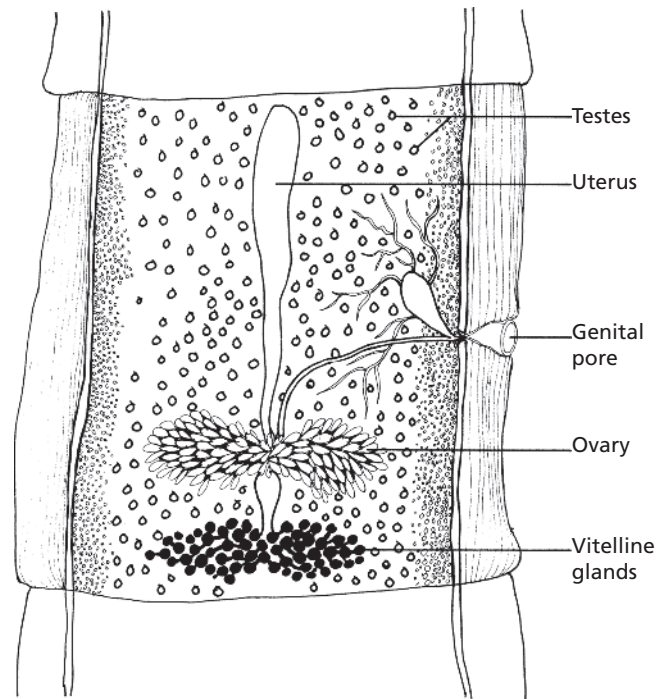


Fig. 1.85 Mature segment illustrating the reproductive organs.

eggs. The gravid segments are usually shed intact from the strobila and pass out with the faeces, either singly or occasionally in chains. Outside the body the eggs are liberated by disintegration of the segment or are shed through the genital pore.

The fully embryonated egg consists of:

- 1 the hexacanth (six-hooked) embryo or **oncosphere**;
- 2 a thick, dark, radially striated 'shell' called the **embryophore** (in the Mesocostoididae it is apparent as a thin cellular membrane);
- 3 a true shell, which is a delicate membrane and is often lost while still in the uterus.

The tegument of the adult tapeworm is highly absorptive, the worm deriving all its nourishment through this structure. Below the tegument are muscle cells and the parenchyma, the latter a syncytium of cells, which fills the space between the organs. The nervous system consists of ganglia in the scolex from which nerves run posteriorly and enter the strobila. The excretory system, as in the Trematoda, is composed of flame cells leading to efferent canals that run through the strobila to discharge at the terminal segment.

LIFE CYCLE

The typical life cycle of these cestodes is indirect with one or more intermediate hosts. With few exceptions, the adult tapeworm is found in the small intestine of the final host, the segments and eggs reaching the exterior in the faeces.

When the egg is ingested by the intermediate host, the gastric and intestinal secretions digest the embryophore and activate the oncosphere. Using its hooks, it tears through the mucosa to reach the blood or lymph stream or, in the case of invertebrates, the body cavity. Once in its predilection site the oncosphere loses its hooks and develops, depending on the species, into one of the following larval stages, often known as **metacestodes** (Fig. 1.86).

- **Cysticercus**: Single fluid-filled cyst or bladder containing an attached single invaginated scolex, sometimes called a protoscolex.
- **Coenurus**: This large cyst is similar to a cysticercus, but with numerous invaginated scolices attached to the cyst wall.
- **Strobilocercus**: The scolex is evaginated and is connected to the cyst by a chain of segmented asexual proglottids. The latter are digested away after ingestion by the final host, leaving only the scolex.
- **Hydatid**: This is a large, fluid-filled, complex cyst lined with germinal epithelium from which are produced invaginated scolices which lie free or in bunches, surrounded by germinal epithelium (brood capsules). The contents of the cysts other than the fluid (i.e. scolices and brood capsules) are frequently described as 'hydatid sand'. Occasionally also, daughter cysts complete with cuticle and germinal layer are formed endogenously or, if the cyst wall ruptures, exogenously.
- **Cysticercoid**: A single evaginated scolex embedded in a small solid cyst. Typically found in very small intermediate hosts such as arthropods.
- **Tetrathyridium**: Worm-like, flattened and elongate larva with an invaginated acetabular scolex; found only in Mesocostoididae.

When the metacestode is ingested by the final host the scolex attaches to the mucosa, the remainder of the structure is digested off, and a chain of proglottids begins to grow from the base of the scolex.

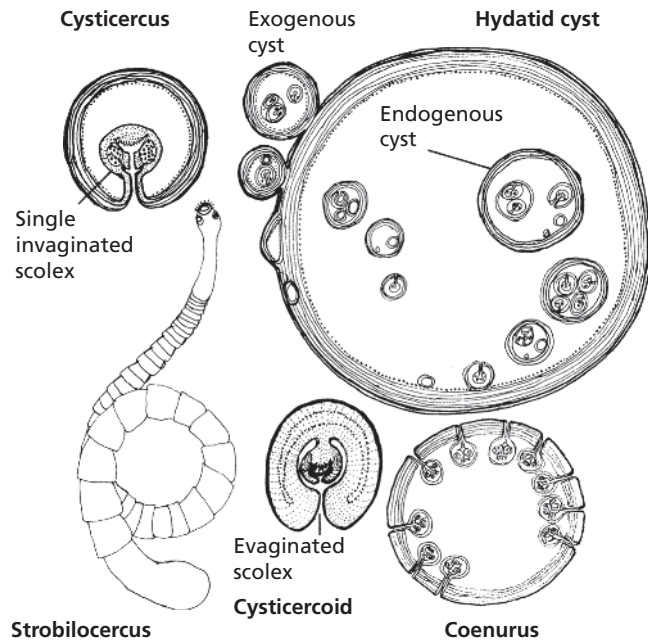


Fig. 1.86 Larval stages of cyclophyllidean cestodes.

The seven main families of veterinary interest in the order Cyclophyllida are the Taeniidae, Anoplocephalidae, Dilepididae, Davaineidae, Hymenolepididae, Mesocostoididae and Paruterinidae.

FAMILY TAENIIDAE

The adults are, in most cases, large tapeworms and are found in domestic carnivores and humans in the small intestine. Genera of importance are *Taenia* (syn. *Multiceps*) and *Echinococcus*. The scolex has an armed rostellum with a concentric double row of hooks (the important exception is *Taenia saginata* whose scolex is unarmed). The gravid segments are longer than they are wide.

The intermediate stage is a cysticercus, strobilocercus, coenurus or hydatid cyst and these occur only in mammals. Historically, the intermediate stage has been named according to the type of metacestode stage present in the intermediate host. Thus *Cysticercus tenuicollis* found in the ruminant host is the metacestode stage of *Taenia hydatigena* in the dog. The correct nomenclature now is for the intermediate host stage to be referred to as the 'metacestode stage' of the adult *Taenia* species.

Taenia

Members of the genus *Taenia* are large tapeworms comprising a number of species. Differentiation is usually based on the size of the scolex, the size of the rostellum and number of hooks, and on the morphology of the genital system within the mature proglottids. The adults of *Taenia* are usually of minor importance in domesticated animals, and it is the larval stages which are of veterinary interest.

Taenia species

Species	Final hosts	Intermediate hosts (larval stage)	Site
<i>Taenia asiatica</i> (syn. <i>Taenia saginata asiatica</i>)	Human	Cattle	Muscle
<i>Taenia crassiceps</i>	Fox, coyote	Rodents	Abdominal cavity, various tissues
<i>Taenia hydatigena</i> (syn. <i>Taenia marginata</i>)	Dog, fox, wild canids, mustelids	Cattle, sheep, goat, pig (<i>Cysticercus tenuicollis</i>)	Abdominal cavity, liver
<i>Taenia multiceps</i> (syn. <i>Multiceps multiceps</i>)	Dog, fox, wild canids	Sheep, cattle, goat, pig, horse, deer, camel, human (<i>Coenurus cerebralis</i>)	Brain, spinal cord
<i>Taenia skrjabini</i>		Sheep (<i>Coenurus skrjabini</i>)	Muscle, subcutaneous tissue
<i>Taenia (Multiceps) gaigeri</i>		Goat (<i>Coenurus gaigeri</i>)	
<i>Taenia ovis</i> (syn. <i>Taenia cervi</i> , <i>Taenia krabbei</i> , <i>Taenia hyaenae</i>)	Dog, fox, wild canids	Sheep, goat (<i>Cysticercus ovis</i>) Deer (<i>Cysticercus cervi</i>) Reindeer (<i>Cysticercus tarandi</i>) Camel (<i>Cysticercus dromedarii</i> , <i>Cysticercus cameli</i>)	Muscle
<i>Taenia pisiformis</i>	Dog, fox, wild canids	Rabbit, hare (<i>Cysticercus pisiformis</i>)	Peritoneum, liver
<i>Taenia saginata</i> (syn. <i>Taeniarhynchus saginata</i>)	Human	Cattle, occasionally other ruminants (<i>Cysticercus bovis</i>)	Muscle
<i>Taenia serialis</i> (syn. <i>Multiceps serialis</i>)	Dog	Rabbit, hare (<i>Coenurus serialis</i>)	Connective tissue
<i>Taenia solium</i>	Human	Pig, wild boar (<i>Cysticercus cellulosae</i>)	Muscle
<i>Taenia taeniaeformis</i> (syn. <i>Hydatigera taeniaeformis</i> , <i>Taenia crassicolis</i>)	Cat, wild felids	Small rodents (<i>Strobilocercus fasciolaris</i> ; syn. <i>Strobilocercus crassicolis</i>)	Liver

Taenia asiatica

Synonym: *Taenia saginata asiatica*

Description: Similar to *T. saginata*. The adult tapeworm is about 3.5 m long with a scolex bearing four simple suckers and the rostellum is usually surrounded by two rows of rudimentary hooklets. It is unique in having posterior protruberances in the gravid proglottid, which are absent in other taeniids including *T. saginata*. The metacestode differs morphologically from that of *T. saginata* in having wart-like formations on the external surface of the bladder wall.

Taenia hydatigena

Synonyms: *Taenia marginata*, *Cysticercus tenuicollis*

Description: *Taenia hydatigena* is a large tapeworm measuring up to 5 m in length. The scolex is large and has two rows of 26 and 46

rostellar hooks. Gravid proglottids measure 12 by 6 mm and the uterus has 5–10 lateral branches. The semi-transparent cysticercus may be up to 5–7 cm in size (see Fig. 9.54) and contains a watery fluid and invaginated scolex with a long neck.

Life cycle: Dogs and wild canids are infested by consuming the cysticercus in the intermediate host. The intermediate host is infected through the ingestion of tapeworm eggs that hatch in the intestine. The oncospheres, infective to sheep, goats, cattle and pigs, are carried in the blood to the liver in which they migrate for about 4 weeks before they emerge on the surface of this organ and attach to the peritoneum. Within a further 4 weeks each develops into the characteristically large metacestode, *Cysticercus tenuicollis*. The complete life cycle of this tapeworm is around 7–8 months.

Taenia multiceps

Synonyms: *Multiceps multiceps*, *Coenurus cerebralis*, *Taenia skrjabini*, *Coenurus skrjabini*, *Taenia (Multiceps) gaigeri*, *Coenurus gaigeri*

Description: Adult tapeworms are 40–100 cm in length and have a small head about 0.8 mm in diameter with four suckers. There is a double ring of 22–32 rostellar hooks (Fig. 1.87). The gravid segments measure 8–12 mm by 3–4 mm and the uterus has 18–26 lateral branches which contain taeniid eggs. The metacestode larval stage (*Coenurus cerebralis*) is readily recognised when mature as a large fluid-filled cyst up to 5.0 cm or more in diameter bearing random clusters of invaginated scolices, sometimes up to several hundred, on its internal wall (Fig. 1.88).

Life cycle: The intermediate host is infected through the ingestion of *T. multiceps* eggs. Each egg contains an oncosphere that hatches and is activated in the small intestine. The oncosphere then penetrates the intestinal mucosa and is carried via the blood to the brain or spinal cord where each oncosphere develops into the metacestode larval stage (*Coenurus cerebralis*). In goats, the cysts can also mature in subcutaneous and intramuscular sites. The cysts in sheep and goats often persist throughout the life of the animal. The life cycle is completed when the final host, dog or wild canid, eats an infected sheep brain or spinal cord.

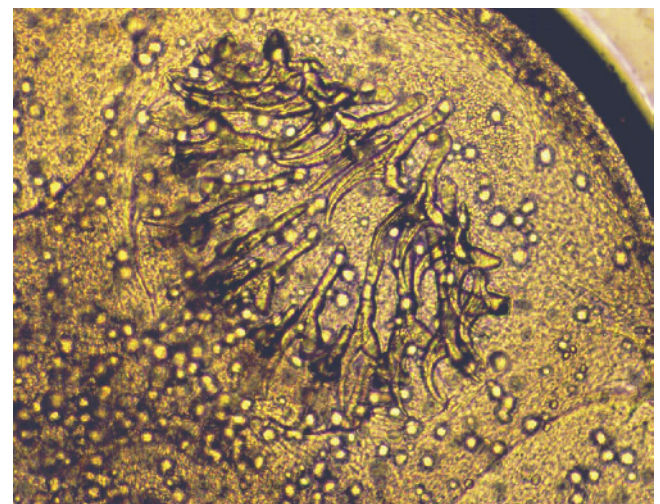


Fig. 1.87 Rostellar hooks of *Taenia (Multiceps) multiceps*.

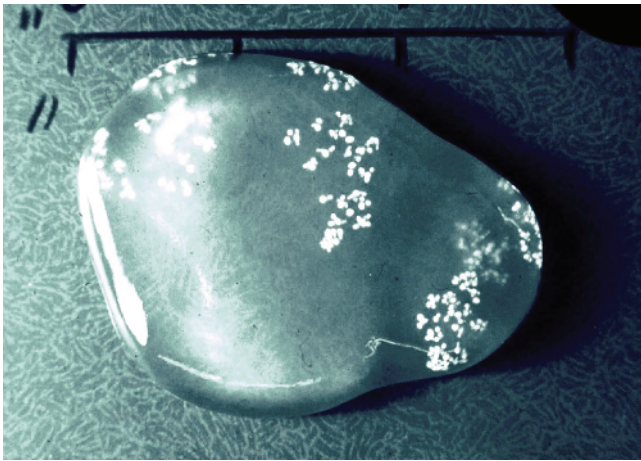


Fig. 1.88 *Coenurus cerebralis* metacestode stage of *Taenia multiceps*.



Fig. 1.90 Scolex of *Taenia pisiformis* showing the four suckers and armed rostellum.

Taenia ovis

Synonyms: *Cysticercus ovis*, *Taenia cervi* (*Cysticercus cervi*), *Taenia krabbei* (*Cysticercus tarandi*), *Taenia hyaenae* (*Cysticercus dromedarii*, *Cysticercus cameli*)

Description: The adult tapeworm is large, measuring 0.5–1.5 m in length. The rostellum bears 24–36 hooks. The strobila has a scalloped edge and is often coiled into a spiral. The mature proglottids have a vaginal sphincter and the ovary and vagina cross each other. The uterus of the gravid proglottids has 20–25 lateral branches on either side. Each cysticercus occurs within a small cyst measuring about 4 mm or less in length (Fig. 1.89).

Life cycle: Dogs and wild canids are infested by consuming the cysticercus in the intermediate host. The intermediate host is infected through the ingestion of tapeworm eggs that hatch in the intestine. The metacestode stage (*Cysticercus ovis*) infects the musculature and cysts are usually located in the skeletal muscle, heart, diaphragm and intermuscular connective tissue. The cyst becomes infective around 2–3 months after infection of the host. The prepatent period in dogs is around 6–9 weeks.

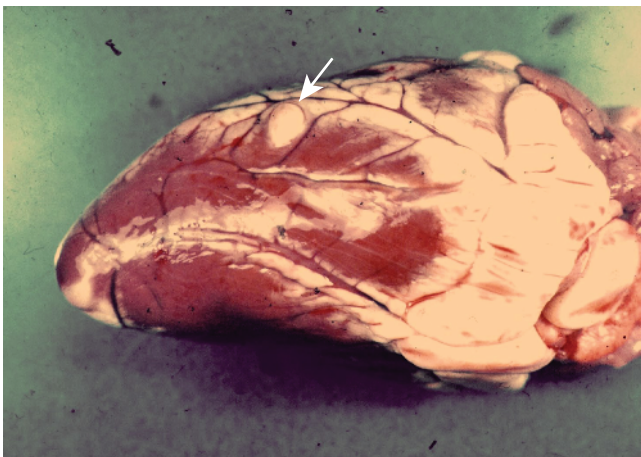


Fig. 1.89 *Cysticercus ovis* metacestode stage of *Taenia ovis* in sheep heart (arrowed).

Taenia pisiformis

Synonym: *Cysticercus pisiformis*

Description: The adult tapeworm can measure up to 2 m in length. It has a large scolex with narrow strobila and the rostellum has 34–48 hooks in two rows (Fig. 1.90). Gravid segments have a uterus with 8–14 lateral branches on either side. The cysticercus is a small pea-like transparent cyst and usually occurs in bunches.

Life cycle: Infection of the intermediate host is through ingestion of tapeworm eggs shed by dogs. Ingested eggs hatch in the small intestine of the intermediate host and penetrate the intestinal wall and pass via the portal system to the liver. Juvenile stages migrate through the liver parenchyma and locate in the abdominal cavity after 2–4 weeks, where they develop into cysts (*Cysticercus pisiformis*) attached to the wall of the mesentery and omentum. Cysts can survive the life of the host. The final host is infected by ingesting the cysticercus. The prepatent period in the dog is around 6–8 weeks.

Taenia saginata

Synonyms: *Taeniarhynchus saginata*, *Cysticercus bovis*

Description: The adult tapeworm is usually 5–8 m long, rarely up to 15 m. The scolex has neither a rostellum nor hooks. Gravid segments are 16–20 mm long by 4–7 mm wide and the uterus has 15–35 lateral branches on either side. In cattle, the mature cysticercus, *C. bovis*, is greyish-white, oval, about 0.5–1.0 by 0.5 cm long, and filled with fluid in which the scolex is usually clearly visible. As in the adult tapeworm, it has neither rostellum nor hooks.

Life cycle: An infected human may pass millions of eggs daily, either free in the faeces or as intact segments each containing about 250,000 eggs, and these can survive on pasture for several months. After ingestion by a susceptible bovine, the oncosphere travels via the blood to striated muscle. It is first grossly visible about 2 weeks later as a pale semi-transparent spot about 1.0 mm in diameter, but is not infective to humans until about 12 weeks later when it has reached its full size of around 1.0 cm. By then it is enclosed



Fig. 1.91 Scolex of *Taenia solium*.

by the host in a thin fibrous capsule but despite this the scolex can usually still be seen. The longevity of the cysts ranges from weeks to years. When they die they are usually replaced by a caseous crumbly mass, which may become calcified. Both living and dead cysts are frequently present in the same carcass. Humans become infected by ingesting raw or inadequately cooked meat. Development to patency takes 2–3 months.

Taenia serialis

Synonyms: *Multiceps serialis*, *Coenurus serialis*

Description: The adult tapeworm is of medium length, around 0.5–0.7 m long. The scolex is armed with two rows of 26–32 hooks (Fig. 1.92). The gravid uterus possesses 20–25 lateral branches on either side. The metacystode cysts may be 4–6 cm in size and the scolices are distributed in packed rows within the cyst.

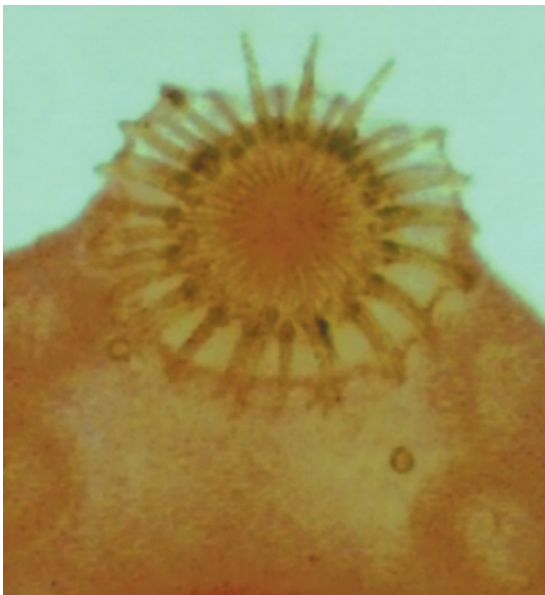


Fig. 1.92 Scolex of *Taenia serialis*.

Life cycle: Infection of the intermediate host is through ingestion of tapeworm eggs shed by dogs. The intermediate stage, *Coenurus serialis*, is found in the rabbit, usually subcutaneously or in the intermuscular connective tissue. The final host is infected by ingesting the metacystode stage.

Taenia solium

Synonym: *Cysticercus solium*

Description: The adult tapeworm is 3–5 m long, rarely up to 8 m. The rostellum has four radially arranged suckers and bears four suckers and 22–32 hooks in two rows (Fig 1.91), one row of large hooks measuring 0.14–0.18 mm and one row of smaller hooks measuring 0.11–0.14 mm. Gravid segments are 10–12 mm long and 5–6 mm wide. The ovary is in the posterior third of the proglottid and has two lobes with an accessory third lobe. The uterus has 7–12 lateral branches on either side.

The cysticerci have morphologically distinct types. The commonest is the ‘cellulose’ cysticercus which has a fluid-filled bladder that is 0.5–1.5 cm in length with an invaginated scolex. The ‘racemose’ form has no evident scolex, but are larger and up to 20 cm in length.

Life cycle: Gravid segments passed in the faeces, frequently in chains, each contain around 40,000 eggs and because they are non-motile they tend to be concentrated over a small area. Eggs can also resist destruction for a relatively long period. After ingestion by a susceptible pig the oncosphere travels via the blood to striated muscle. The principal location is the striated muscles, but cysticerci may also develop in other organs, such as the lungs, liver, kidney and brain. Humans become infected by ingesting raw or inadequately cooked pork containing viable cysticerci. The human final host may also act as an intermediate host and become infected with cysticerci. This is most likely to occur from the accidental ingestion of *T. solium* eggs via unwashed hands or contaminated food. There is also, apparently, a minor route of autoinfection in a person with an adult tapeworm, from the liberation of oncospheres after the digestion of a gravid segment that has entered the stomach from the duodenum by reverse peristalsis. The prepatent period is 2–3 months.

Taenia taeniaeformis

Synonyms: *Hydatigera taeniaeformis*, *Taenia crassicollis*, *Strobilocercus fasciolaris*, *Strobilocercus crassicollis*

Description: The adult tapeworm is of medium size, up to 70 cm in length. The scolex is large with a double row of rostellar hooks and there is absence of a neck region (Fig. 1.93). The uterus has five to nine lateral branches and the posterior proglottids are bell-shaped. The metacystode stage is a strobilocercus (*Strobilocercus fasciolaris*), which is a small cyst connected with an evaginated scolex by a segmented juvenile strobila.

Life cycle: The metacystode (*Cysticercus fasciolaris*) develops in the liver of rodents and is infective to cats after about 9 weeks. When a cat ingests the metacystode the scolex attaches to the wall of the intestine. Tapeworms in cats become patent around 6 weeks and eggs are ingested by the intermediate host. Cats can remain infected for up to about 2 years.



Fig. 1.93 Scolex of *Taenia taeniaeformis*.

Echinococcus

The genus *Echinococcus* is composed of several species that exploit predator-prey systems between carnivores (mainly canids) as principal hosts and intermediate hosts that range from rodents to livestock depending on the species. Six species are currently recognised in the genus *Echinococcus* with a seventh, *Echinococcus shiquicus*, recently described. Considerable phenotypic and genetic variability has been observed within the species *E. granulosus* and several strains have been identified based on molecular genotyping. New data demonstrate that '*E. granulosus*' is an assembly of several rather diverse strains and genotypes (designated G1–G10) that show fundamental differences, not only in their epidemiology but also in their pathogenicity to humans. *Echinococcus equinus* was formerly known as the horse strain (G4) of *E. granulosus*. *Echinococcus ortelevpi*, the former cattle strain (G5), is adapted to transmission by cattle. *Echinococcus oligarthus* and *E. vogeli* exist in wildlife cycles and are morphologically similar to *E. multilocularis* and cause polycystic echinococcosis in humans.

Echinococcus species

Species	Hosts	Intermediate hosts	Site
<i>Echinococcus granulosus</i>	Dog, fox, wild canids	Sheep, cattle, camel, pig, buffalo, deer, human	Liver, lungs
<i>Echinococcus equinus</i> (G4)	Dog	Horse, donkey	Liver
<i>Echinococcus ortelevpi</i> (G5)	Dog	Cattle	Liver
<i>Echinococcus multilocularis</i>	Dog, fox, cat, wild canids, human	Rodents, pig	Liver
<i>Echinococcus vogeli</i>	Wild canids	Rodents	Liver
<i>Echinococcus oligarthus</i>	Wild felids	Rodents	Liver

Echinococcus granulosus (*Echinococcus equinus*, *Echinococcus ortelevpi*)

Description: The entire cestode is only about 6.0 mm long, and is therefore difficult to find in the freshly opened intestine. It consists of a scolex and usually three or four segments, the terminal gravid one occupying about half the length of the complete tapeworm (Fig. 1.94). The scolex is typically taeniid and the rostellum has two rows of hooks, varying from in number from 30 to 60. Each segment has a single genital opening, with the penultimate segment sexually mature and the last segment gravid. The genital pores alternate irregularly. The gravid proglottid normally disintegrates in the alimentary tract and only eggs are expelled in faeces.

Hydatid cysts are large fluid-filled vesicles, 5–10 cm in diameter, with a thick concentrically laminated cuticle and an internal germinal layer. The germinal layer produces numerous small vesicles or brood capsules each containing up to 40 scolices, invaginated into their neck portions and attached to the wall by stalks. Brood capsules may become detached from the wall of the vesicle and float freely in the vesicular fluid and form 'hydatid sand'.

Life cycle: The prepatent period in the final host is around 40–50 days, after which only one gravid segment is shed per week. The oncospheres are capable of prolonged survival outside the host, being viable on the ground for about 2 years. After ingestion by the intermediate host, the oncosphere penetrates the gut wall and travels in the blood to the liver or in the lymph to the lungs. These are the two commonest sites for larval development, but occasionally oncospheres escape into the general systemic circulation and develop in other organs and tissues. Growth of the hydatid is slow, maturity being reached in 6–12 months. In the liver and lungs the cyst may have a diameter of up to 20 cm, but in the rarer sites, such as the abdominal cavity, where unrestricted growth is possible, it may be very large and contain several litres of fluid. The cyst capsule consists of an outer membrane and an inner germinal epithelium from which, when cyst growth is almost complete, brood capsules each containing a number of scolices are budded off. Many of these brood capsules become detached and exist free in the hydatid fluid; collectively these and the scolices are often referred to as 'hydatid sand'. Sometimes, complete daughter cysts are formed either inside the mother cyst or externally; in the latter case they may be carried to other parts of the body to form new hydatids.



Fig. 1.94 *Echinococcus granulosus* showing the scolices, and the large gravid posterior proglottids.

Echinococcus multilocularis

Description: *Echinococcus multilocularis* is a very small tapeworm (2–4 mm) and is generally similar to *E. granulosus*, but usually with three to five segments, the terminal one measuring less than half the length of the whole worm (Fig. 1.95). The scolex has four suckers and possesses a double row of large and small hooks (about 14–34). The third segment of the adult tapeworm is sexually mature and the genital pores are in front of the middle of each segment. The uterus is sac-like with no lateral sacculations in the terminal proglottid. Gravid segments contain around 200–300 spherical eggs. Eggs that are shed have a diameter of about 30–40 µm. The structure of the metacestode consists of a germinative gelatinous matrix forming a cystic structure with internal brood capsules and protoscolices which form racemose proliferative masses of metacestodes within infected livers of the intermediate hosts.

Life cycle: *Echinococcus multilocularis* is typically maintained in a sylvatic (wildlife) cycle, although in some rural communities a synanthropic cycle occurs with the domestic dog acting as definitive host. The intermediate host is infected by ingestion of the oncosphere and subsequent passage, via the circulatory system, to the liver where it develops into a multilocular or alveolar cyst (metacestode stage). The cycle is completed when the definitive host consumes an infected intermediate host, the mature tapeworm developing in about 5 weeks. Adult tapeworms are relatively short-lived, about 6 months.

Echinococcus vogeli

Description: *Echinococcus vogeli* is a very small tapeworm (4–6 mm) and usually has three segments, the terminal gravid segment being very long in comparison to the rest of the tapeworm. The uterus is sac-like, long and tubular in shape. The metacestode has a polycystic structure.



Fig. 1.95 *Echinococcus multilocularis*.

Echinococcus oligarthus

Description: *Echinococcus oligarthus* is an extremely small tapeworm (2.5–3.0 mm) and usually has three segments.

FAMILY ANOPLOCEPHALIDAE

These are essentially tapeworms of horses (*Anoplocephala*, *Paranoplocephala*) and ruminants (*Moniezia*, *Stilesia*, *Thysanosoma*, *Thysaniezia* and *Avitellina*). Species of *Cittotaenia* are found in lagomorphs. The scolex has neither rostellum nor hooks and the gravid segments are wider than they are long. The intermediate stage is a cysticercoid present in forage mites of the family Oribatidae.

Life cycle: Mature segments are passed in the faeces and disintegrate, releasing the eggs. These are ingested by forage mites in which they develop to the cysticercoid stage in 2–4 months. The adult tapeworms are found in the intestine of horses 1 or 2 months after the ingestion of infected mites in the herbage.

Anoplocephala

Anoplocephala species

Species	Hosts	Site	Intermediate hosts
<i>Anoplocephala perfoliata</i>	Horse, donkey, other equids	Terminal ileum, rarely caecum	Forage mites (Oribatidae)
<i>Anoplocephala magna</i>	Horse, donkey, other equids	Small intestine	Forage mites (Oribatidae)

Anoplocephala perfoliata

Description: Adult tapeworms measure 4–8 cm in length and 1.2 cm in width. There is a small rounded scolex, 2–3 mm in diameter, with a pair of 'lappets' just behind the four suckers, but there is neither rostellum nor hooks. It has a very short neck and the strobila widens rapidly, individual proglottids being much wider than they are long and containing only a single set of reproductive organs. The large gravid uterus is lobed and shaped like a sac.

Anoplocephala magna

Description: *Anoplocephala magna* is similar morphologically to *A. perfoliata* but much longer, up to 80 cm long by 2.5 cm wide and is similar to a broad ribbon. The scolex is large, 4–6 mm wide, with suckers opening anteriorly, and there are no lappets on the scolex. The neck is short as are the segments. The genital organs are single and the pores are unilateral.

Paranoplocephala

Paranoplocephala species

Species	Hosts	Site	Intermediate hosts
<i>Paranoplocephala mamillana</i> (syn. <i>Anoplocephaloides mamillana</i>)	Horse, donkey	Small intestine	Forage mites (Oribatidae)
<i>Paranoplocephala cuniculi</i>	Rabbit	Small intestine	Forage mites (Oribatidae)

Paranoplocephala mamillana

Synonym: *Anoplocephaloides mamillana*

Description: *Paranoplocephala mamillana* is only 10–50 mm long by 4–6 mm wide and is often referred to as the equine ‘dwarf tapeworm’. There are no lappets on the narrow scolex and the suckers are slit-like and located ventrally and dorsally. The scolex is large and without rostellum and hooks. The gravid segments are wider than they are long.

Life cycle: Mature proglottids or eggs are passed in the faeces and on to pasture where the oncospheres are ingested by forage mites. The oncospheres are only infective for mites for about 3 months. The embryos migrate into the body cavity of the mite where they develop to cysticercoids in 1–4 months and infection of the final host is by ingestion of infected mites during grazing. The prepatent period is approximately 6 weeks, but the adult worms appear to be short-lived, patent infections persisting for only about 3 months.

Moniezia

Moniezia species

Species	Hosts	Site	Intermediate hosts
<i>Moniezia expansa</i>	Sheep, goat	Small intestine	Forage mites (Oribatidae)
<i>Moniezia benedeni</i>	Cattle, buffalo	Small intestine	Forage mites (Oribatidae)

Moniezia expansa

Description: These are long tapeworms, up to 600 cm or more, which possess unarmed scolices and have four prominent suckers (Fig. 1.96). Segments are broader than they are long (up to 1.5 cm wide) and contain two sets of genital organs grossly visible along the lateral margin of each segment (Table 1.10 and Fig. 1.97). There is a row of inter-proglottid glands extending along the whole breadth of the posterior border of each segment, which may be used in species differentiation.



Fig. 1.96 Scolex of *Moniezia expansa* with four prominent suckers.

Table 1.10 Tapeworms of ruminants.

Tapeworm	Description
<i>Moniezia</i>	Long wide tapeworms up to 600 cm long. Segments broader than long with two sets of genital organs
<i>M. expansa</i>	Row of inter-proglottid glands along whole breadth of posterior border
<i>M. benedeni</i>	Inter-proglottid glands confined to short row close to the middle of the posterior margin
<i>Thyasanosoma actinoides</i>	Short tapeworms up to 30 cm long. Segments short and fringed posteriorly containing two sets of genital organs
<i>Thyasaniezia ovilla</i>	Long tapeworms up to 200 cm long. Segments wider than long with single genital pore alternating irregularly
<i>Stilesia globipunctata</i>	Short thin tapeworms up to 60 cm long. Single genital pore alternating irregularly. Two distinct set of testes present
<i>Avitellina centripunctata</i>	Long thin tapeworms up to 300 cm in length. Segments wider than long and indistinct except for last few. Single genital pore alternating irregularly

Source: Drawings reproduced from Ransom (1911) and Soulsby (1971). Reproduced with permission from Lord Soulsby of Swaffham Prior.

Moniezia benedeni

Description: Grossly similar to *M. expansa*. Segments are broader than they are long (up to 2.5 cm wide). In *M. benedeni*, the inter-proglottid glands are confined to a short row close to the middle of the posterior margin of the segment (Table 1.10).

Thyasanosoma

Thyasanosoma species

Species	Hosts	Site	Intermediate hosts
<i>Thyasanosoma actinoides</i>	Sheep, cattle, deer	Small intestine, bile and pancreatic ducts	Oribatid mites (<i>Galuma</i> , <i>Schelioribates</i>) and psocids (bark lice, dust lice)

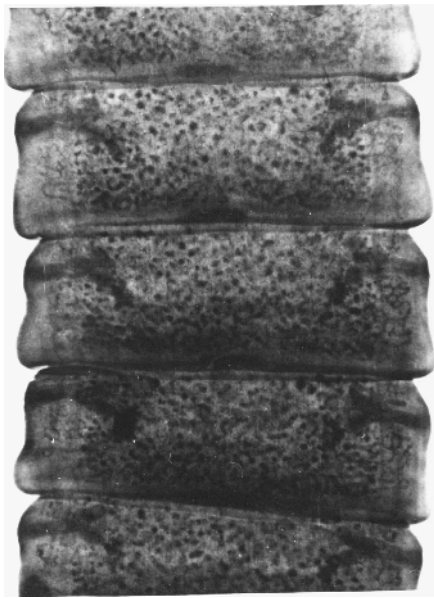


Fig. 1.97 Proglottids of *Moniezia expansa* containing two sets of genital organs.

Thysanosoma actinoides

Description: The adult ‘fringed’ tapeworms measure 15–30 cm in length by 8 mm in width. The scolex is up to 1.5 mm in breadth; segments are short and fringed posteriorly. In the distal regions of the tapeworm the ‘fringes’ are as long as the proglottid (Table 1.10 and Fig. 1.98). Each proglottid contains two sets of genital organs with the testes lying medially. Several paruterine organs are present in each proglottid.

Life cycle: Mature segments are passed in the faeces of the infected host on to pasture, where forage mites ingest the oncospheres. Cysticercoids develop within the oribatid intermediate hosts and infection of the final host is by ingestion of infected mites during grazing.

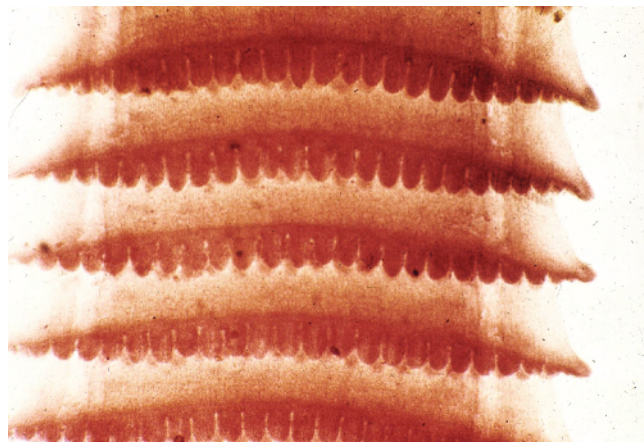


Fig. 1.98 *Thysanosoma actinoides* showing ‘fringed’ proglottids.

Thysaniezia

Thysaniezia species

Species	Hosts	Site	Intermediate hosts
<i>Thysaniezia ovilla</i> (syn. <i>Thysaniezia giardia</i> , <i>Helictometra giardi</i>)	Cattle, sheep, goat, camel and wild ruminants, occasionally pig	Small intestine	Oribatid mites (<i>Galuma</i> , <i>Scheloribates</i>) and psocids (bark lice, dust lice)

Thysaniezia ovilla

Synonyms: *Thysaniezia giardia*, *Helictometra giardi*

Description: Adults reach 200 cm in length, varying in width up to 12 mm. The scolex is small, measuring up to 1 mm in diameter, and the suckers are slit-like in appearance. Segments are short, bulge outwards giving the margin of the worm an irregular appearance, and contain a single set of genital organs, rarely two, with genital pores alternating irregularly. Mature segments have an undulating uterus (Table 1.10).

Stilesia

Stilesia species

Species	Hosts	Site	Intermediate hosts
<i>Stilesia globipunctata</i>	Sheep, goat, cattle, other ruminants	Small intestine	Oribatid mites and psocid lice
<i>Stilesia hepatica</i>	Sheep, goat, cattle, wild ruminants	Liver, bile ducts	Oribatid mites?
<i>Stilesia vittata</i>	Camel	Small intestine	Oribatid mites?

Stilesia globipunctata

Description: Adults measure 45–60 cm in length by 3–4 mm in width. The narrow scolex has four large suckers, but no hooks. Strobila is broader than long. A single set of genital organs is present and genital pores alternate irregularly (Table 1.10). Two distinct sets of testes are present in each segment, one on each side, but no testes in the median line.

Stilesia hepatica

Description: The adult tapeworm measures 20–50 cm in length and 2–3 mm in width. The neck is narrow and the scolex is large with prominent suckers. The genital organs are single and the opening pores alternate irregularly. There are 10–12 testes on either side lying dorsal to the ventral canal. The proglottids are short.

Life cycle: The life cycle is not known but probably involves oribatid mites.

Stilesia vittata

Description: Adults are 18–23 cm long. Mature proglottids contain five to seven testes lying lateral to the ventral canal.

Avitellina

Species of this genus occur in the small intestine of ruminants in parts of Africa, Europe and India.

Life cycle: The life cycle is similar to that of *Moniezia*.

Avitellina species

Species	Hosts	Site	Intermediate hosts
<i>Avitellina centripunctata</i> (syn. <i>Avitellina woodlandi</i>)	Sheep, goat, camel and other ruminants	Small intestine	Oribatid mites or psocid lice
<i>Avitellina goughi</i>	Sheep	Small intestine	Oribatid mites or psocid lice
<i>Avitellina chalmersi</i>	Sheep	Small intestine	Oribatid mites or psocid lice
<i>Avitellina tatia</i>	Goat	Small intestine	Oribatid mites or psocid lice

Avitellina centripunctata

Synonym: *Avitellina woodlandi*

Description: This tapeworm resembles *Moniezia* on gross inspection except that the segmentation is so poorly marked that it appears somewhat ribbon-like. It can reach 3 m in length and about 3–4 mm in width and the posterior end is almost cylindrical in appearance. Proglottids are short with indistinct segmentation and single genitalia present with the pores alternating irregularly (Table 1.10).

Cittotaenia

Parasites of this genus are found in rabbits and hares.

Life cycle: Mature proglottids or eggs are passed in the faeces and on to pasture where the oncospheres are ingested by forage mites. The embryos migrate into the body cavity of the mite where they develop to cysticercoids. Infection of the final host is by ingestion of infected mites during grazing.

Cittotaenia species

Species	Hosts	Site	Intermediate hosts
<i>Cittotaenia ctenoides</i>	Rabbit	Small intestine	Oribatid mites
<i>Cittotaenia denticulata</i>	Rabbit	Small intestine	Oribatid mites
<i>Cittotaenia pectinata</i>	Rabbit, hare	Small intestine	Oribatid mites

Cittotaenia ctenoides

Description: Mature tapeworms grow up to 80 cm long and 1 cm wide. The scolex is about 0.5 mm wide and bears a short neck. The proglottids are much wider than they are long and each contains two sets of genital organs containing 60–80 testes behind an ovary on each side.

Cittotaenia denticulata

Description: Differs from *C. ctenoides* by having a wider scolex (0.8 mm) and no neck.

Cittotaenia pectinata

Description: Very similar to *C. ctenoides* but with a smaller scolex (0.25 mm) but also bears a short neck.

FAMILY DILEPIDIDAE

These are small to medium-sized tapeworms of the dog, cat (*Dipylidium*) and fowl (*Amoebotaenia*, *Choanotaenia*). The scolex usually has an armed rostellum with several rows of hooks. The suckers may also possess fine hooks. The gravid uterus is retained as a transverse sac. The intermediate stage is a cysticercoid.

Dipylidium

This is the commonest tapeworm genus of the domestic dog and cat. *Dipylidium* is a much shorter tapeworm than *Taenia*, the maximum length being about 50 cm.

Life cycle: The newly passed segments are active, and can crawl about on the tail region of the animal. The oncospheres are contained in egg packets or capsules, each with about 20 eggs, and these are either expelled by the active segment or released by its disintegration.

After ingestion by the intermediate host, the oncospheres travel to the abdominal cavity where they develop into cysticercoids. All stages of the biting louse can ingest oncospheres, but the adult flea, with its mouthparts adapted for piercing, cannot do so and infection is only acquired during the larval stage, which has chewing mouthparts. Development in the louse, which is permanently parasitic and therefore enjoys a warm habitat, takes about 30 days, but in the flea larva and the developing adult in the cocoon, both of which are on the ground, development may extend over several months. The final host is infected by ingestion of the flea or louse containing the cysticercoids, usually while grooming. Development to patency, when the first gravid segments are shed, takes about 3 weeks.

Dipylidium species

Species	Hosts	Site	Intermediate hosts
<i>Dipylidium caninum</i>	Dog, fox and cat; rarely human	Small intestine	Fleas (<i>Ctenocephalides</i> spp., <i>Pulex irritans</i>) and lice (<i>Trichodectes canis</i>)

Dipylidium caninum

Description: This medium-sized tapeworm can be up to 50 cm in length. The small scolex has four suckers and a protrusible rostellum, which is armed with three or four rows of small rose-thorn shaped hooks (Fig. 1.99). The mature gravid proglottids are easily recognised, being oval/elongate like a large rice grain, and have two sets of genital organs, with a pore opening on each margin (Fig. 1.100). Each egg capsule can contain 5–30 eggs (see Fig. 12.8).

Amoebotaenia

Small tapeworms found in the duodenum of chickens with earthworms as intermediate hosts.



Fig. 1.99 Scolex of *Dipylidium caninum* with four suckers and protrusible rostellum.

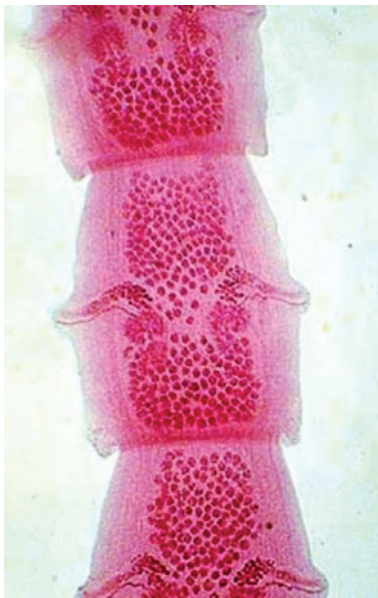


Fig. 1.100 Proglottids of *Dipylidium caninum* with two sets of genital organs.

Life cycle: See *Raillietina cesticillus*. The prepatent period is around 4–5 weeks.

Amoebotaenia species

Species	Hosts	Site	Intermediate hosts
<i>Amoebotaenia sphenoides</i> (syn. <i>Amoebotaenia cuneata</i>)	Chicken	Small intestine	Earthworms

Amoebotaenia sphenoides

Synonym: *Amoebotaenia cuneata*

Description: A very small tapeworm, up to about 4.0 mm long by 1 mm wide, with up to 20 proglottids, each wider than long.

These proglottids are approximately triangular in shape, although the last few segments decrease in size. Its overall appearance is slightly fluke-like. The rostellum bears a single circular row of 12–14 hooks. In the single reproductive organ the genital pores alternate regularly.

Choanotaenia

These are large robust tapeworms, up to 20 cm in length, found in chickens, turkeys and other gallinaceous birds.

Choanotaenia species

Species	Hosts	Site	Intermediate hosts
<i>Choanotaenia infundibulum</i>	Chicken, turkey, gamebirds	Small intestine	House fly (<i>Musca domestica</i>), beetles (<i>Aphodius</i> , <i>Calathus</i> , <i>Geotrupes</i> , <i>Tribolium</i>) and grasshoppers

Choanotaenia infundibulum

Description: A relatively large tapeworm up to 20 cm in length and 1.5–3 mm in width. Each segment is wider posteriorly, giving the margin of the tapeworm a ‘saw-edge’ appearance. The scolex is triangular, pointed anteriorly with a distinctive rostellum, ringed with about 18 slender hooks. A single set of reproductive organs is present in each proglottid and the genital pores alternate regularly.

Joyeuxiella and *Diplopylidium*

These two genera contain a couple of species of restricted veterinary importance. In these tapeworms the genital apertures are sited anterior to the middle of the proglottid. Each egg capsule contains only one egg.

Joyeuxiella pasquale has been found in the cat and the dog in Africa and the Middle East and Australia. It is very similar to *Dipylidium*. It requires two intermediate hosts: firstly, various beetles and secondly, a lizard or small mammals.

Diplopylidium nolleri and *D. trinchesi* occur in the cat and the dog in the Middle East. Two intermediate hosts are involved: firstly, various beetles and secondly, a reptile or small mammals.

FAMILY PARUTERINIDAE

Members of this family, which are parasites of birds, are closely related to the Dilepididae but possess a paruterine organ.

Metroliasthes

Metroliasthes species

Species	Hosts	Site	Intermediate hosts
<i>Metroliasthes lucida</i> (syn. <i>Hexaparuterins lucida</i>)	Turkey, chicken	Small intestine	Grasshoppers (<i>Chorthippus</i> , <i>Paroxya</i> , <i>Melanopus</i>)

Metroliaesthes lucida

Synonym: *Hexaparuterins lucida*

Description: The tapeworm is about 20 cm long and 1.5–2.0 mm wide. The scolex has no rostellum or hooks and the suckers are devoid of spines. The single genital pores are irregularly alternating and can be prominent. Each gravid proglottid possesses a single paruterine organ containing one egg.

FAMILY DAVAINIIDAE

These are mainly parasites of birds (*Davainea*, *Raillietina*, *Cotugnia*, *Houttuynia*). These tapeworms usually have rows of hooks on both rostellum and suckers. Egg capsules replace the uterus in this family. The intermediate stage is a cysticeroid.

Davainea

This genus contains *Davainea proglottina*, the most pathogenic cestode of poultry.

Life cycle: Gravid proglottids are shed in faeces and eggs are ingested by various gastropod molluscs, in which they develop to the cysticeroid stage after about 3 weeks. Following ingestion of the mollusc by the final host, the cysticeroids develop into adult tapeworms in about 2 weeks.

Davainea species

Species	Hosts	Site	Intermediate hosts
<i>Davainea proglottina</i>	Chicken, turkey, pigeon and other gallinaceous birds	Small intestine	Slugs (<i>Agriolimax</i> , <i>Arion</i> , <i>Cepaea</i> and <i>Limax</i>) and land snails

Davainea proglottina

Description: *Davainea proglottina* is an extremely small cestode up to 1–4 mm long, and usually possesses only four to nine segments. The rostellum bears 80–94 hooks, arranged in a double row, and the suckers bear a few rows of small hooks. Each segment contains a single set of reproductive organs. The genital pores alternate regularly. Eggs are located singly in capsules in the gravid segment.

Raillietina

Species of this genus are found in the small intestine of chickens and turkeys and other fowl with the cysticeroid intermediate stage, depending on the species, in ants or beetles.

Life cycle: Gravid proglottids are passed in faeces and eggs are ingested by various intermediate hosts. The embryo hatches from the egg in the intestine and then changes into a cysticeroid in the body cavity. Following ingestion by the final host the activated cysticeroid attaches to the mucosa of the anterior or mid small intestine. The prepatent period is around 2–3 weeks.

Raillietina species

Species	Hosts	Site	Intermediate Hosts
<i>Raillietina cesticillus</i> (syn. <i>Skrjabinia cesticillus</i>)	Chicken, turkey, guinea fowl	Small intestine	Various genera of beetles, cockroaches, <i>Musca domestica</i>
<i>Raillietina echinobothrida</i>	Chicken, turkey	Small intestine	Ants of the genera <i>Pheidole</i> and <i>Tetramorium</i>
<i>Raillietina tetragona</i>	Chicken, guinea fowl, peafowl and pigeon	Small intestine	Houseflies (<i>Musca domestica</i>) and ants of the genera <i>Pheidole</i> , <i>Tetramorium</i> and <i>Onthophagus</i>
<i>Raillietina georgiensis</i>	Turkey	Small intestine	Ants of the genera <i>Pheidole</i> and <i>Tetramorium</i>

Raillietina cesticillus

Description: A small tapeworm that can reach around 10–14 cm in length, but is often much shorter at about 4–5 cm long. The broad scolex is large and the rostellum wide. The unarmed suckers are not prominent and the rostellum is armed with several hundred small hammer-shaped hooks arranged in a double row. The gravid proglottids contain several thin-walled egg capsules, each housing a single egg.

Raillietina echinobothrida

Description: Tapeworms of this species may be up to 20–25 cm in length, and similar in shape to *R. tetragona*. The suckers are circular and armed with several rows of small hooklets and the rostellum is well endowed with two rows of around 200 hooks (these features enable it to be distinguished from *R. tetragona*). A 'neck' is absent behind the scolex. The gravid proglottids contain multiple fibrous-walled egg capsules, each housing several eggs (around 6–12).

Raillietina tetragona

Description: Often the largest tapeworm of fowl reaching around 20–25 cm in length. The scolex is smaller than that of *R. echinobothrida* and the 'neck' is quite prominent. The oval suckers are lightly armed with several rows of fine hooklets and the rostellum bears one or sometimes two rows of around 100 hooks. The gravid proglottids contain multiple fibrous-walled egg capsules, each housing many eggs (about 8–14).

Raillietina georgiensis

Description: The length of this tapeworm is around 15–35 cm. The rostellum is covered with about 100 hooks.

Cotugnia

Cotugnia species

Species	Hosts	Site	Intermediate hosts
<i>Cotugnia digonopora</i>	Chicken	Small intestine	Ants, beetles?
<i>Cotugnia fastigata</i>	Duck, goose	Small intestine	Unknown
<i>Cotugnia cuneata</i>	Pigeon	Small intestine	Unknown

Cotugnia digonopora

Description: The tapeworm is up to 10 cm long. The head is large with a small rudimentary retractile rostellum, which is armed with two rows of small hooklets. The suckers are large and unarmed and the proglottids are wider than long. Segments possess a double set of genital organs.

Life cycle: The life cycle is unknown but is thought to involve ants or beetles.

Houttuynia

Houttuynia species

Species	Hosts	Site	Intermediate hosts
<i>Houttuynia struthionis</i>	Ostrich, rhea	Small intestine	Unknown

Houttuynia struthionis

Description: These are large, long, flat, white segmented tapeworms (60–120 cm long by 9 mm wide). The scolex is 1–2 mm wide and bears a double row of about 160 large and small hooks. The eggs are contained within parenchymatous capsules in the gravid proglottid. There are around 15–25 eggs in each capsule. Genital pores are unilateral.

Life cycle: The life cycle is unknown.

FAMILY HYMENOLEPIDIDAE

These small to medium-sized parasites are of minor veterinary importance. Members of this family, which have a characteristically slender strobila with a conical rostellum, infect birds, humans and rodents (*Hymenolepis*, *Rodentolepis*, *Fimbriaria*). The intermediate stage is a cysticercoid present in an arthropod host.

Hymenolepis

This genus contains a large number of species occurring mainly in domestic and wild birds. The tapeworms are usually narrow and thread-like in appearance with three testes in each segment.

Hymenolepis species

Species	Hosts	Site	Intermediate hosts
<i>Hymenolepis cantaniana</i> (syn. <i>Stephylepis cantaniana</i>)	Chicken, turkey, pheasant, quail and other fowl	Small intestine	Beetles (Scarabaeidae)
<i>Hymenolepis carioca</i> (syn. <i>Echinolepis carioca</i>)	Chicken, turkey and other fowl	Small intestine	Dung and flour beetles; occasionally <i>Stomoxys</i> spp.
<i>Hymenolepis lanceolata</i> (syn. <i>Drepanidotaenia lanceolatum</i>)	Duck, goose	Small intestine	Freshwater crustaceans (copepods)

Hymenolepis cantaniana

Synonym: *Stephylepis cantaniana*

Description: A slender tapeworm, reaching a length of up to 2 cm. The rostellum is rudimentary and the suckers are unarmed.

Hymenolepis carioca

Synonym: *Echinolepis carioca*

Description: This is a slender thread-like tapeworm reaching a length of up to 8 cm. The scolex is unarmed. The proglottids number 500–1100 and are broader than they are long.

Hymenolepis lanceolata

Synonym: *Drepanidotaenia lanceolatum*

Description: A slender tapeworm reaching up to 15–20 cm in length. The proglottids are much wider than they are long.

Fimbriaria

Fimbriaria species

Species	Hosts	Site	Intermediate hosts
<i>Fimbriaria fasciolaris</i>	Chicken, duck, goose and wild anseriform birds	Small intestine	Copepods (<i>Cyclops</i> spp. and <i>Diaptomus</i> spp.)

Fimbriaria fasciolaris

Description: This is not a common cestode. The adult tapeworms vary in length from 2.5 cm up to about 40 cm. The scolex is small with 10 hooks but the anterior part of the body possesses a 'pseudoscolex' (a folded body expansion) for attachment to the host. The presence of this expansion aids diagnosis. The uterus is a continuous tube which separates into small tubules in the posterior of the worm. These tubules contain eggs which retain the outer spindle-shaped shell and they contain the oval embryophores. The genital pores are unilateral with three testes to each set of genital organs.

Rodentolepis

Parasites of rats and mice (formerly *Hymenolepis*) and includes the dwarf tapeworm (*Rodentolepis nana*) and the rat tapeworm (*Rodentolepis diminuta*), which can infect humans.

Rodentolepis species

Species	Hosts	Site	Intermediate hosts
<i>Rodentolepis nana</i> (syn. <i>Hymenolepis nana</i> , <i>Hymenolepis fraterna</i> , <i>Vampirolepis nana</i>)	Rat, mouse, human	Small intestine	Flour beetles (<i>Tenebrio</i>) or fleas
<i>Rodentolepis diminuta</i> (syn. <i>Hymenolepis diminuta</i>)	Rat, mouse, human	Small intestine	Moths, cockroaches, fleas, beetles, millipedes

Rodentolepis nana

Synonyms: *Hymenolepis nana*, *Hymenolepis fraterna*, *Vampirolepis nana*

Description: The tapeworm is small, 2.5–4 cm in length, and has a characteristically slender strobila with about 200 segments. The scolex has four suckers and is armed with a retractable rostellum

bearing a single row of 20–30 hooks. The genitalia are single and the segments are wider than they are long.

Life cycle: The life cycle can be direct, the cysticercoids developing in the villi of the small intestine of the final host and then emerging to develop to the adult tapeworm in the intestinal lumen. Otherwise flour beetles or fleas can serve as intermediate hosts.

Rodentolepis diminuta

Synonym: *Hymenolepis diminuta*

Description: A small tapeworm, about 20–60 mm in length. The rostellum does not possess hooks.

FAMILY MESOCESTOIDIDAE

Also of minor veterinary importance, these cestodes of carnivorous animals and birds have two metacestode stages. The first is a cysticercooid in an insect or mite, and the second a solid larval form, a tetrathyridium, in a vertebrate. Genera include *Mesocestoides* found in dogs, cats and wild mammals, and *Dithyridium* in chickens, turkeys and wild birds.

Mesocestoides

Adult tapeworms are found in the small intestine of dogs, cats and wild carnivores. The second intermediate stages (tetrathyridia) occur in the peritoneal and pleural cavities or subcutaneous tissue of a wide variety of vertebrate hosts (*Dithyridium*, *Tetrathyridium*).

Life cycle: The life cycle requires two intermediate hosts. A cysticercooid is produced in the first intermediate host which, when eaten by the second intermediate host, forms a tetrathyridium; this may remain as an encapsulated form for some time. The tetrathyridium is located in the peritoneal cavity in reptiles and mammals and in the lungs in birds. Dogs and cats can start to shed tapeworm segments in faeces as early as 3 weeks after infection.

***Mesocestoides* species**

Species	Hosts	Site	Intermediate hosts
<i>Mesocestoides lineatus</i>	Dog, cat, fox, mink and wild carnivores, occasionally human	Small intestine	Oribatid mites (cysticercooid) Coprophagus beetles Birds, amphibians, reptiles, mammals (tetrathyridium)

Mesocestoides lineatus

Synonyms: *Dithyridium variable*, *Tetrathyridium bailetti*, *Tetrathyridium elongatum*

Description: The adult tapeworm ranges from 30 to 250 cm in length and up to 3 mm wide. The scolex is large, unarmed and without a rostellum, and the four suckers are elongate and oval. The strobila is thin and narrow, up to 1.5 cm in length. Mature segments are longer than wide and each contains a single set of central reproductive organs, the central genital pore opening on the dorsal surface (Fig. 1.101). The ovary and vitelline glands are bilobed and there are numerous testes. Oncospheres in gravid segments progress from the uterus into a paruterine organ.



Fig. 1.101 Proglottid of *Mesocestoides lineatus* with single set of central genital organs opening dorsally.

ORDER PSEUDOPHYLLIDEA

The morphology of the Pseudophyllidea is generally similar to that of the Cyclophyllidea, but there are three distinct features. First, the unarmed scolex has no suckers and instead has two weakly muscular, shallow longitudinal grooves or **bothria**, which become flattened to form organs of attachment. Secondly, the proglottids possess a uterine pore that enables eggs to be discharged from a large length of the strobila. The terminal proglottids are not gravid and usually are exhausted and may become detached in short chains. Thirdly, the eggshell is thick, brownish-yellow and operculate, and the **coracidium**, which emerges after hatching, is an oncosphere with an embryophore which is ciliated for mobility in water.

The pseudophyllidean life cycle utilises two intermediate hosts. The coracidium must first be ingested by a crustacean in whose body cavity a larval **procercooid** develops. Subsequently, if the crustacean is eaten by a freshwater fish, amphibian or reptile, the procercooid is liberated and in the muscles of the new host develops into a second larval stage, a **plerocercoid**, which possesses the characteristic scolex; it is only this stage which is infective to the final host.

This order contains only two genera of veterinary importance, *Diphyllobothrium* and *Spirometra*.

FAMILY DIPHYLLOBOTHRIIDAE

Parasites of cetaceans, fish-eating mammals and other vertebrates with well-developed bothria.

Diphyllobothrium

The genus *Diphyllobothrium* is an important cestode of humans and fish-eating mammals. They are long tapeworms with an unarmed scolex, with two muscular bothria.



Fig. 1.102 Egg of *Diphyllbothrium latum*.

Life cycle: Eggs are continuously discharged from the genital pores of the attached gravid segments of the strobila and pass to the exterior in the faeces. They resemble *F. hepatica* eggs, being yellow and operculate, but are approximately half the size (Fig. 1.102). The eggs must develop in water and within a few weeks each hatches to liberate a motile ciliated coracidium which, if ingested by a copepod, develops into the first parasitic larval stage, a worm-like procercoïd. When the copepod is ingested by a freshwater fish, the procercoïd migrates to the muscles or viscera to form the second larval stage, the plerocercoid; this solid larval metacestode is about 5.0 mm long and possesses the characteristic scolex. The life cycle is completed when the infected fish is eaten raw, or insufficiently cooked, by the final host. Development to patency is rapid, occurring within 3–4 weeks of ingestion of the plerocercoid. However, if the infected fish is eaten by a larger fish, the plerocercoid has the ability to establish itself in its new host.

Diphyllbothrium species

Species	Hosts	Site	Intermediate hosts
<i>Diphyllbothrium latum</i>	Human and fish-eating	Small intestine	Copepods: <i>Cyclops</i> spp. and <i>Diaptomum</i> spp. (procercoïd)
(syn. <i>Dibothriocephalus latus</i>)	mammals such as dog, cat, pig, polar bear		Freshwater fish: pike, trout, perch (plerocercoid)

Diphyllbothrium latum

Synonym: *Dibothriocephalus latus*

Description: A very long, ivory-coloured tapeworm measuring up to 10–15 m in length or longer, with several hundred, or in some cases a few thousand, proglottids. The scolex is unarmed with two weak muscular longitudinal grooves or bothria as organs of attachment. Anterior proglottids are broader than long while the mature and gravid segments are rectangular-shaped with a central genital pore. The uterus is situated centrally and is rosette-shaped.

Spirometra

Spirometra are small to medium-sized tapeworms of dogs, cats and wild carnivores and an occasional human zoonosis (sparganosis). A couple of features enable differentiation from the very similar genus *Diphyllbothrium*: the vagina and uterus exit separately onto the ventral surface of the proglottid; and the uterus has a spiral form whereas in *Diphyllbothrium* it has a rosette shape.

Life cycle: The morphology and life cycle of these tapeworms is similar to that of *D. latum*, the procercoïds being found in crustaceans, such as *Cyclops*, and the plerocercoids in a wide variety of hosts. These can also act as paratenic hosts. The plerocercoids can also transfer between intermediate hosts. The prepatent period is around 20–30 days.

Spirometra species

Species	Hosts	Site	Intermediate hosts
<i>Spirometra mansoni</i>	Dog, cat, wild carnivores, occasionally human	Small intestine	Copepods: <i>Cyclops</i> spp. (procercoïd) Amphibia, reptiles, birds (plerocercoid)
<i>Spirometra mansonoides</i> (syn. <i>Diphyllbothrium mansonoides</i>)	Cat, bobcat, raccoon, occasionally dog	Small intestine	Crustacea (procercoïd) Rats, snakes, mice (plerocercoid or spargana)
<i>Spirometra erinacei</i> (syn. <i>Spirometra erinacei-europaei</i>)	Cat, dog, fox	Small intestine	Crustacea (procercoïd) Frogs (plerocercoid)

Spirometra mansoni

Description: The adult tapeworms are very similar to *Diphyllbothrium*, measuring around 6–35 cm in length. Proglottids possess both a uterine and a vaginal pore and the uterus is spiral in shape.

Spirometra mansonoides

Synonym: *Diphyllbothrium mansonoides*

Description: The adult worms are pinkish in color and gravid proglottids have a tightly coiled uterus full of brown eggs.

Spirometra erinacei

Synonym: *Spirometra erinacei-europaei*

Description: Adult tapeworms can reach 1.5 m in length and possess a finger-like scolex with the bothria fading into the strobila. The proglottids contain a spiral uterus with two to three coils and a dumbbell-shaped ovary that is transversely long.