II

Parasites of Cattle

CONTENTS

J. Kaufmann, *Parasitic Infections of Domestic Animals*

1 Stages in the gut and faeces

PROTOZOA

- Protozoa oocysts found in the faeces

Eimeria spp. Bovine coccidiosis

Location: Terminal ileum, caecum, colon
Hosts: Cattle
Species description: Of the 21 species of *Eimeria* that infect cattle, *E. bovis* and *E. zuerni* are most often associated with clinical disease. Coccidiosis is commonly a disease of young cattle and occurs especially in management systems (night holding place, limited water source, paddocks) which concentrate the hosts and the parasites within a restricted area. Bloody diarrhoea, progressive weight loss and death, especially in animals after weaning can result from heavy infections. Ruminants do normally excrete a few *Eimeria* spp. oocysts. The condition called coccidiosis includes both severe dysentery and excretion of a high number of oocysts.
Geographic distribution: World-wide
Symptoms: Diarrhoea lasting for a few hours, followed by a self cure or development of severe dysentery accompanied by a haemorrhagic and viscous diarrhoea, dehydration and paralysis. Death can occur rapidly, mainly in calves. Another form of coccidiosis is characterized by persisting, non-haemorrhagic diarrhoea with continuous weight loss until cachexia. This condition may last for several weeks. Animals that survive severe illness can have significant weight loss that is not quickly regained, or can remain permanently stunted.
Significance: *E. bovis* and *E. zuerni* are most commonly involved in clinical coccidiosis of cattle.
Diagnosis: Clinical signs and extremely high numbers of oocysts per gram of faeces (50,000–500,000).
Therapy: The drugs that are commonly used to treat clinical coccidiosis in ruminants are listed in Table 1. These include sulfonamids, nitrofurazone, amprolium (10 mg/kg po. > 10 days), monensin (1 mg/kg po. for 10–30 days) and lasalocid (0.5–1 mg/kg po. for up to 6 weeks). Sulfadimidine (33% solution for intravenous injection), sulfamethazine (50–100 mg/kg, po. daily for 4 days), sulfaquinoxaline (15 mg/kg, po. for 3 days) may be used to treat sick animals. Sulfaguanidine is less effective than the soluble sulfonamides which can be administered orally or parenterally. Sulfonamides, combined with trimethoprime can also be used to treat clinical coccidiosis. Toltrazuril (1 × 20 mg/kg) is highly effective to treat clinical coccidiosis in ruminants.
Prophylaxis: Young animals should be kept in clean and dry quarters, and watering devices should be protected from faecal contamination. Decoquinate, amprolium and ionophorous antibiotics can be used in cattle for prophylaxis (Table 3). Neonates should receive colostrum within 6 hours after birth and stress (e.g. weaning, sudden change in feed, etc.) should be minimized.
(Figures 14, 15, 16, 17, 18, 19, 20, 21, 23, Table 3)

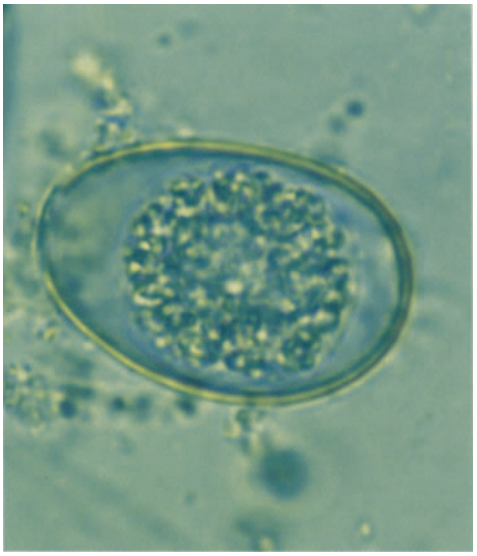


Fig. 14 Oocyst of *Eimeria bovis*
(26–32 × 18–21 µm)

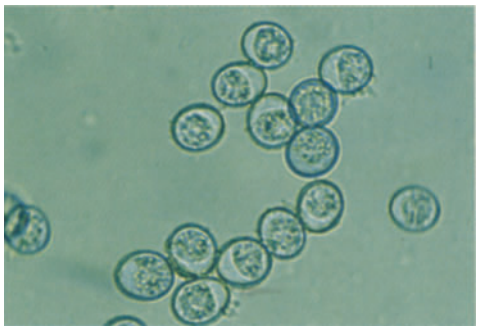


Fig. 15 Oocysts of *Eimeria zuerni*
(16–20 × 15–18 µm)

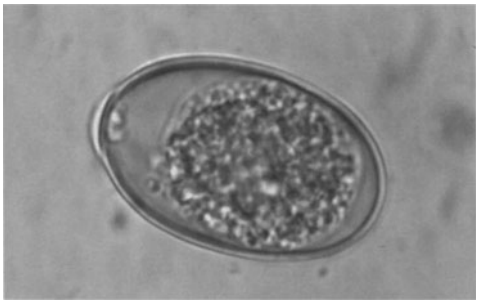


Fig. 16 Oocyst of *Eimeria brasiliensis*
(33–42 × 23–30 µm)

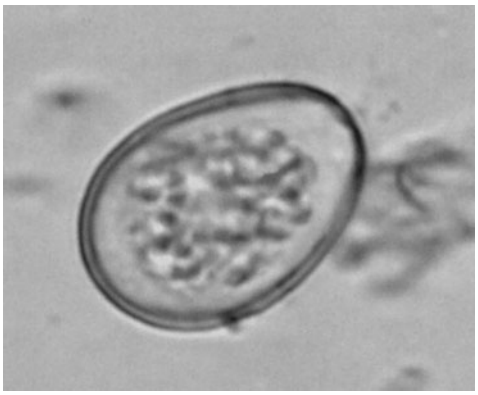


Fig. 17 Oocyst of *Eimeria alabamensis*
(16–24 × 12–16)

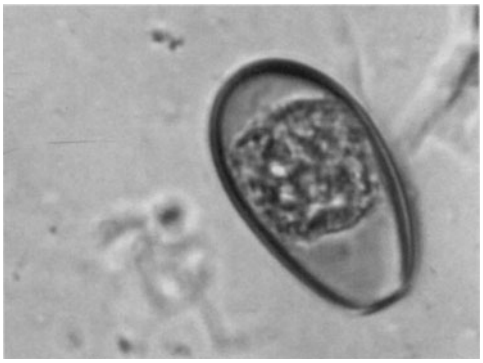


Fig. 18 Oocyst of *Eimeria auburnensis*
(36–42 × 19–26 µm)

Fig. 19 Oocyst of *Eimeria bukidnonensis*
(44 × 32 µm)

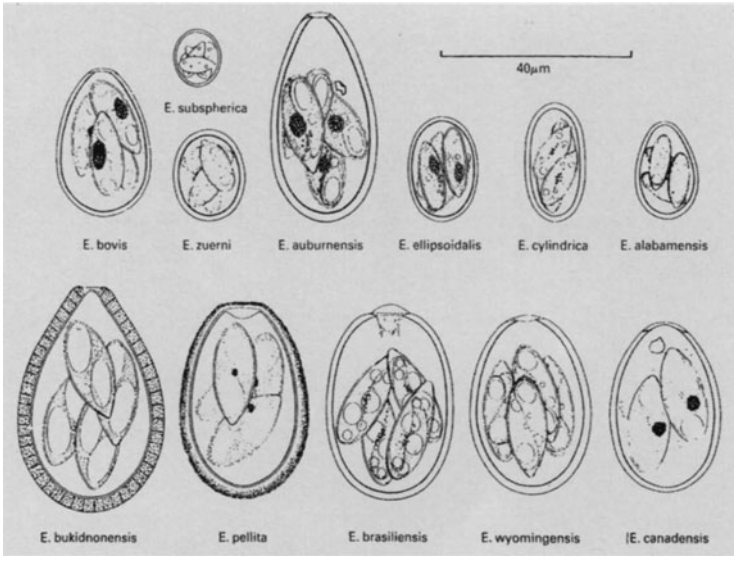


Fig. 20 Coccidia found in cattle [1]

Fig. 21 Bull with an acute coccidiosis

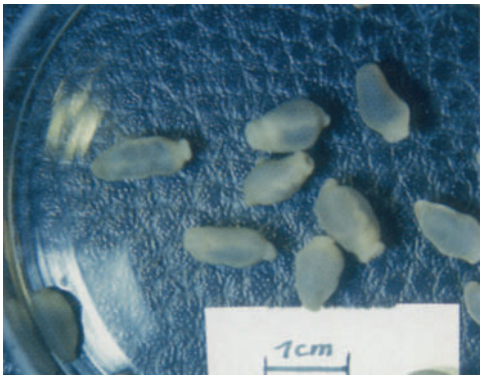


Fig. 22 Rumen flukes found in the rumen of N'Dama cattle

Fig. 23 Haemorrhage in the small intestine of a calf with an acute coccidiosis (*Eimeria bovis*)

Table 3 Recommended use, dosage and dosage form of anticoccidial drugs used in cattle, goats, sheep, and swine

Drug[1]	Use	Animal	Dosage	Dosage forms
Amprolium	Therapeutic	Cattle	10 mg/kg daily for 5 days	20 % soluble powder
		Sheep	50 mg/kg daily for 5 days	9.6 % solution
		Goats	100 mg/kg daily for 5 days	Feed additive crumbles
		Swine	25-65 mg/kg once or twice daily for 3-4 days	
	Prophylactic	Cattle, sheep, goats	5-10 mg/kg daily for 21 days	
		Swine	25 mg/kg in piglets for first 3-4 days of life	
Sulfonamides				
Sulfamethazine	Therapeutic	Cattle, sheep, goats	50-100 mg/kg daily for 4 days	Soluble powder or bolus
Sulfaquinoxaline	Therapeutic	Cattle, sheep, goats	15 mg/kg, po.[2] daily for 4 days	9.6 % liquid soluble powder and feed additive
Sulfaguanidine	Prophylactic	Sheep	0.5-3 g per lamb per day for 20 days	
		Swine	60 mg/kg for 7-10 days	
Ionophorous antibiotics				
Monensin	Prophylactic	Cattle, sheep & goats	1 mg/kg for 30 days	Feed additive
Lasalocid	Prophylactic	Cattle, sheep & goats	0.5-1 mg/kg per day for up to 6 weeks	Feed additive
Other compounds				
Nitrofurazone	Therapeutic	All	10-20 mg/kg daily for 5 days	88.9 % m/m
Decoquinate	Prophylactic	Cattle	0.5 mg/kg in feed for at least 28 days	6 % premix for addition to feed
Toltrazuril	Therapeutic	Sheep	20 mg/kg, single treatment	25 % liquid
Diclazuril	Therapeutic	Sheep, goats	20 mg/kg, po.	2.5 % suspension

[1] Several trade names, [2] po. = orally; [2]

Cryptosporidium parvum (syn. *C. bovis*)

Location: Small and large intestine
Hosts: All domestic animals
Species description: Spherical oocysts 4.5–5 µm in diameter are passed in the faeces. Especially calves younger than 8 weeks may be affected, showing different degrees of diarrhoea, associated with oedema and hyperplasia of the mesenteric lymph nodes. Cryptosporidial diarrhoea in both immunodeficient and non-immunodeficient human beings have been reported.
Geographic distribution: World-wide
Symptoms: Persistent diarrhoea in calves 5–35 days old that does not respond to therapy.
Significance: *Cryptosporidium parvum* is pathogenic for calves, sheep, pig, rat and man. Bovine cryptosporidiosis is a zoonosis. Diarrhoea due to *Cryptosporidium parvum* alone is often mild and self-limiting, although the severity may be related to the general strength of the calf and the density of the pathogen in the environment and the intensity of the exposure to the organism. Combination of the infection with rota- and/or coronavirus are common and result in persistent diarrhoea, emaciation and death.
Diagnosis: Oocysts may be demonstrated in Ziehl-Neelsen's carbol-fuchsin stained smears of diarrhoeic faeces (☞ METHODS, 1.10).
Therapy: No effective specific treatment known. Supportive therapy, such as rehydration and antibiotics may help in mild cases. Chemoprophylaxis of bovine cryptosporidiosis can be made experimentally with halofuginone lactate (60–120 µg/kg/day, po. for 7 days) or by paromomycin (100 mg/kg/day for 11 days).
Prophylaxis: Animals with a massive oocyst excretion should be separated from other animals and man. Contamination with faeces should be avoided. Oocysts are resistant to many disinfectants (exception 5% formalin). Emphasis should therefore be on regular removal of contaminated faecal material.

Note: Trophozoites of *Giardia bovis* (small intestine) and *Entamoeba bovis* (rumen, intestines) occur world-wide in the faeces of cattle, but are considered to be non-pathogenic.
(Figures 24, 25)

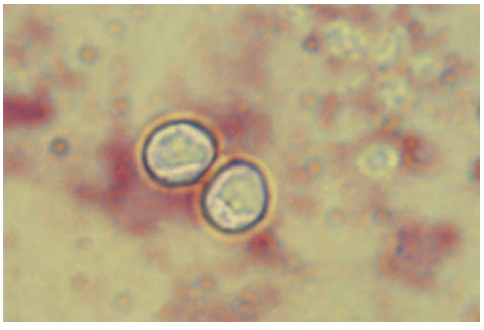


Fig. 24 Oocysts of *Cryptosporidium parvum* (4.5–5 µm) stained with carbol-fuchsine (☞ METHODS 1.10)

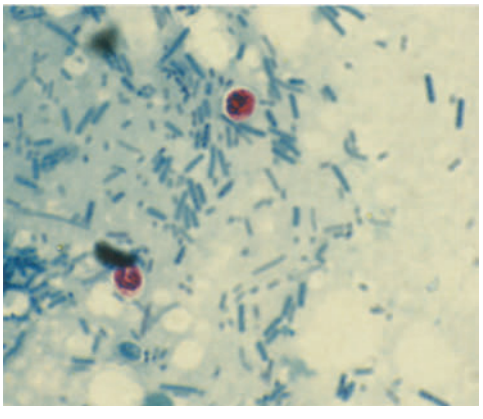


Fig. 25 Oocysts of *Cryptosporidium parvum* (4.5–5 µm) stained with the modified Ziehl-Neelsen's carbol-fuchsine (☞ METHODS, 1.10)

Buxtonella spp.

Remarks: This is a protozoan parasite found occasionally in the large intestine of cattle. Oocysts are found in the faeces. The parasite is non-pathogenic.
(Figure 26)

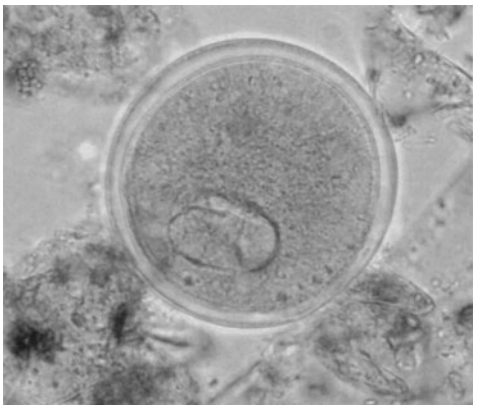


Fig. 26 Cyst of *Buxtonella* sp. (50–131 µm)

HELMINTHS

- Trematoda eggs found in the faeces and adult trematodes living in the gastrointestinal tract

PARAMPHISTOMATIDAE

Location: Adult flukes in the rumen; immature flukes in the small intestine

Hosts: Domestic and wild ruminants

Species description: A great number of species of this family has been described in Africa. Indirect life cycle with development in freshwater snails (*Bulinus* spp.; *Planorbis* spp.). The cercariae encyst on herbage which is in contact with water and develop into the infective stages (metacercariae). Infection is acquired by ingestion of herbage contaminated with metacercariae, especially around water holes. The adult flukes are generally non-pathogenic (>80% of adult cattle are infected in endemic areas). Disease occurs when masses of immature worms attach to the intestinal mucosa after excystment, causing destruction and inflammation. Peaks usually at the end of the dry season. Game animals, using the same water holes, may be a source of reinfection. Standing water, troughs and other water bodies are preferred habitats of the intermediate hosts.

Geographic distribution: World-wide

Symptoms: Enteritis with extensive diarrhoea, hypoproteinaemia, weakness during the intestinal phase, when immature worms irritate the small intestinal mucosa. Severe symptoms mainly in young stock. Irregular rumination and progressive degeneration of the animal's condition may be found. Infections with adult rumen flukes are generally inapparent, despite the high numbers of adult parasites in the rumen. Rumenitis may occur due to adult flukes, especially if *Carmyerius* spp. are involved. Adult flukes are generally non-pathogenic.

Significance: Severe diarrhoea and weakness, generally caused by the immature intestinal flukes, may lead to death.

Diagnosis: This is based on the demonstration of immature flukes in the diarrhoeic faeces and the presence of previous cases in the area.

Cave: In acute paramphistomidosis the large, clear, operculated eggs may not be found in the faeces. In many areas > 80% of the adult ruminants pass paramphistome eggs in the faeces. The presence of eggs without clinical signs does not necessarily indicate paramphistomidosis.

Therapy: Niclosamide (90 mg/kg po.), resorantel (65 mg/kg po.) and closantel are active against immature forms. Triclabendazole (12 mg/kg) and albendazole (10 mg/kg) may also be used against immature flukes. Resorantel is active only against mature flukes (☞ Table 4).

Prophylaxis: Avoiding infection by supplying the herds with clean water, e.g. bore holes or raised, snail-free troughs.

Table 4 Recommended drugs against *Paramphistomum* spp. infections in cattle

Drug	Dosage (mg/kg)	Immat. flukes	Mature flukes
Niclosamide	160.0*	+	
Oxyclozanide and Levamisole	18.7 19.4*	+	
Oxyclozanide	15		+
Resorantel	65		+

*at 3-day intervals

Remarks: Rumen flukes in Africa belong to the families of Paramphistomatidae (*Bothriophoron bothriophoron*; *Stephanopharynx compactus*; *Cotylophoron cotylophorum* and other *Cotylophoron* spp.; *Paramphistomum* spp. [8 species] and *Cotylophoron* spp.; [*C. daubneyi* and *C. microbothrium* are the most frequent species]) and Gastrothylacidae (*Carmyerius* spp. [*C. spatiosus; C. papillatus; C. dollfusi* [Zebu only in Madagascar]).
(Figures 27, 28, 29)

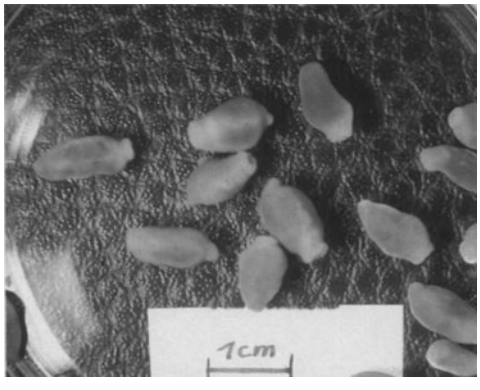


Fig. 27 Rumen flukes found in the rumen of N'Dama cattle

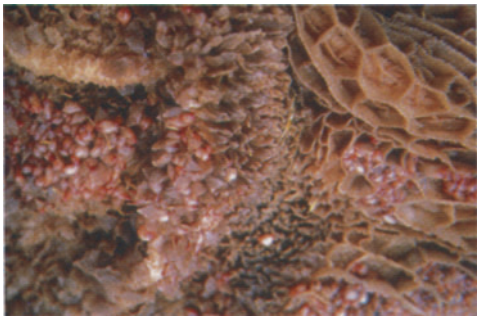


Fig. 28 *Paramphistomum* sp. attached to the rumen mucosa

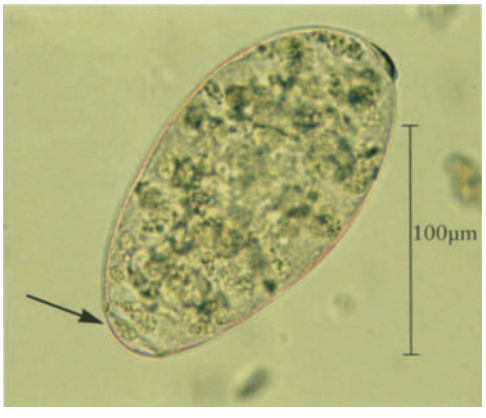


Fig. 29 Egg of a rumen fluke (Paramphistomatidae)

F. gigantica Tropical large liver fluke
(☞ CATTLE, ■ 4.2)

F. hepatica Large liver fluke of temperate areas and high altitude regions in East Africa

Location: Adult flukes in biliary ducts; eggs in the faeces (☞ CATTLE, ■ 4.2)
(Figures 30, 31)

Dicrocoelium hospes African small liver fluke
(☞ CATTLE, ■ 4.2)

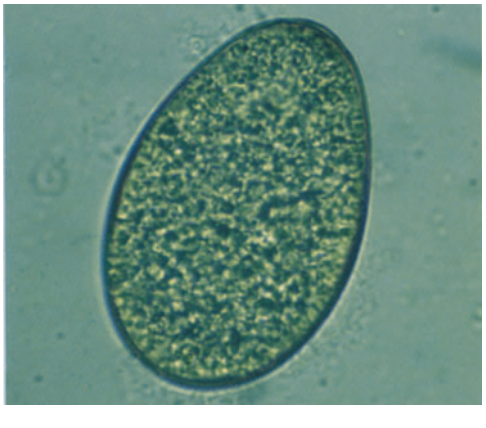


Fig. 30 Egg of *Fasciola hepatica* (130–150 × 63–90 µm)

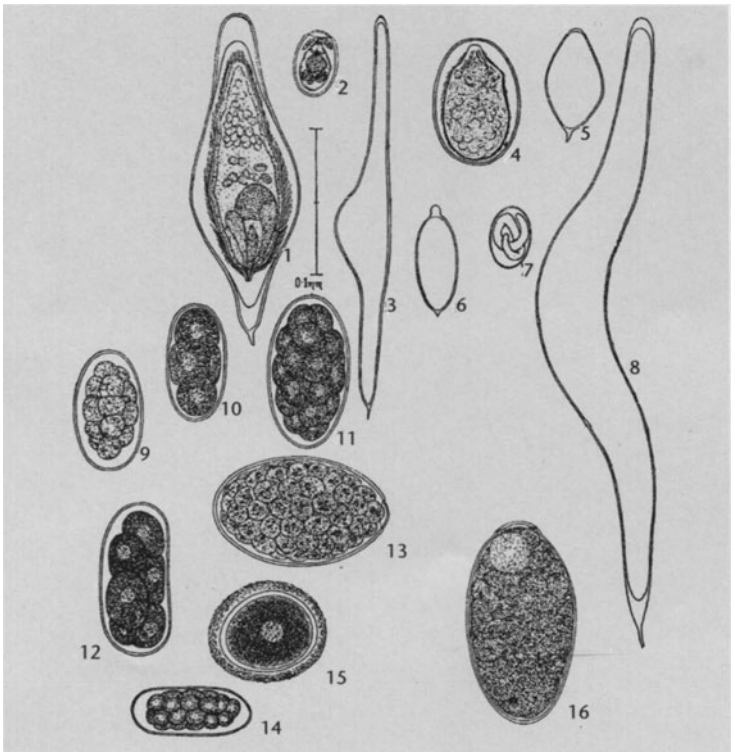


Fig. 31 Eggs of helminth parasites of cattle (not drawn completely to scale) [3]
(1) *Schistosoma bovis*, (2) *Eurytrema pancreaticum*, (3) *Schistosoma spindale*, (4) *Schistosoma japonicum*, (5) *Schistosoma indicum*, (6) *Ornithobilharzia turkestanicum*, (7) *Thelazia rhodesi*, (8) *Schistosoma nasalis*, (9) *Oesophagostomum radiatum**, (10) *Mammomonogamus laryngeus*, (11) *Mecistocirrus digitatus*, (12) *Bunostomum phlebotomum**, (13) *Carmyerius spatiosus*, (14) *Cooperia pectinata**, (15) *Toxocara vitulorum* and (16) *Fasciola hepatica*.
* Strongyle-type eggs are difficult to differentiate in routine examinations

D. dentriticum Small liver fluke

Location: Adult flukes in biliary ducts; eggs in the faeces (☞ CATTLE, ■ 4.2)

(Figures 32, 33)

Fig. 32 Egg of *Dicrocoelium dendriticum* (36–45 × 25 µm)

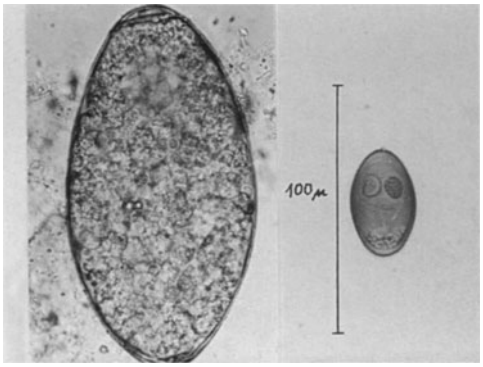


Fig. 33 Egg of *Fasciola hepatica* (a) and *Dicrocoelium dendriticum* (b) [4]

Eurytrema pancreaticum Pancreas fluke

Location: Adult flukes in pancreatic ducts; eggs in the faeces (☞ SHEEP AND GOATS, ■ 4.5)

(Figure 34)

Fig. 34 Egg of *Eurytrema pancreaticum* (40–50 × 23–34 µm)

Schistosoma spp. (S. bovis, S. mattheei, S. curassoni) Blood flukes

Location: Adult flukes in mesenteric veins; eggs in the intestinal wall and faeces (☞ CATTLE, ■ 2)
(Figures 35, 36)

Fig. 35 Egg of *Schistosoma bovis* (180 × 60 µm)

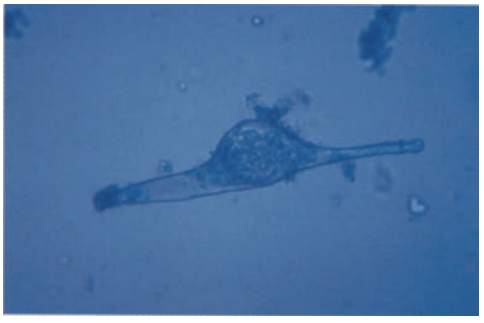


Fig. 36 Eggs of *Schistosoma spindale* (300 × 80 µm) [4]

- Cestoda eggs found in the faeces and adult cestodes living in the gastrointestinal tract

(Figure 37)

Moniezia expansa* and *Moniezia benedeni Common tapeworms

Location: Small intestine
Hosts: Cattle, sheep, goat and many other ruminants
Species description: Worms are up to 6 m long and 1.6 cm wide (*M. expansa*). *M. benedeni* which occurs more often in cattle is broader (up to 2.6 cm). The life cycle of *Moniezia* is indirect, including many species of oribatid mites as intermediate hosts. Ruminants are infected by ingestion of the

Characteristics	*Moniezia expansa*	*Moniezia benedini*	*Avetellina spp.*	*Thysaniezia giardi*	*Stilesia hepatica*
Length	1–6 m	26 mm	3 m	2 m	20–50 cm
Width	16 mm	26 mm	3 mm	12 mm	2 mm
Egg	Semi-triangle	Diamond-shaped	Oval	Oval	Round
Genitalia	Double	Double	Single	Single	Single
Interproglottid glands	Follicular	Compact	-	-	-
Paruterine organs in gravid segment	-	-	One: lemon-shaped	Numerous: onion-shaped	Two: round

Fig. 37 Morphological identification of common cestodes in ruminants [5]

infected mites with herbage. The prepatent period is 35–40 days. Infections with *Moniezia* spp. may be found in more than 50% of a particular population. *M. expansa* eggs are triangular, contain a pyriform apparatus and measure 56 × 67 µm. *M. benedeni* eggs are cuboid, with a thick, ornamented shell and measure 75 µm in diameter.

Geographic distribution: World-wide
(Figures 38, 39, 40, 41, 42)

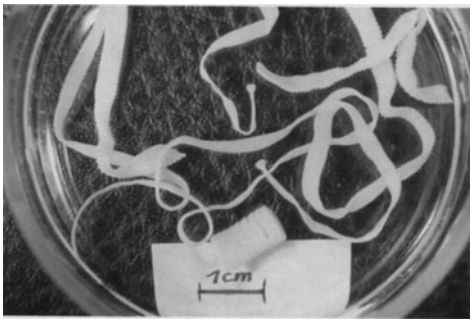
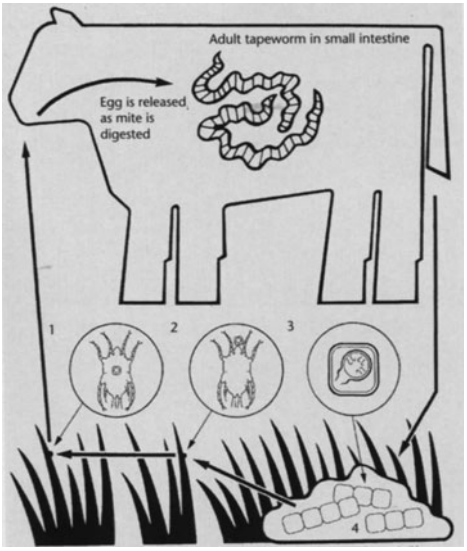


Fig. 38 *Moniezia* sp.



1 Mite on grass eaten by cattle, 2 Mite eats tapeworm egg, 3 Tapeworm egg in proglottid, 4 Dung pat containing proglottids

Fig. 39 Life cycle of *Moniezia* spp. [6]

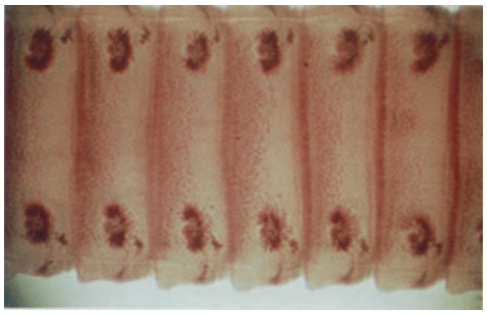


Fig. 40 *Moniezia* sp.; segments with double genitalia [4]

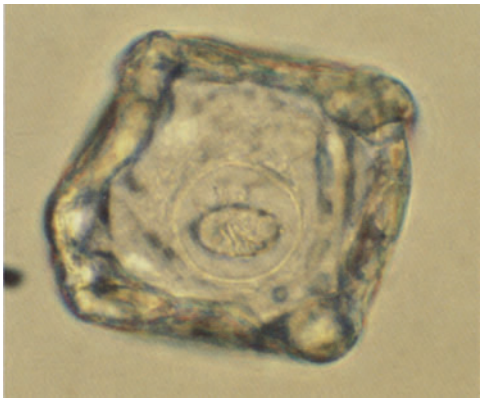


Fig. 41 Egg of *Moniezia* sp. (60–80 µm in diameter)

Fig. 42 *Moniezia* sp. in the small intestine of a calf

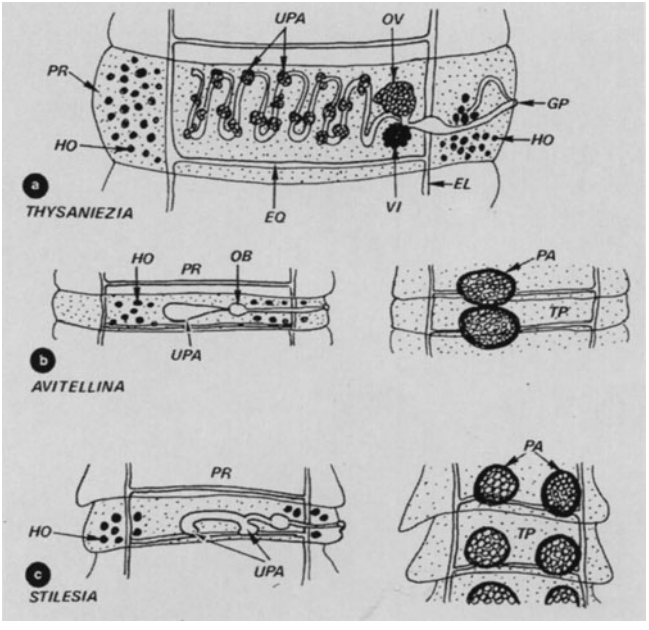


Fig. 43 Morphology (schematic) of proglottids of different tapeworms found in ruminants; EL, EQ = excretion pores, GP = genital pore, HO = testicular vesicles, OB, OV = ovary, PA = paruterine organ with eggs, PR = internal proglottis, TP = terminal proglottis, UPA = uterus with paruterine organ and VI = vitellarium [7]

Avitellina centripunctata

Location: Small intestine
Hosts: Sheep, goat, dromedary and rarely cattle
Species description: Adults reach 3 m in length and are about 3 mm wide. Proglottids appear not segmented. The uterus and the paruterine organs show an opaque line in the medial portion of the proglottids. The eggs measure 21–45 µm. This genus is non-pathogenic. Oribatid mites but also bark lice and dust lice are suspected to act as intermediate hosts.
Geographic distribution: Arid areas of Africa (Figure 37, 43)

Thysaniezia ovilla (syn. *T. giardi*)

Location: Small intestine
Hosts: Sheep, goat and cattle, dromedary and wild ruminants
Species description: Adults reach 2 m in length and are 12 mm wide. The side of the segment bulges out, giving the margin of the worm an irregular appearance. Eggs are found in groups of 10–15 in elongated paruterine organs (about 100 µm long), with a thick gray shell and a protuberance at one end. Oribatid mites and psocids (bark lice, dust lice) are the intermediate hosts. This species is not clinically important but frequently encountered, especially in southern parts of Africa.
Geographic distribution: Arid areas of Africa (Figures 37, 43, 44)

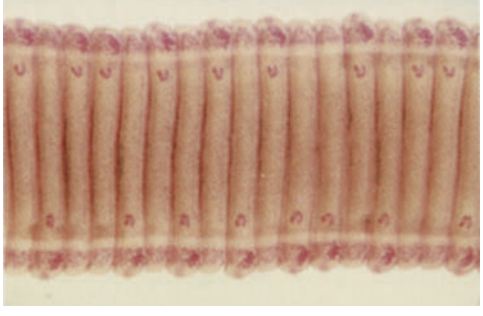


Fig. 44 *Thysaniezia ovilla*; segments with single genitalia which alternate irregularly [8]

Stilesia globipunctata

Remarks: This tapeworm occurs in the small intestine mainly of sheep, goat, dromedary and rarely of cattle and other ruminants in Europe, Africa and Asia (☞ Sheep and Goats, ■ 1).
(Figures 45, 46)

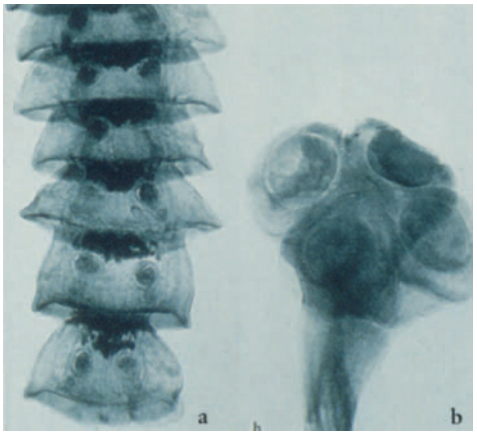


Fig. 45 *Stilesia* sp.; proglottids (a) and scolex (b); PA = paruterine organ [4]

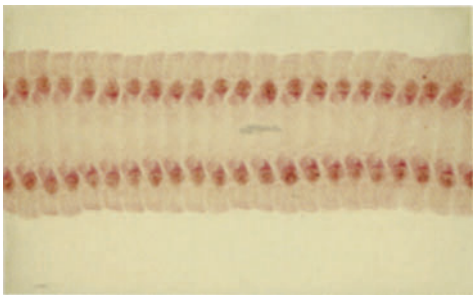


Fig. 46 *Stilesia globipunctata*; immature segments [8]

- **General features of intestinal tapeworms (*Moniezia* spp., *Thysaniezia* spp., *Avitellina* spp. and *Stilesia* spp.) of ruminants**

Symptoms: Generally inapparent infections; heavy infections are found only in young animals and can cause reduced weight gain. Masses of *Moniezia* can cause obstruction of the intestine.

Cave: Because of the large size of the tapeworms their presence is obvious and the underlying cause of parasitism, the small trichostrongylids, easily overlooked.

Significance: Tapeworms are widespread in ruminants, but their pathogenicity has not been proved conclusively and it seems that they are relatively low-pathogenic.

Diagnosis: Proglottids which look like cooked rice grains, containing typical thick-shelled or imperfectly rounded eggs, appear in the faeces. Eggs may also appear isolated in the faeces. The presence of tapeworms in the small intestine at slaughter is conclusive.

Therapy: Niclosamide (75–90 mg/kg) and praziquantel (5 mg/kg, sheep only) are specific cestodicidal drugs. In addition the following benzimidazoles are effective against tapeworms: albendazole (7.5 mg/kg), fenbendazole (5–10 mg/kg), oxfendazole (5 mg/kg), mebendazole (15–20 mg/kg, po.), netobimin (7.5–20 mg/kg, po.), febantel (5–7.5 mg/kg, po.). Special attention should be given to the control of tapeworms in lambs to avoid losses in heavily infected populations.

Prophylaxis: Reduction of the mite population is not feasible and emphasis should be given to anthelmintic treatments when losses due to tapeworms occur.

- Nematoda eggs found in the faeces, adult nematodes living in the gastrointestinal tract and first-stage larvae of *Dictyocaulus viviparus*

Gongylonema pulchrum

Gullet worm, zigzag worm

Location: Mucosa of oesophagus and forestomachs

Hosts: Sheep, goat and less frequently cattle

Species description: Eggs laid by adult worms are passed in faeces and hatch into larvae when swallowed by manure-eating beetles or cockroaches. Larvae in cattle may be liberated in the stomach and migrate towards

the oesophagus. Adult worms are 6 to 14 cm in length and a number of oval cuticular thickenings appear in longitudinal rows at the anterior end. The worms are embedded in the oesophageal lining in a zigzag pattern.

Geographic distribution: World-wide

Symptoms: Rarely observed

Significance: This is a harmless parasite and mainly found at autopsy. Irritation of the oesophageal and gastric mucosae may occur in infected animals.

Diagnosis: Mainly at necropsy; eggs occur in the faeces.

Therapy: Generally not indicated

Prophylaxis: Keeping the animals on dry, well-drained grounds or concrete floors has been described to be effective in controlling infection.

(Figures 47, 48, 49)

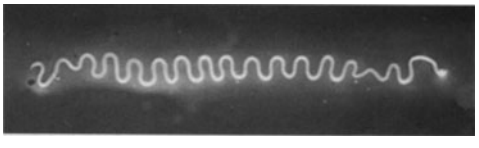


Fig. 47 *Gongylonema pulchrum*; typical zigzag pattern [4]

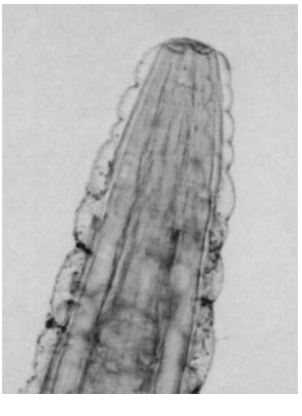


Fig. 48 *Gongylonema pulchrum*; anterior end with cuticular plaques [8]

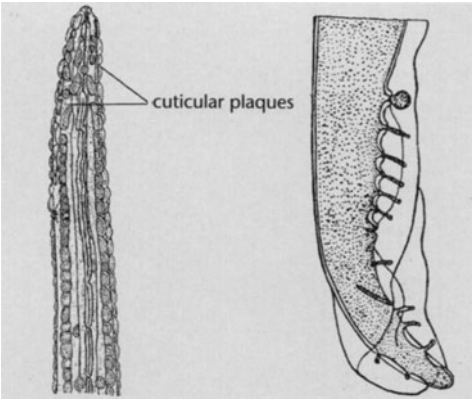


Fig. 49 *Gongylonema pulchrum*; anterior end with cuticular plaques [5]

Gongylonema verrucosum

Rumen gullet worm

Location: Mucosa of rumen, reticulum, omasum

Hosts: Cattle, sheep and goat

Species description: Not well known; dung beetles are intermediate hosts. The worms have a reddish colour when fresh. Males are 32–41 mm long and females 70–95 mm. A festooned cervical ala as well as cuticular bosses on one side only are typical.

Geographic distribution: South Africa, India, USA

Symptoms: Inapparent

Significance: Non-pathogenic

Diagnosis: Casually at necropsy

Therapy: Unknown

Prophylaxis: ☞ above *G. pulchrum*

Parabronema skrjabini

Location: Abomasum

Hosts: Cattle, sheep, goat and dromedary

Species description: This parasite belongs to the Spiruridae. *Stomoxys* spp. and *Lyperosia* spp. are intermediate hosts. Infective third-stage larvae develop in the flies and are deposited on the final host where the larvae are ingested. Males are 15–18 mm long, with one spicule measuring 600–710 µm and the other one 290–310 µm. Female

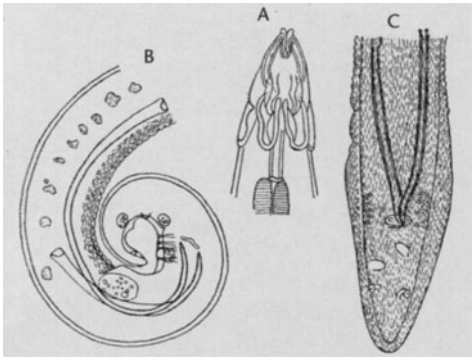


Fig. 50 *Parabronema rhodesiense*; anterior end (a), lateral view of the tail end of a male (b), ventral view of the tail of a male (c) [9]

worms are > 36 mm long and the vulva is situated at 5 mm distance to the hind end. The anterior end is characterised by pseudo-lips, which are wound around the buccal opening. Four papillae are found on these lips. The tail end of the male is reeled to a spiral and four pairs of preanal papillae are found. A group of terminal papillae is present as it is in all the spirurids.

Geographic distribution: Asia, Central and East Africa

Symptoms: Unspecific; abomasitis may be found.

Significance: Unknown; *P. skrjabini* may play a role together with other gastrointestinal nematodes

Diagnosis: At necropsy, adult worms may be found in abomasal scrapings.

Therapy and Prophylaxis: A specific therapy and prophylaxis is not described and probably also not necessary. For further information ☞ below THERAPY OF NEMATODE INFECTIONS, p. 53

(Figure 50)

Haemonchus contortus Large stomach worm, twisted wire worm, barber's pole worm

Location: Abomasum

Hosts: Cattle, sheep, goat and other ruminants

Species description: *H. contortus* is known as the "red stomach-worm" or "wire worm" of ruminants and one of their most prevalent and most pathogenic parasites. Adults are 10 to 30 mm long. Males are shorter than females and have a reddish colour and a bursa with an asymmetrical dorsal lobe and barbed spicules. Females are identified as "barber's pole worms" because their white uteri are wound around their red blood-filled intestine. The vulva flap is prominent in female worms. The life cycle is direct and typical for the strongyle nematodes. The prepatent period is 19–21 days but it can be shortened by immunosuppressive pathogens such as concomitant trypanosome infections and stress factors. In arid areas, the parasite survives the dry season as inhibited fourth-stage larvae within the abomasal mucosa of the host. The inhibited larvae resume their development a few weeks before the onset of the new rainy season. This phenomenon is accompanied by a drastic increase of the egg output of infected animals before the wet season starts ("rains rise").

Geographic distribution: World-wide

Symptoms: Anaemia, oedema ("bottle jaw"), rough coat, weight loss or retarded growth

Significance: *H. contortus* is a very common parasite and one of the most pathogenic nematodes of ruminants. Heavy infections cause death in young animals, whereas chronic infections cause anaemia, hypoproteinaemia, progressive emaciation. These effects are generally compensated during the rainy season and only appear progressively during the following dry season when previously heavily infected animals may die.

Diagnosis: Eggs of strongyle-type appear in the faeces. In acute infections anaemia and death may occur before the worms reach maturity. No eggs are found in this case in the faeces and only the examination of the abomasum at necropsy allows an exact diagnosis.

Therapy and Prophylaxis: ☞ below THERAPY OF NEMATODE INFECTIONS, p. 53

(Figures 51, 52, 53, 54, 55, 56, 57, 58, 59, 60)

Fig. 51 *Haemonchus contortus*; adult parasites

Fig. 54 *Haemonchus contortus*; bursa copulatrix (schematic) with barbed spicules (490–540 µm long) and asymmetrical dorsal lobe [3]

Fig. 52 *Haemonchus contortus*; twisted unteri and intesine [10]

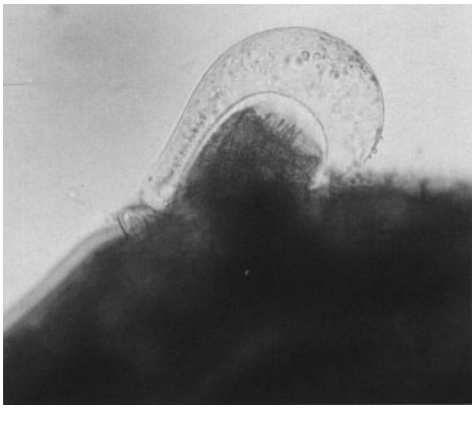


Fig. 55 *Haemonchus contortus*; vulva flap

Fig. 53 *Haemonchus contortus*; prominent cervical papillae (50×)

Fig. 56 N'Dama calf showing emaciation and "bottle jaw" due to a chronic haemonchosis

Fig. 57 Pale mucosa membranes following a heavy *Haemonchus contortus* infection

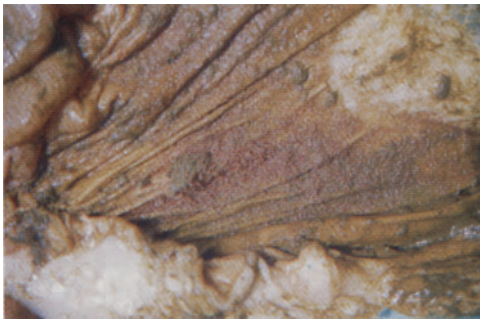


Fig. 59 *Haemonchus contort* on the abomasal mucosa of a calf

Fig. 58 Oedematous abomasal mucosa due to hypoproteinaemia [10]

Fig. 60 Strongyle-type egg [11]

Mecistocirrus digitatus

Location: Abomasum of ruminants, stomach of pigs, rarely small intestine

Hosts: Cattle, buffalo, sheep, goat, pig and very rarely man

Species description: This nematode resembles *Haemonchus contortus*. The females also have the ovaries wound spirally around the intestine but they differ from the latter by the position of the vulva which is situated about 0.6–0.9 mm from the tip of the tail and the absence of a vulvar flap. The male bursa has a symmetrical dorsal lobe, which is very small. The spicules are long (3.8–7 mm) and united together for almost their whole length. The eggs measure 95–120 × 56–60 µm. This nematode is a blood sucker.

Geographic distribution: Widespread in Central and South America, Asia, Africa (including island of Mauritius)

Symptoms: Acute infections are associated with anaemia, weakness, poor growth and sometimes death. Chronic infections are associated with oedema, bottle jaw and progressive weight loss.

Significance: *M. digitatus* is an important parasite in endemic areas and young animals are particularly at risk. The effects are similar to those of *Haemonchus contortus*. This parasite generally occurs together with other gastrointestinal nematodes.

Diagnosis: Strongyle-type eggs appear in the faeces. Adult worms may be identified at necropsy.

Therapy and Prophylaxis: ☞ below THERAPY OF NEMATODE INFECTIONS, p. 53

(Figures 61, 62, 63)

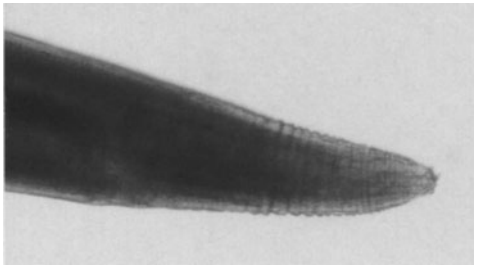


Fig. 61 *Mecistocirrus digitatus*; anterior end [8]

Fig. 62 *Mecistocirrus digitatus*; bursa copulatrix [3]

Trichostrongylus axei Stomach hair worm

Location: Abomasum and occasionally small intestine

Hosts: *T. axei* occurs in the abomasum of sheep, goat, cattle, wild ruminants and in the stomach of pig, horse donkey and man.

Species description: Direct nematode life cycle; males are 2.5–6 mm long and females are 3.5–8 mm long. The spicules are dissimilar: one measures 74–98 µm and the other 96–128 µm. The gubernaculum length is 50–61 µm. The eggs measure 79–92 × 31–41 µm.

Geographic distribution: World-wide

Symptoms: Weight loss and poor growth occur when animals are heavily infected especially in mixed infections with other trichostrongyles.

Significance: Serious weight loss and poor growth occur when animals are heavily infected especially in mixed infections with *Haemonchus, Ostertagia* and heavy *Cooperia* burdens.

Diagnosis: Detection of strongyle-type eggs in the sediment or flotation of faeces. An accurate diagnosis of the species can only be obtained by microscopic examimination of adult specimens at necropsy.

Therapy and Prophylaxis: ☞ below THERAPY OF NEMATODE INFECTIONS, p. 53

(Figures 64, 65, 66)

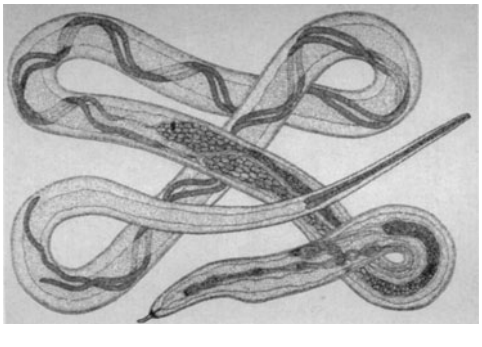


Fig. 63 *Mecistocirrus digitatus*; female worm (19–43 mm long; 470 µm in diameter) [9]

Fig. 64 *Trichostrongylus axei*; spicula (74–98µm and 96–128 µm) and gubernaculum (50–61 µm)

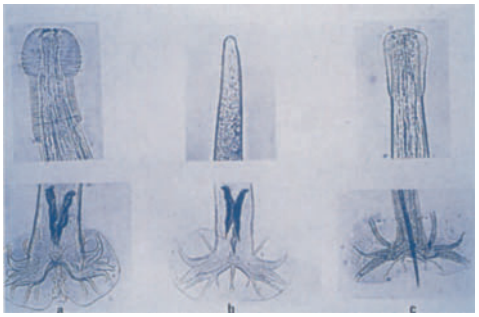


Fig. 65 (Berlin) *Cooperia* spp.; (a), *Trichostrongylus* spp. (b) and *Nematodirus* sp. (c); anterior ends (above) and bursa copulatrix (below) [4]

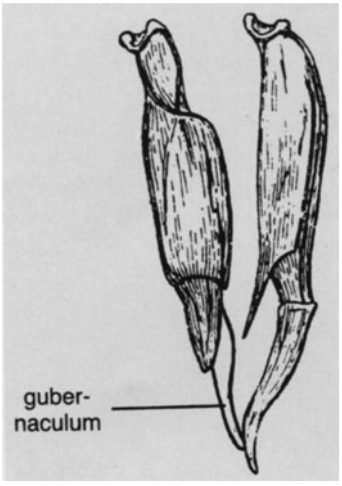


Fig. 66 *Trichostrongylus axei*; spicula (74–98 µm and 96–128 µm) and gubernaculum (50–61 µm) [5]

Trichostrongylus colubriformis and other *Trichostrongylus* spp. Hair worms, black scours worms

Location: Small intestine
Hosts: Cattle
Species description: ☞ above *T. axei;* the male worms are 4–4.5 mm and the females 5–7 mm long. The spicules of *T. colubriformis* are equal (135–156 µm long) and show a prominent distal end. The gubernaculum is present. Infection is acquired by ingestion of infective third stage larvae which burrow superficially into the crypts of the intestinal cells.
Geographic distribution: World-wide
Symptoms: *Trichostrongylus* spp. infections may be difficult to diagnose. The symptoms they produce are similar to those of other trichostrongylid infections. Weakness, diarrhoea or constipation and in chronic infections anaemia due to emaciation and malnutrition may be seen.
Significance: *T. colubriformis* and other small intestinal *Trichostrongylus* spp. are commonly present in mixed-species infections, so their effect is additive.
Diagnosis: Strongyle-type eggs appear in the faeces. Adult worms can be identified at necropsy.
Therapy and Prophylaxis: ☞ below THERAPY OF NEMATODE INFECTIONS, p. 53
(Figures 67, 68)

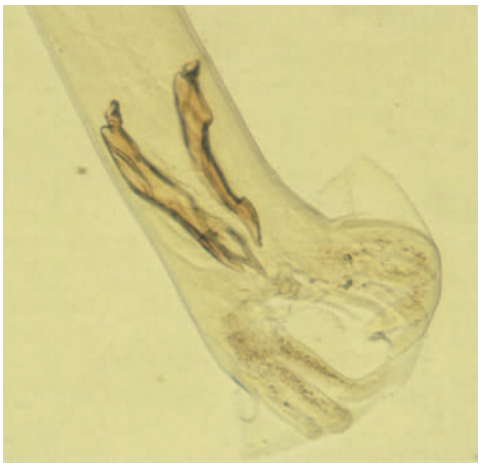


Fig. 67 *Trichostrongylus colubriformis*; bursa copulatrix with spicula (135–156 µm)

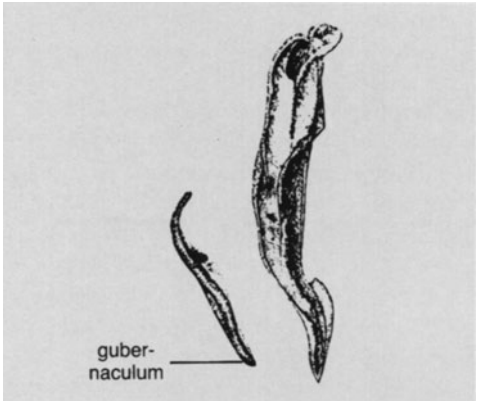


Fig. 68 *Trichostrongylus colubriformis*; spicula (135–156 µm) and gubernaculum (65–75 µm) [5]

***Ostertagia* spp. (*O. ostertagi, O.* [syn. *Skrjabinagia*] *lyrata* and other species)**
Brown stomach worms

Location: Abomasum, upper small intestine
Hosts: Cattle, sheep and goat
Species description: *O. ostertagi* is the most important trichostrongylid of cattle world-wide. In Africa it plays a role in imported cattle and autochthonous infections are reported from East Africa. *O. circumcincta* was reported from sheep and goats in East Africa (Kenya, Ethiopia, Uganda, Zambia) and South Africa, and *O. pinnata* was only reported from sheep in Kenya. *O. lyrata* (syn. *Skrjabinagia lyrata* or *Grosspiculagia lyrata*) occurs in cattle in Africa. It is very similar to *O. ostertagi* which accounts for enormous losses world-wide in cattle rasing areas. Adult worms of the genus *Ostertagia* are brownish, thread-like, and grow to 9 mm in length. They all have a restricted and small cephalic vesicle, small cervical papillae projected from the body surface and pronounced longitudinal, cuticular ridges. The life cycle is direct and typical for roundworms. Environmental conditions of cold or excessive dryness may trigger a condition known as *hypobiosis*, in which larval development in the abomasal mucosa is arrested and maturation is resumed several months later. Ingested larvae enter the glands of the abomasum, causing erosion of the cells, maldigestion, protein losses with the consequence of weight loss, diarrhoea and hypoproteinaemia.
Geographic distribution: World-wide
Symptoms: Severe diarrhoea, oedema (bottle jaw or ascites), weight loss leading to emaciation.
Significance: *Ostertagia* spp. are widespread parasites of cattle. Affected cattle not only lose weight but often die of clinical ostertagiosis. *Ostertagia* spp. infections are generally accompanied by other gastrointestinal nematodes.
Diagnosis: Strongyle-type eggs appear in the faeces. Eggs per gramm > 1000 in calves indicate a harmful condition. It should be controlled with an anthelmintic treament.
Therapy and Prophylaxis: Avoid overstocking, use pasture management to avoid accumulation of infective larvae on herbage and soil; regular or strategic use of anthelmintics ☞ below THERAPY OF NEMATODE INFECTIONS, p. 53
(Figures 69, 70, 71, 72)

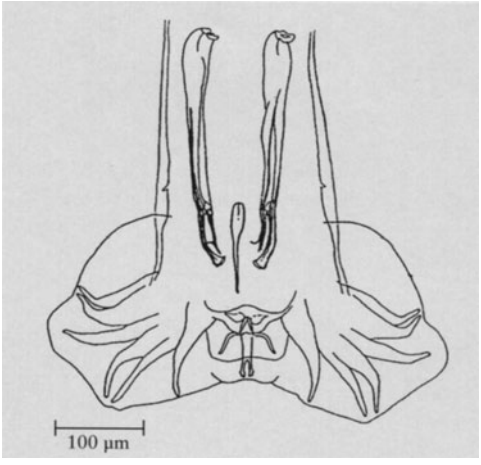


Fig. 69 *Ostertagia ostertagi*; bursa copulatrix with spiculum (200 – 280 µm) [12]

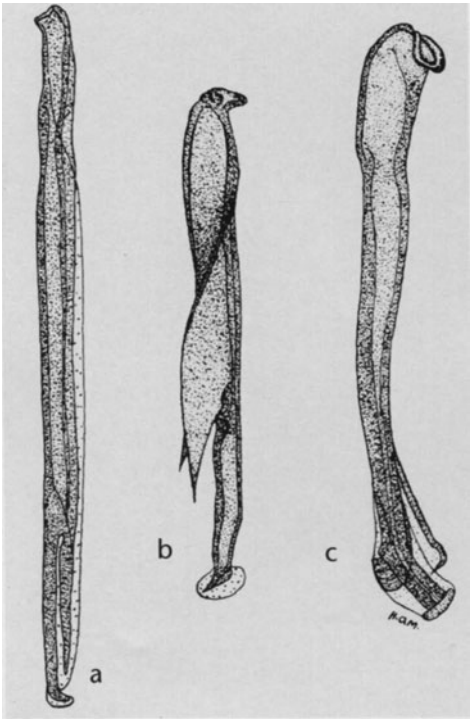


Fig. 70 Spicules of: (a) *Ostertagia circumcincta* (up to 450 µm long), (b) *Ostertagia trifurcata* (150–180 µm long) and (c) *Ostertagia ostertagi* (200–280 µm long) [3]

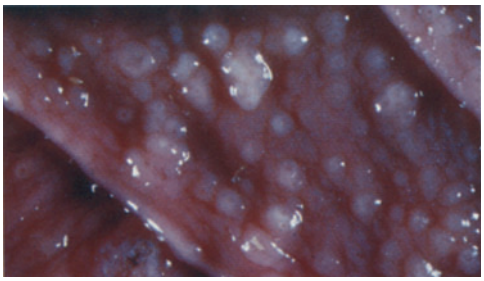


Fig. 71 *Ostertagia ostertagi*; nodules in abomasal mucosa (2–4 mm in diameter)

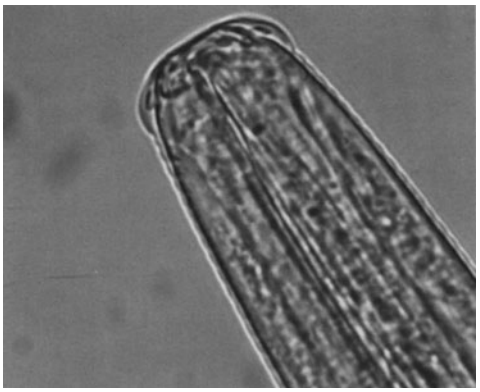


Fig. 72 *Ostertagia* sp.; anterior end with cephalic vesicle

Cooperia spp. (*C. pectinata, C. punctata, C. spatulata* and other species)

Cattle bankrupt worms

Location: Small intestine

Hosts: Cattle

Species description: Direct life cycle; infective larvae develop within 4 days after faecal deposition. Typical for all *Cooperia* spp. the "swollen" head because of a pronounced cephalic vesicle. The body cuticle bears 14–16 longitudinal ridges which appear punctuated. There are no cervical papillae. The spicules are stout, pigmented brown and usually have a ridged, wing-like expansion in the middle. When present in large numbers calves may show markedly reduced weight gains. *Cooperia* spp. are generally accompanied by other trichostrongylids.

Geographic distribution: World-wide; widespread in Africa

Symptoms: Reduced weight gain, especially in calves; diarrhoea can occur, causing dehydration which can severely affect young stock.

Significance: Heavy burdens with *Cooperia* spp. result in poor utilization of feed, weight loss and transient diarrhoea. Especially in calves they can significantly contribute to the overall damage of gastrointestinal nematode infections.

Diagnosis: Strongyle-type eggs occur in the faeces. Species diagnosis only with adult specimens at necropsy.

Therapy and Prophylaxis: ☞ below THERAPY OF NEMATODE INFECTIONS, p. 53

(Figures 73, 74, 75, 76, 77, 78)

Fig. 73 *Cooperia* spp.; adult parasites [10]

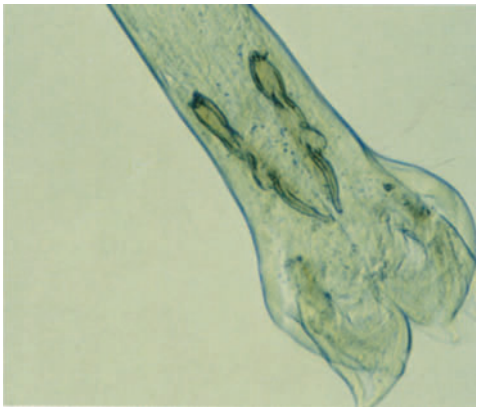


Fig. 74 *Cooperia punctata*; bursa copulatrix with spicules (123–145 µm)

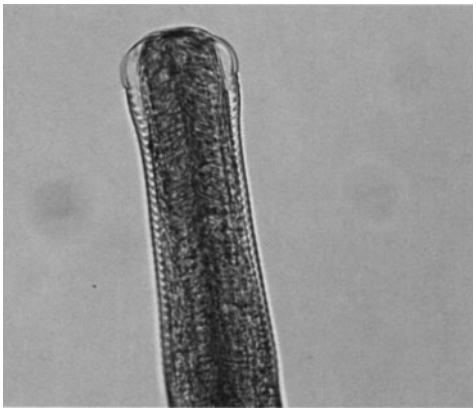


Fig. 75 *Cooperia pectinata*; anterior end with enlarged cephalic vesicle

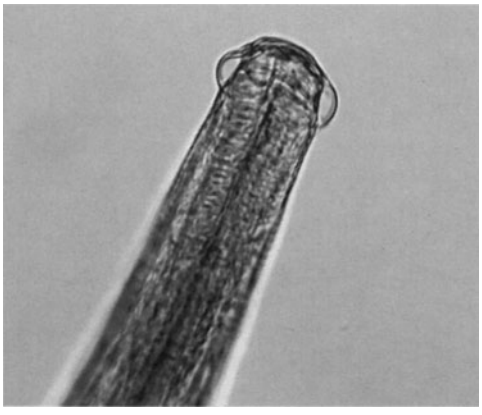


Fig. 76 *Cooperia punctata*; anterior end with enlarged cephalic vesicle

Fig. 77 *Cooperia pectinata*; spicules (240–390 µm)

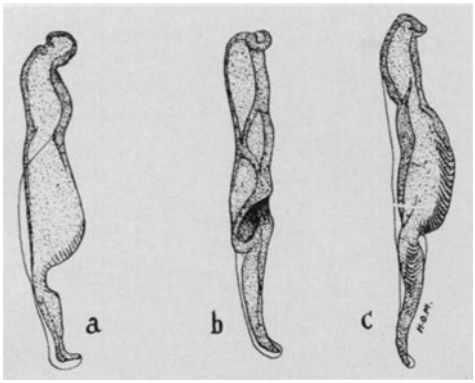


Fig. 78 Spicules of (a) *Cooperia curticei* (135–145 µm long), (b) *Cooperia punctata* (123–145 µm long) and (c) *Cooperia pectinata* (240–390 µm) [3]

***Nematodirus* spp. (*N. filicollis, N. spathiger, N. helvetianus, N. battus*)** Thin-necked intestinal worms, thread-necked strongyles

Location: Small intestine

Hosts: Cattle (*N. helvetianus, N. filicollis,* seldom *N. spathiger*); sheep and goat (*N. spathiger, N. filicollis, N. battus*); and dromedary (*N. spathiger*)

Species description: *Nematodirus* species have an inflated cuticle (bell-glass) around their anterior end. The anterior end is clearly thinner than the posterior part. The bursa of the males has elongate lateral lobes and the spicules are long and slender and their tips are fused together. The tail of the females is short with a slender terminal appendage. The eggs are large (150–260 × 65–110 µm) and can be distinguished from those of other trichostrongylids by their large size. The life cycle is direct. Infective third-stage larvae develop within the eggs which are resistant to adverse environmental conditions. Infection occurs when infective larvae are ingested. The prepatent period is 15–28 days.

Geographic distribution: World-wide; 5–6 *Nematodirus* species are known to occur in North Africa (Maghreb) and certain regions of South Africa. Little is known about the tropical regions of Africa but it seems that *N. spathiger, N. helvetianus* and *N. filicollis* occur in tropical areas.

Symptoms: Intestinal symptoms, diarrhoea, inappetence may be associated with heavy *Nematodirus* infections.

Significance: Heavy infections together with other gastrointestinal nematodes may cause poor growth, emaciation and death. The host is harmed mainly by the larvae which may cause significant destruction of the intestinal epithelial cells.

Diagnosis: Typical eggs which are larger than most strongyle eggs appear in the faeces.

Cave: The eggs of the small ruminant hookworm *Gaigeria pachyscelis* are also large and should be differentiated from those of *Nematodirus* spp. During the prepatent period damage and symptoms of infection may be seen without the typical eggs being excreted in the faeces. Mucosal scrapings may demonstrate the immature worms in the mucosa.

Therapy and Prophylaxis: ☞ below THERAPY OF NEMATODE INFECTIONS, p. 53

(Figures 79, 80, 81, 82)

Fig. 79 Eggs of *Nematodirus* spp. (150–260 × 65–110 µm)

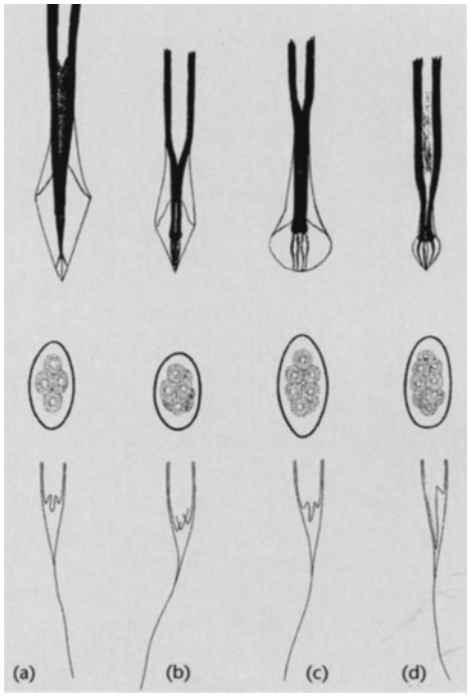


Fig. 80 Posterior end of spicules of: (a) *Nematodirus helvetianus*, (b) *N. filicollis*, (c) *N. spathiger* and (d) *N. battus* [5]

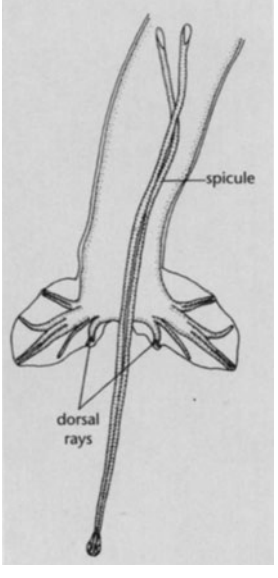


Fig. 81 *Nematodirus spathiger*; bursa copulatrix with spicules (950 µm long; tips fused together) [5]

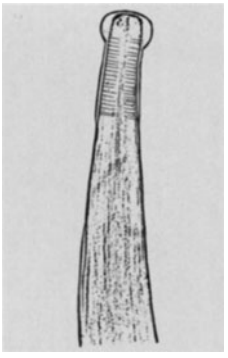


Fig. 82 *Nematodirus helvetianus*; anterior end with enlarged cephalic vesicle (schematic)

Impalaia tuberculata

Remarks: This is mainly a parasite of the dromedary, rarely of zebu, cattle and sheep in many parts of Africa. It occurs in the abomasum and upper small intestine (☞ DROMEDARIES, ■ 1).

Dictyocaulus viviparus Cattle lungworm

Remarks: The first-stage larvae of *Dictyocaulus viviparus* (☞ Cattle, ■ 4.3) is found in the faeces of infected animals. The larvae are recovered from the faeces by means of the Baermann technique (☞ METHODS, 1.7). (Figure 83)

Fig. 83 First-stage larvae of *Dictyocaulus viviparus* (390–490 × 25 µm) [4]

Oesophagostomum radiatum Nodular worm

Location: Adult worms are found in the large intestine (caecum and colon ascendens). Larvae occur in nodules between small intestine and rectum.

Hosts: Cattle

Species description: Direct life cycle; ingested larvae penetrate the intestinal wall, forming nodules anywhere between the small intestine and the rectum. The head end of the adult worms is characterised by a large cephalic vesicle which is constricted behind its middle. Eggs appear in the faeces about 40 days after ingestion of the third-stage larvae.

Geographic distribution: World-wide

Significance: One of the most damaging worms to cattle when present in high numbers (> 200 adults in calves; > 1000 adults in adult cattle). Young stock may die from nodular worm infections.

Symptoms: Heavy infections are accompanied by anaemia, oedema (hypoalbuminaemia) and diarrhoea (reduced fluid absorption). *Oesophagostomum* infections occur generally with other gastrointestinal nematodes.

Diagnosis: Thin-shelled strongyle-type eggs appear in the faeces and pea-shaped nodules in the intestinal wall at necropsy indicate infection with the nodular worm. The diagnosis can be confirmed by demonstrating the typical large worms at necropsy.

Therapy and Prophylaxis: ☞ below THERAPY OF NEMATODE INFECTIONS, p. 53

(Figures 84, 85, 86, 87)

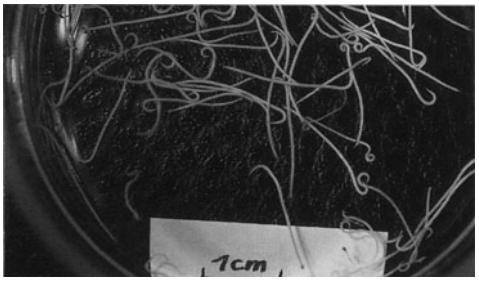


Fig. 84 *Oesophagostomum* spp.; adult parasites

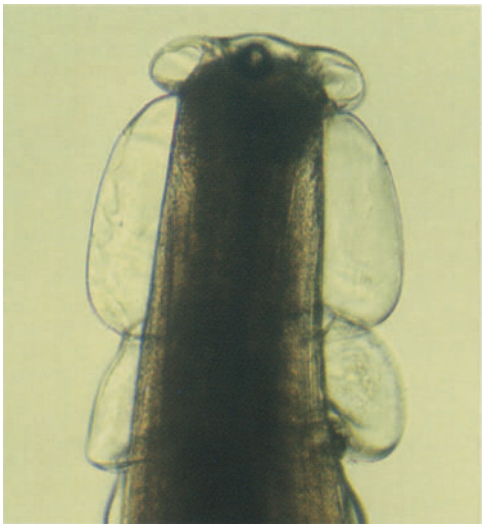


Fig. 85 *Oesophagostomum radiatum*; anterior end with large, constricted cephalic vesicle

Fig. 86 Multiple nodules caused by *Oesophagostomum radiatum* in the caecal mucosa of a calf

Fig. 87 Multiple nodules in the wall of the large intestine caused by *Oesophagostomum radiatum*; view from the serosa side

Oesophagostomum multifoliatum

Remarks: This is mainly a large intestinal parasite of sheep, goats but also zebu. Its occurrence has been reported from Nigeria, Kenya, Tanzania and Zimbabwe (☞ SHEEP AND GOATS, ■ 1).

Oesophagostomum columbianum

Remarks: This parasite occurs in the colon of sheep, goats, camel, a number of antelopes and occasionally of zebu. It occurs worldwide and is particularly reported from tropical Africa (☞ SHEEP AND GOATS, ■ 1).

Bunostomum phlebotomum

Cattle hookworm

Location: Small intestine

Hosts: Cattle

Species description: Adults are 10–28 mm long. There is a prominent buccal capsule with two pairs of subventral lancets. The spicules of the male measure 3.5–4 mm. The life cycle is direct. Infective larvae usually enter cattle by ingestion or by skin penetration.

Significance: *B. phlebotomum* is one of the most pathogenic helminths of cattle in warm and humid areas. Especially for suckling and freshly weaned calves, during the rainy season it can be a major pathogen causing severe anaemia. Only 50 adult specimens in the small intestine can cause severe anaemia in calves. This parasite is generally accompanied by other gastrointestinal nematodes. *Bunostomum* was found to occur focally only in certain herds of a region.

Geographic distribution: World-wide, especially in warm, humid zones

Symptoms: Penetration of the skin by larvae may cause irritation of the host: itching of the legs and feet results in cattle stamping their feet. Iron-deficiency anaemia and hypoproteinaemia, accompanied by oedma ("bottle jaw") are the predominant symptoms of cattle hookworm infections.

Significance: *B. phlebotomum* may be a serious threat to cattle, especially to calves. Because of its skin-penetrating infection mode, it can also affect suckling calves, killing them within a few days. Heavy infections cause acute anaemia and death. Chronic infections result in poor growth.

Diagnosis: Strongyle-type eggs in the faeces and severe anaemia especially in young calves during the rainy season may suggest hookworm infection.

Therapy and Prophylaxis: ☞ below THERAPY OF NEMATODE INFECTIONS, p. 53

(Figures 88, 89)

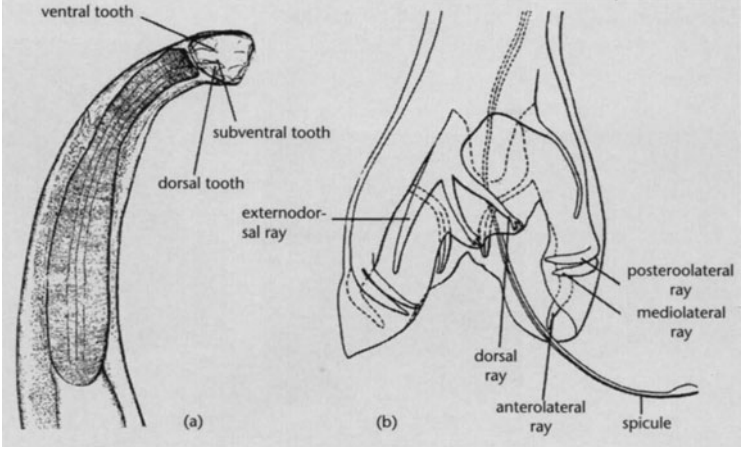


Fig. 88 *Bunostomum phlebotomum*; anterior end (a) and bursa copulatrix (b) [5]

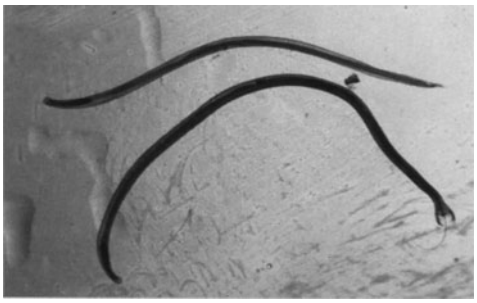


Fig. 89 *Bunostomum phlebotomum*; adult male (10–18 mm) and female (25–28 mm)

Toxocara (syn. *Neoascaris*) *vitulorum*
Large cattle roundworm

Location: Small intestine

Hosts: Cattle

Species description: Large white worms with blunt ends, up to 30 cm long and 5 mm in diameter. The head end is characterised by three lips without papillae. The cuticle is thin and these worms therefore have a soft, translucent appearance. Adults are almost exclusively found in young calves. Adult females produce enormous numbers of eggs (8×10^6 eggs per day).

The patency is low and 4–6 months after birth no adults remain in calves. Eggs become infective within 15 days and may survive for extended periods. Infection is acquired by ingestion of embryonated eggs (containing second-stage larvae). The larvae hatch in the intestine of the host and penetrate the intestinal wall and either migrate via liver, lungs, trachea, oesophagus to the intestines where they develop to adults or they migrate to several tissues, including mammary glands. These larvae may remain dormant until they are mobilized during the late pregnancy to pass via the milk to the calves. These larvae may reach maturity about three weeks after the calf is born. *Toxocara* larvae can also cross the placenta. *T. vitulorum* is found almost exclusively in calves and prenatal and trans-mammary infections constitute the major sources of infection of young calves.

Geographic distribution: World-wide

Symptoms: Unspecific; intermittent diarrhoea, steatorrhoea, colic due to intestinal obstruction, weight loss and death.

Significance: In tropical and subtropical regions of Africa *T. vitulorum* is considered as a serious parasite with high mortality rates among neonatal calves. In temperate areas this parasite occurs without producing great losses.

Diagnosis: Eggs with thick, pitted shells (75–95 × 60–75 µm) appear in the faeces of calves which are around 4–6 weeks old. Sometimes adult, almost transparent worms appear on the faeces. An increased antibody titer of the pregnant cow close to birth may indicate a risk of prenatal infection of the foetus.

Therapy: Several of the anthelmintics commonly used for trichostrongyle infections in cattle are also effective against *T. vitulorum* in calves. These include albendazole, fenbendazole, oxfendazole, febantel, mebendazole and levamisole. Piperazine (70–150 mg, po.) also eliminates *T. vitulorum* (☞ below THERAPY OF NEMATODE INFECTIONS).

Prophylaxis: In endemic areas pregnant cows and neonatal calves should be treated with compounds which are effective especially against immature stages such as levamisole (7.5 mg/kg po. or pour on), pyrantel (10–20 mg/kg po.) or fenbendazole (7.5 mg/kg po.).

(Figures 90, 91)

Fig. 90 *Toxocara vitulorum*; adult worms (up to 30 cm long) found in the small intestine at slaughter [8]

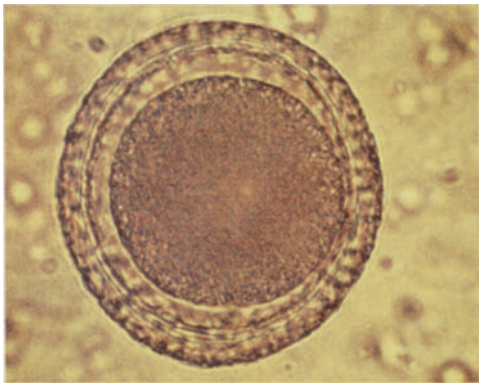


Fig. 91 Egg of *Toxocara vitulorum* (69–95 × 60–77 µm) [11]

Trichuris ovis, Trichuris globulosa and *Trichuris discolor* Whipworms

Location: Caecum and colon

Hosts: Cattle, sheep, goat and many other ruminant species

Species description: Whip worms are 3–8 cm long and easily identified by their long filamentous anterior portion and a thick shorter posterior portion. The male posterior end is usually tightly coiled and there is a single spicule. Direct roundworm life cycle. Infective larvae (second-stage larvae) develop within the eggs after at least 3 weeks on pasture. Eggs may remain infective for several years. Animals become infected by ingesting embryonated eggs, and the larvae penetrate the anterior small intestine for 2–10 days before they move to the caecum where they develop to adults. Prepatent period is 50–84 days and varies markedly among the species. High numbers of preadult and adult worms cause irritation and inflammation of the caecum and colon.

Geographic distribution: World-wide

Symptoms: Mild infections (up to 50 adult *Trichuris* spp. in cattle or small ruminants) do not cause symptoms. Heavy infections (> 500 adult *Trichuris* spp.) may cause colitis, diarrhoea, progressive weight loss. Oedema may occur in the neck and thoracic region.

Significance: Whipworms are widespread but the naturally acquired infections in cattle, sheep and goats usually do not cause clinical disease. Sheep older than 8 months show an age resistance, resulting in a resistance to reinfection 2–3 weeks after a primary infection. However, animals kept in poor condition and carrying multiple infections (e.g. trypanosomes and trichostrongylids) are often heavily parasitised by *Trichuris* spp.

Diagnosis: Demonstration of the characteristic, brown, barrel-shaped eggs with a transparent plug at either pole.

Therapy: Some of the modern benzimidazoles (at increased dose rates) may be used to treat *Trichuris* spp. and *Capillaria* spp. infections in ruminants. These include albendazole, fenbendazole, netobimin and oxfendazole. Ivermectin (200 µg/kg, sc.) is effective.

Prophylaxis: Difficult because of the tenacity of the infective eggs. Regular removal of faeces in the surroundings of the animals may drastically reduce the infection risk.

(Figures 92, 93, 94)

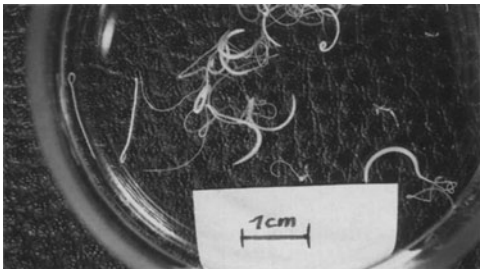


Fig. 92 *Trichuris* spp.; adult parasites

Fig. 93 *Trichuris* spp.; masses of worms in the large intestine of a calf

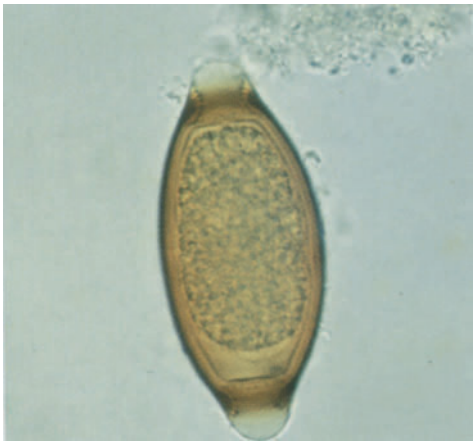


Fig. 94 Egg of *Trichuris* spp. (70–80 × 25–40 µm) [4]

Fig. 95 *Capillaria bovis*; adult parasite containing eggs

Fig. 96 Egg of *Capillaria bovis* (40–50 × 22–25 µm)

Trichuris skrjabini

Remarks: This parasite occurs in dromedaries and may occasionally be found in cattle (☞ DROMEDARIES, ■ 1).

Capillaria bovis

Location: Small intestine
Hosts: Cattle, sheep, goat and other ruminants
Species description: *C. bovis* occurs in the gastrointestinal tract of cattle, sheep and goats. The males are 8–13 mm and the females are 12–20 mm in length. The eggs measure 45–50 µm × 22–25 µm. The life cycle is direct.
Geographic distribution: Temperate climates but via imports also in Africa
Symptoms: Low or no pathogenic effect in ruminants
Significance: Little is known about *Capillaria* spp. except that they occur frequently.
Diagnosis: Detection of *Capillaria* eggs by the flotation or sedimentation method.
Therapy and Prophylaxis: ☞ *Trichuris* spp.
(Figures 95, 96)

Strongyloides papillosus
Intestinal threadworm

Location: Small intestine
Hosts: Cattle, sheep, goat, dromedary and other ruminants
Species description: *S. papillosus* is a hair-like nematode which is 3.5–6 mm long and only 0.05–0.06 mm wide. Only the parthenogenetic females are parasitic. They are embedded in the mucosa of the upper small intestine. Free-living males and females reproduce sexually outside the host. Infection is acquired by ingestion of infective third-stage larvae and skin penetration.

S. papillosus can cross the placenta and infect calves before birth. This parasite can also pass via the colostrum to newborn calves.

After ingestion or skin penetration of infective larvae they migrate via blood to the lungs. After penetration of the alveoli they are coughed up and swallowed, and develop within 9 days into adults. There are two possible ways of development; one is a homogonic cycle involving adult females in the host producing eggs that do not require fertilisation to develop. These eggs are passed in the faeces and then develop to infective third-stage larvae.

In the heterogonic cycle adult threadworms in the intestine lay eggs which develop into a different type of larvae. These larvae can develop to adult males and females which can live outside the host. The fertilised eggs of this population produce infective larvae that are ingested by the host. The prepatent period is about 10 days!

Geographic distribution: World-wide

Symptoms: The migratory phase is associated with coughing, fever and pneumonia which may be followed by secondary infections, especially in calves kept under poor conditions. Adult parasites cause irritation and severe inflammation of the small intestine. Catarrhal enteritis, digestive disturbances and intermittent diarrhoea may be seen. Death may occur in suckling calves.

Significance: Intestinal threadworms are widespread in warm and humid areas. They may cause great losses, particularly in young calves.

Diagnosis: Small, embryonated, thin-shelled eggs appear in the faeces. The adult, parasitic females are difficult to recognise at necropsy. Microscopical examination of mucosa scrapings is necessary to discover them.

Therapy: Not all the anthelmintics are effective against the intestinal threadworms. Albendazole, febantel and fenbendazole, oxfendazole are effective and proven against *S. papillosus*. Most of the modern benzimidazoles are effective against *S. papillosus* (Table 5). Thiabendazole (75 mg/kg, po.) is very effective. Ivermectin (200 µg/kg, sc.) is effective against the adult worms. Levamisole and mebendazole are insufficiently effective against intestinal threadworm infections.

Prophylaxis: Special attention must be paid to pasture management. The night holding areas should be rotated regularly to reduce the infection risk in the surroundings of the herds. Suckling calves should be kept on clean, dry areas to avoid infection by skin penetration. In heavily infected herds, the pregnant cows should be treated with an anthelmintic to avoid transplacental infection of the unborn calf. Treatments must be repeated more frequently than with other nematodes because of the extremely short prepatent period.

(Figures 97, 98)

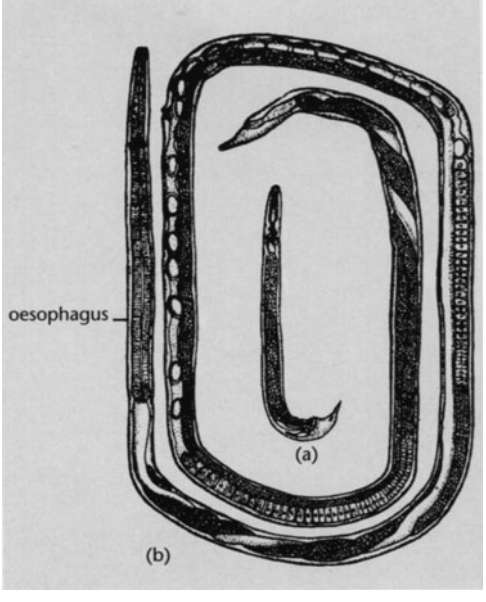


Fig. 97 *Strongyloides papillosus*; free living male (a) and parthenogenetic parasitic female (3.5–6 mm long) with elongated oesophagus (b) [5]

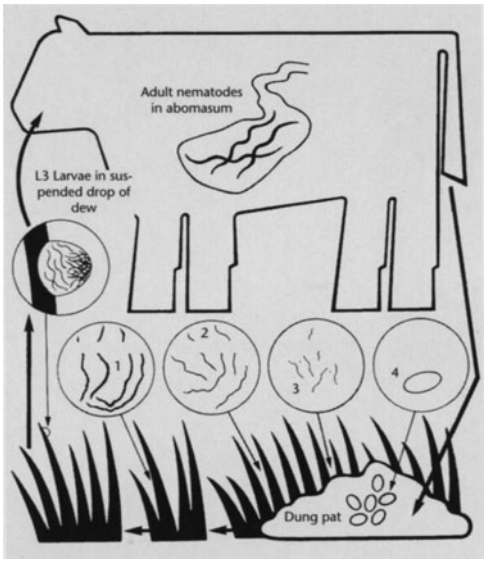
Fig. 98 Embryonated egg of *Strongyloides papillosus* (45–65 × 25 µm)

- **Therapy of nematode infections**

Species of *Haemonchus, Mecistocirrus, Parabronema, Trichostrongylus, Ostertagia, Cooperia, Impalaia, Nematodirus, Bunostomum,* and *Oesophagostomum*

Gastrointestinal nematodes occur wherever ruminants are raised. Attempts to control nematode infections should concentrate on a reduction of the worm load rather than on an eradication of these parasites. The risk to acquire a harmful infection is high where the stocking rate is high (fenced paddocks, correos, night holding places, etc.) or when the daily grazing time is short at the time when animals should put on body weight (e.g. rainy season in mixed farming-systems of sub-Saharan regions). Priority should be given to strategic control rather than to a regular dosing of anthelmintics. Animals at risk (weaned calves) should be treated repeatedly during the first grazing season. Strategic control programs of first season grazing animals in temperate areas are described extensively (☞ FURTHER READING). In semiarid areas first season calves should be treated at least twice during the rainy season, 4 weeks after the onset of the rains and at the end of the rains with an anthelmintic listed below, in order to make animals use the great food resources of the wet season. An additional treatment at the culmination of the wet season may markedly increase the growth rate. Regular rotation of the heavily contaminated pastures or night holding places and long daily grazing periods during the rainy season are effectively reducing the risk of nematode infections. Rainy season treatment is more effective than dry season treatment.
(Figures 99, 100, 101, Table 5)

Fig. 99 N'Dama cattle tethered on a "correo". The night holding areas may represent an important source of infections with gastrointestinal nematodes



1 L3 Larvae in grass, 2 L2 Larvae in dung, 3 L1 Larvae in dung pat, 4 Nematode egg in dung pat

Fig. 100 Direct life cycle of a typical round worm

Table 5 Anthelmintics recommended for cattle and sheep

Anthelmintics	Spectrum	Dosage (mg/kg)		
		Cattle	Sheep	AM
Albendazole	Nematodes, cestodes, trematodes	7.5	5.0	po.
Coumaphos	*Trichostrongylid* spp.	2 (6x)		po.
Febantel	Nematodes	7.5	5	po.
Fenbendazole	Nematodes, cestodes	7.5	5.0	po.
Ivermectin	Nematodes, arthropods	0.2	0.2	po. or sc.
Ivermectin and Clorsulon	Nematodes, trematodes, arthropods	0.2/7		po.
Ivermectin	Nematodes, trematodes, arthropods	0.5		pour on
Levamisole	Nematodes	5 0	5.0	sc. or im.
Levamisole	Nematodes	7.5	7.5	po.
Levamisole	Nematodes	10	10	pour on
Mebendazole	Nematodes	20		po.
Netobimin	Nematodes, cestodes	7.5	7.5	po.
Morantel tartrate	Nematodes	10	10	po.
Morantel tartrate	Nematodes	SRB*		ir.
Oxfendazole	Nematodes, cestodes	4.5	5	po.
Phenothiazine	Nematodes	220[1]		po.
Pyrantel tartrate	Nematodes	12.5	25	po.
Thiabendazole	Nematodes	44–75		po.
Moxidectin	Nematodes, arthropods	0.2	0.2	po.

*Slow Release Bolus (rumen retention device releases about 200 mg/day for 60 days)

[1] safety index very low (= 1); AM = application method, po. = orally, sc. = subcutaneously, im. = intramuscularly and ir. = intraruminal

PROTOZOA

TRYPANOSOMATIDAE

Trypanosoma congolense, Trypanosoma vivax, Trypanosoma brucei Tsetse-transmitted trypanosomosis, Nagana, sleeping sickness

Hosts: Cattle, sheep, goat and many other domestic and wild animal species

Vector: Several species of tsetse flies: *Glossina morsitans* (savanna areas), *Glossina palpalis* (areas around rivers and lakes) and *Glossina fusca* (high forest areas). All three species transmit trypanosomosis and feed on a wide spectrum of mammals.

Species description: The most important trypanosomes affecting cattle, sheep and goats are as follows (in order of importance): *T. congolense, T. vivax* and *T. brucei*. These three species belong to the Salivaria (Table 6). The differentiation and the morphological characteristics of these pathogenic trypanosomes are listed in Table 7. All three species are transmitted by tsetse flies. Most tsetse-transmission is cyclic and begins when blood from a trypanosome infected animal is ingested by the fly. The trypanosomes lose their surface coat, multiply in the fly, re-acquire a new surface coat and become infective. The life cycle within the tsetse fly varies among the different trypanosome species. The infective form for animals in the tsetse fly is referred to as the metacyclic form. The development in the tsetse flies may be as short as 1 week with *T. vivax* or extend to a few weeks for *T. brucei*. Mechanical transmission requires blood containing trypanosomes being transferred from one animal to another. Tsetse flies inoculate metacyclic trypanosomes into the skin of animals, where the trypanosomes multiply and cause swellings (chancres). They enter the blood stream either directly or through the lymph nodes, then the bloodstream where they divide rapidly by binary fission. *T. congolense* attach to endothelial cells and localize in capillaries. *T. brucei* and *T. vivax* invade tissues and cause tissue damage in several organs. The necropsy findings vary and are not specific. Extensive petechiae of the serosal membranes, especially in the peritoneal cavity may occur in acute, fatal cases. The lymph nodes and the spleen are usually swollen. Chronic cases are associated with atrophy of body and organ fat, severe anaemia and swollen lymph nodes.

The immune response of infected animals is vigorous, and immune complexes cause inflammation, which contributes to the clinical signs and lesions of trypanosomosis. Trypanosomes have multiple genes that code for different surface-coat glycoproteins. The number of different antigenic types of glycoprotein that can be made is unknown but exceeds several hundred. The antigenic variation results in persistence of the organisms in the host and is a way of the parasite to evade the host's immune system. Antigenic variation has prevented the development of a vaccine and permits reinfections when animals are exposed to a new antigenic type of the same trypanosome species. Animals infected with trypanosomes show some degree of immunodepression and are more susceptible to a.o. gastrointestinal helminth infections. *Haemonchus contortus* shows a reduced prepatent period and causes a markedly increased mortality in animals that are chronically infected with trypanosomes.

Some *bos indicus* (Zebu) are very sensitive to trypanosomosis and they are generally

Table 6 Pathogenicity[1] of salivarian trypanosomes in livestock

Trypanosome subgenus	Trypanosome species	Cattle	Sheep and Goats	Pigs	Camels	Equines
Trypanozoon	*T. brucei*[2]	+	+ +	+	+ + +	+ + +
	T. evansi[3]	+ +	+	+ +	+ + +	+ + +
	T. equiperdum[4]	-	-	-	-	+ + +
Nannomonas	*T. congolense*	+ + +	+ +	+	+ +	+ +
	T. simiae	-	+	+++	+++	-
Duttonella	*T. vivax*	+ + +	+ +	-	+ +	+ +
Pycnomonas	*T. suis*[5]	-	-	+ +	-	-

- = not pathogenic; + = mildly pathogenic; + + = moderately pathogenic; + + + = severely pathogenic;
[1]under usual field conditions, but which is modified by many factors; [2]*T. brucei gambiense* and *T. brucei rhodesiense* cause human sleeping sickness in West and East Africa, respectively, and have animal reservoirs, in which pathogenicity is low; *T. brucei brucei* is not infective to humans; [3]mechanical transmission by biting flies other than tsetse; [4]venereal transmission; [5]rarely encountered

Table 7 Morphological characteristics of trypanosomes

Species	Free flagellum	Kinetoplast	Undulating membrane	size in µm	Size and motility in dark ground
T. vivax	present	large, terminal	not prominent	20-26	large,extremely active, transverses the whole field quickly
T. brucei	present in all but stumpy forms central	small, subterminal	prominent	12-35*	large, rapid movements in confined areas
T. congolense	absent	medium, subterminal, marginal	not prominent	9-18	small, adheres to red blood cells by anterior end

* polymorphic: slender, intermediate and stumpy forms; *T. theileri* is frequently found in cattle and may be distinguished by its large size; *T. theileri* is more than twice the size of the pathogenic African trypanosomes

not raised within the tsetse-belt. The most pathogenic species for cattle is *T. congolense*, which causes an acute, lethal disease in zebu cattle. Some pure taurine cattle breeds are less susceptible and succumb less to the disease. *T. vivax* causes a less acute disease than *T. congolense*. In East Africa, however, *T. vivax* can cause an acute hemorrhagic syndrome. Development of clinical symptoms is slower but remissions are frequent. *T. brucei* causes a chronic infection without distinct symptoms.

A number of indigenous African taurine cattle breeds (e.g. N'Dama, Baoulé, West African Shorthorn and many others) are less susceptible to trypanosomosis (often referred to as "trypanotolerance"). These breeds are adapted to a certain environment and tsetse-challenge and may be an alternative way to control losses due to trypanosomosis. However, "trypanotolerance" is not an absolute trait and refers to a lower susceptibility of an indigenous breed to its innate environment. If such animals are kept under heavy trypanosomosis challenge they may equally succumb like other non-tolerant breeds. Many indigenous breeds of sheep and goats from western and Central Africa are also resistant to trypanosome infections.

Geographic distribution: *T. congolense* and *T. brucei* occur mainly within the tsetse-belt (area from latitude 15°N to 29°S) of Africa. *T. vivax* occurs in Africa within the tsetse-belt where it is transmitted by tsetse flies but also in non-tsetse areas (Central and South America, West India, Mauritius) where it may be transmitted by Tabanids and biting flies.

Symptoms: The primary clinical signs are intermittent fever, anaemia and weight loss. Cattle usually have a chronic course with a high mortality, especially if there are other stress factors such as poor nutrition or other diseases. Mortality rates are increased if concomitant infections with gastrointestinal helminths are present. Blood sucking nematodes (e.g. *Haemonchus contortus, Bunostomum* spp. and *Gaigeria* spp.) may severely aggravate the anaemia. Ruminants generally recover gradually if the number of infected tsetse flies is low. However, stress results in relapse.

Significance: Tsetse-transmitted trypanosomosis is one of the major constraints for cattle rearing within the tsetse-belt of Africa. Trypanosomes render their host more susceptible to other diseases (e.g. worm infections) which then may contribute to the high mortality.

Diagnosis: A presumptive diagnosis is based on finding an animal in poor condition in an endemic area. Confirmation depends on demonstrating trypanosomes in a wet mount of the buffy coat area of a PCV tube after centrifugation (☞ METHODS, 3.4). Other infections that cause anaemia and weight loss, such as gastrointestinal nematodes, babesiosis, anaplasmosis and theileriosis should be eliminated by further examinations. Various serological tests are suitable for herd and area screening rather than for individual diagnosis. Tests for the detection of circulating trypanosome species-specific antigens in peripheral blood may be useful for both individual and herd diagnosis.

Therapy: Most of the drugs commonly used to treat trypanosomosis (Table 8) have a narrow therapeutic index. Therefore the administration of the correct dosing is essential. Resistance to trypanocidal drugs is widespread and should be considered in refractory cases. The following compounds may be used in ruminants: Diminazene aceturate (3.5–7 mg/kg, im.), homidium bromide (1 mg/kg, im.), isometamidium (0.5–1 mg/kg, im.) and quinapyramine sulfate (5 mg/kg, sc.) (☞ Table 8). Concomitant gastrointestinal nematode infections should be treated at the same time and supportive treatment (e.g. iron dextrane) may help recovery (☞ CATTLE, ■ 1).

Prophylaxis: Control can be carried out at several levels. Attempts to eradicate tsetse flies have failed and are no longer justifiable. Tsetses can be partially controlled in the surrounding of a herd by spraying or dipping of animals. The strategic use of insecticide-impregnated screens may drastically reduce the tsetse population in the surrounding of herds and thus the infection risk. Pour-on application of insecticides on a herd level is an effective way of controlling both tsetse flies and fly nuisance (☞ CATTLE, ■ 5). Losses due to trypanosomosis are often drastically increased by other opportunistic infections (mainly gastrointestinal nematodes) and other stress fac-

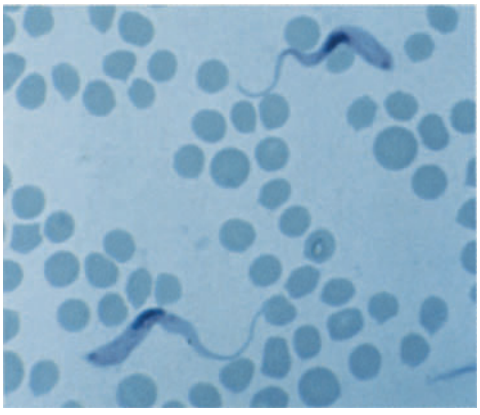


Fig. 101 *Trypanosoma vivax* (20–26 µm); Giemsa-stained bloodsmear [4]

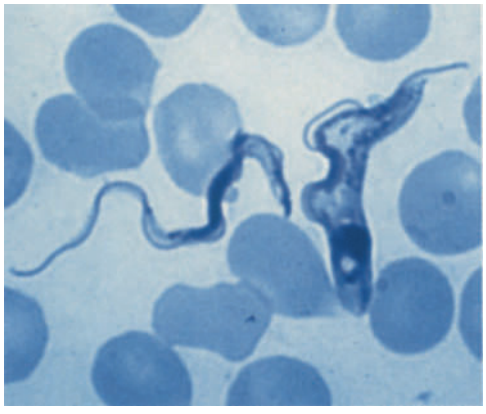


Fig. 102 *Trypanosoma brucei* (12–35 µm); Giemsa-stained bloodsmear; this species is polymorphic: slender form (left), stumpy form (right) [13]

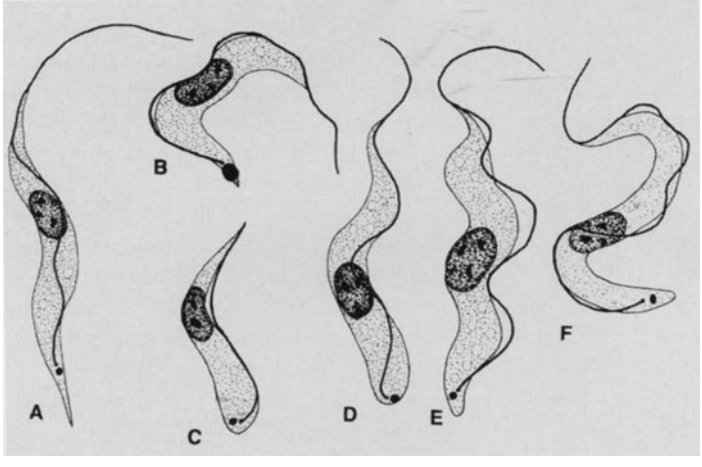


Fig. 103 Important *Trypanosoma* species of livestock: (a) *Trypanosoma theileri* (60–70 µm), (b) *T. cruzi*, (c) *T. congolense* (9–18 µm), (d) *T. vivax* (20–26 µm), (e) *T. equiperdum* (25 µm) and (f) *T. brucei* (12–35 µm, polymorphic) [14]

tors. Control measures should also include these factors. The prophylactic use of trypanocidal drugs requires a regular application of the drug and includes the risk of creating resistance. It should therefore be limited to emergencies, such as cattle trekking through infested areas and herds seasonally exposed to high trypanosomosis risk. Isometamidium (1–2 mg/kg, im.) protects cattle for 2 to 6 months. Prophylactic use of trypanocidal drugs should be avoided in cattle prior to slaughtering, since drug residues may be detrimental to human health. Proper nutrition is essential in all cases and the strategic application of crop residues at the late dry season may significantly improve the nutritional status and thus the resistance of animals in endemic areas. The exploitation and propagation of indigenous breeds can be a promising way of animal production in endemic areas.

(Figures 101, 102, 103, 104, 105, Table 6, Table 7, Table 8)

Table 8 Generic and trade names of trypanocides for the the treatment and prevention of animal trypanosomosis

Compound generic name	Trade name	Manufacturer	Action	Range of dosage Rates (mg/kg)	Route of administration	Remarks
Diminazene aceturate	Berenil	Hoechst AG, Germany	T	3.5-7.0	IM SC	Also babesiacidal; toxic to horses, donkeys, dogs, and camels
	Ganasag	Squibb, USA	T	3.5-7.0	IM or SC	
Homidium bromide	Ethidium	CAMCO Animal Health, UK	T(P)	1.0	IM	
Homidium chloride	Novidium	Rhône-Merieux, France	T(P)	1.0	IM	
Isometamidium	Samorin	Rhône-Merieux, France	P/T	0.25-1.0	IM, IV[3]	Toxic above 2 mg/kg; highly irritant; avoid SC administration
	Trypamidium	Rhône-Poulenc Sante France	P/T	0.25-1.0	M, IV[3]	
Quinapyramine sulfate[1]*	Antrycide	Coopers Animal Health Ltd, UK	T	3.0-5.0	SC	Rest animals before and after treatment
Quinapyramine prosalt[1]	Antrycide[2] R.F.	Coopers Animal Health Ltd, UK	PT	3.0-5.0	SC	Dosage calculated as sulfate
Suramin*	Naganol Antrypol	Bayer AG, Germany	T	10.0	IV	Severe local reactions by other routes
Melaminophenylarsine dihydrochloride	Cymelarsan	Rhône-Merieux, France	T	0.25-0.5	IM, SC	The IM route is preferred in equines. *T. evansi* and *T. brucei*

Many of these preparations are sold under a variety of trade names. Consult publications such as *Veterinary Pharmaceuticals and Biologicals*, 6th ed. Lenexa, KS, Veterinary Medicine Publishing Co, 1989/1990;

[1]Reintroduced in 1985 to treat mainly *T. evansi* infections;

[2]Prosalt. This is a mixture of sulfate and chloride salts of quinapyramine;

[3]Given by very slow injection of 1% W/V solution at 0.5 mg/kg;

T = therapeutic action; P = prophylactic action; (P) = short prophylactic activity; IM = intramuscular; IV = intravenous; SC = subcutaneous;

* no longer commercially available

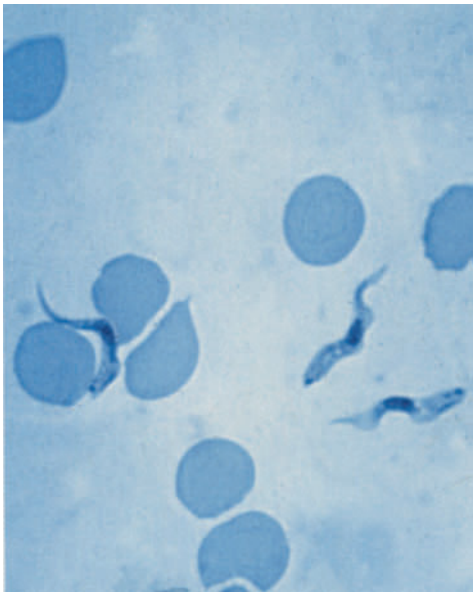


Fig. 104 *Trypanosoma congolense* (9–18 µm); Giemsa-stained bloodsmear [15]

Fig. 105 Comparison of a trypano-tolerant N'Dama cattle (left) and susceptible zebu (right) after 15 weeks' exposure to a middle-grade tsetse challenge. Both animals were chronically infected with *Trypanosoma congolense* [36]

Trypanosoma evansi (syn. *T. brucei evansi*) Surra

Remarks: *T. evansi* occurs in dromedaries, equines, buffaloes, carnivores and many other mammalian species. It occurs in North Africa, Asia, Middle and South America. The pathogenicity of *T. evansi* strains varies considerably but the highest pathogenicity is commonly observed in camels and equines (☞ DROMEDARIES, ■ 2). Several species of blood-sucking flies act as vectors. *T. evansi* is not transmitted by tsetse flies. No developmental stages have been demonstrated in the vectors which differentiate the parasite from *T. brucei*. *T. evansi* is 15–35 µm long and 1.5–2.5 µm wide. *T. evansi* is morphologically identical with *T. brucei* and other members of the subgenus Trypanozoon (☞ DROMEDARIES, ■ 2).

Trypanosoma theileri

Hosts: Cattle

Vector: Tabanid flies (*Tabanus* spp. and *Haematopota* spp.)

Species description: This is a large species (60–70 µm, sometimes up to 120 µm in length=twice the size of the pathogenic trypanosomes) and belongs to the Stercoraria. The undulating membrane is well developed and the free flagellum is well defined. Although the parasite is considered as non-pathogenic it may assume increased significance when stress conditions arise or when concurrent infections with other pathogens are present.

Geographic distribution: World-wide
Symptoms: Infections are often asymptomatic.
Significance: This species may be very prevalent but it seems to be nonpathogenic.
Diagnosis: ☞ above *T. congolense*, *T. vivax*, *T. brucei*
Therapy and Prophylaxis: Generally not indicated
(Figure 106)

Fig. 106 *T. theileri* (60–70 µm, sometimes up to 120 µm); Giemsa-stained bloodsmear [4]

BABESIIDAE

Babesia bovis
Redwater, tropical bovine babesiosis

Hosts: Cattle
Vector: *Boophilus* spp. (*B. microplus, B. annulatus*) and possibly *Rhipicephalus bursa.*
Species description: This is a small form, 2.4 × 1.5 µm and slightly larger than *B. divergens*. The organisms (merozoites) are usually found in the centre of the erythrocytes. Vacuolated "signet-ring" forms are especially common. Transovarian transmission occurs in the ticks.
Geographic distribution: Tropical Africa, Madagascar, Mediterranean basin and southern Europe
Significance: The disease caused by *B. bovis* is similar to that caused by *B. bigemina*. Affected animals may die. The strains vary in virulence. In some regions *B. bovis* is more virulent than *B. bigemina*.
(Figures 107, 108)

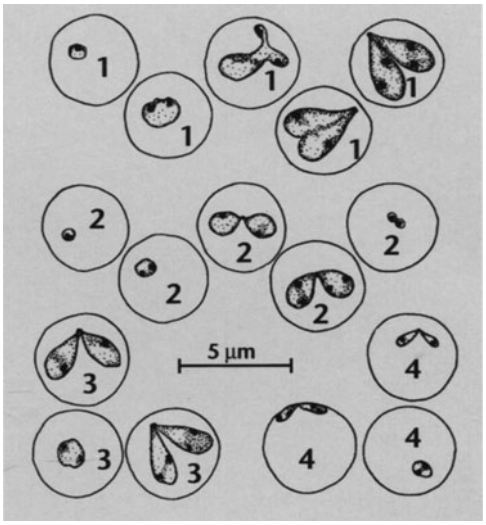


Fig. 107 Morphology of bovine *Babesia* spp. 1 *Babesia bigemina* , 2 *Babesia bovis* , 3 *Babesia major* and 4 *Babesia divergens* [16]

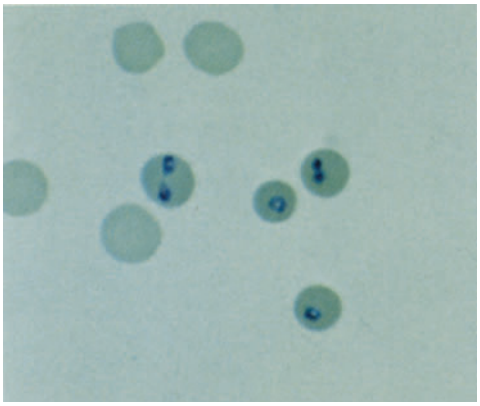


Fig. 108 *Babesia bovis* (2.4 × 1.5 µm, "small form"); Giemsa-stained bloodsmear [4]

Babesia divergens
European bovine babesiosis

Hosts: Cattle
Vector: *Ixodes ricinus* and possibly other ticks
Species description: This species is smaller than *B. bovis*. The merozoites usually occur as paired, club-shaped organisms about 1.5 × 0.4 µm. The angle between the pair is relatively large, so that they diverge more from each other than those of *B. bovis*. The organisms tend to lie along the circumference of the host erythrocyte. Other forms may be stout and pyriform, measuring 2 × 1 µm; some may be circular and others may be vacuolated and up to 2 µm in diameter. Transovarian transmission occurs in the vector. Highest parasitaemia levels are found during the period of high fever.
Geographic distribution: Northwestern Africa in woodlands at altitudes above 1000 m. It also occurs in northern and central Europe.
Significance: The disease entity produced by *B. divergens* is less severe than that caused by *B. bigemina*. In severe infections death may occur.
(Figure 109)

Babesia bigemina (syn. *Piroplasma bigeminum*), Redwater, tropical bovine piroplasmosis, tick fever, "Texas fever"

Hosts: Cattle
Vector: *Boophilus* spp. (*B. microplus, B. decoloratus, B. calcaratus*), *Rhipicephalus* spp. (*R. evertsi, R. bursa* and *R. appendiculatus*), and *Haemaphysalis* spp. (*H. punctata*)
Species description: This is a large form, 4–5 µm by 2 µm wide. Round forms are 2–3 µm in diameter. The organisms are characteristically pear-shaped and lie in pairs forming an acute angle in the erythrocyte. Round, oval or irregularly shaped forms may occur, depending on the stage of development. Transovarian transmission occurs in the ticks. *B. bigemina* is one of the most pathogenic *Babesia* species known.
Geographic distribution: Tropical Africa, Madagascar, Mediterranean basin and many other parts of the world
Significance: *B. bigemina* is one of the most important diseases of cattle in some tropical and subtropical areas.
(Figure 110)

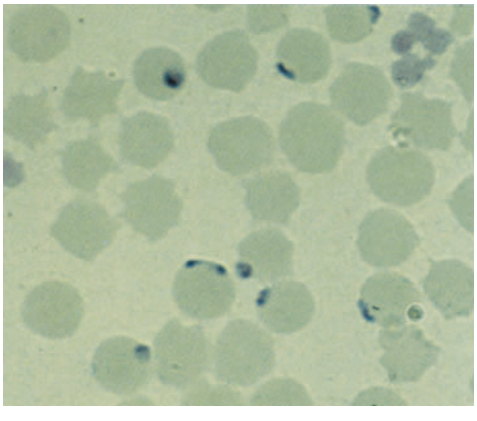


Fig. 109 *Babesia divergens* (1.5 × 0.4 µm); Giemsa-stained bloodsmear [4]

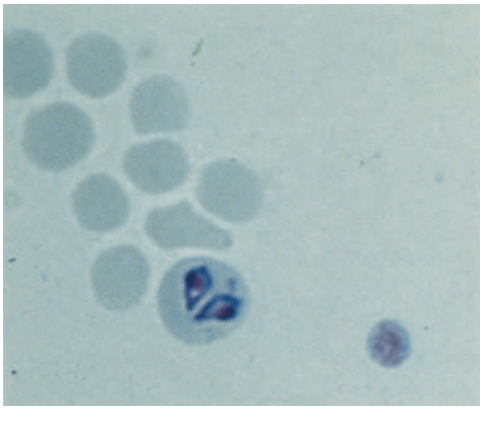


Fig. 110 *Babesia bigemina* (4–5 × 2 µm, "large form"); Giemsa-stained bloodsmear [4]

Babesia major (syn. *Piroplasma major*)
European bovine piroplasmosis

Hosts: Cattle
Vector: *Haemaphysalis punctata*
Species description: This species resembles *B. bigemina* except that it lies in the centre of the erythrocyte. The pyriform bodies are 2.6 × 1.5 µm and the angle formed by the organisms is less than 90°. Round forms are about 1.8 µm in diameter. Transovarian transmission may occur in the tick vector.
Geographic distribution: North Africa, Europe, UIS, South America
Significance: *B. major* is less pathogenic than *B. bovis*. Clinical signs are moderate and sometimes infections are inapparent.
(Figure 111)

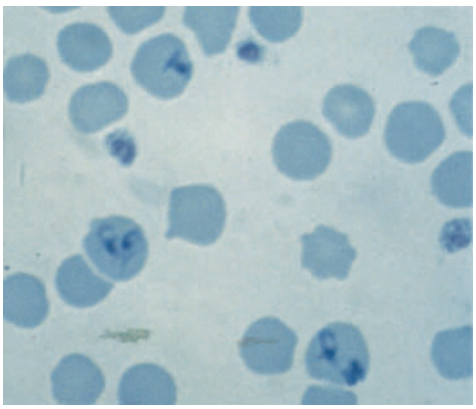


Fig. 111 *Babesia major* (2.6 × 1.5 µm); Giemsa-stained bloodsmear [15]

- **General features of bovine babesiosis**

Symptoms: Infections with *B. bigemina*, *B. major* and *B. divergens* are characterised by a haemolytic syndrome (haemolytic babesiosis), including continuous fever (40–41°C), high parasitaemia (2.5–10%), anaemia, icterus (intense yellow-brownish ocular, gingival and vaginal mucosae) and haemoglobinuria (dark brown, frothy urine) and general depression. Abortion and agalactia in dairy cows are early signs. The symptoms are less pronounced in the subacute form. *B. bovis* infections are dominated by a shock syndrome, leading to death following a steep rise in temperature in the peracute form. Acute disease is accompanied by fever, ataxia, pedalling movements and overt agressivity (attacks). Haemolysis, icterus and haemoglobinuria are less apparent than in other babesioses.
Significance: Widespread throughout the tropics, causing heavy losses in non-resistant (often imported) livestock. Without treatment mortality rates are very high (30% for *B. bigemina*, 70–80% for *B. bovis*). *B. bigemina* is one of the most important diseases of cattle in some tropical and subtropical areas.
Diagnosis: Clinical diagnosis is difficult and can be confused with leptospirosis (peracute disease), anaplasmosis (chronic in nature) or cowdriosis (no movements). Splenomegaly, icterus and haemoglobinuria and thickened bile in the gall bladder are characteristics of haemolytic babesiosis. Petechiae and microinfarcts suggest infections with *B. bovis*. The presence of Babesia parasites in the blood smears of animals without clinical symptoms does not necessarily support the diagnosis of babesiosis. It can be a resurgence of a chronic infection following an immunosuppression due to another disease. In *B. bigemina* infections the severity of the disease can be deducted from the percentage of parasitized red blood cells (< 0.1% mild, 0.5–1% subacute, 5–10% severe infection), whereas in *B. bovis* infections the presence of parasites indicates babesiosis, because parasite concentration in the peripheral blood is considerably lower than in the organs. In acute *B. bovis* infections impression smears of congested organs show punctiform babesial bodies in agglutinated erythrocytes. Serological techniques (IFAT, ☞ METHODS, 5.1) are available and should be used especially in epidemiological studies. For the individual

Table 9 Drugs used in the treatment of babesiosis in cattle

Drug	Dosage	AM	Parasite	Remark
Trypan blue*	2-3 mg/kg	IV	*B. bigemina*	Not effective against small babesias; discouloration of animal's flesh; can cause severe tissue sloughing if not given IV
Acridine derivatives				
Euflavine[1]*	4-8 ml/100 kg as 5% solution	IV	*B. bigemina* *B. bovis* *B. divergens*	Highly irritant if not given IV
Diamidine derivatives				
Amicarbalide Diampron[1]	5-10 mg/kg	IM	*B. bigemina* *B. divergens* *B. bovis*	
Diminazene Berenil[2]	3-5 mg/kg	IM	*B. bigemina* *B. bovis* *B. divergens*	
Imidocarb	1-3 mg/kg Imizol[3]	SC or IM	*B. bigemina* *B. bovis* *B. divergens*	Prophylactic activity up to 8 weeks depending on dose and *Babesia spp.* involved; nephrotoxic; cholinesterase inhibitor; slowly metabolized and eliminated–tissue
Phenamidine Lomadine[1]	8-13.5 mg/kg	SC or IM	*B. bigemina* *B. bovis*	Cholinesterase inhibition
Quinoline derivatives				
Quinuronium Babesan[4]	1 mg/kg	SC	*B. bigemina* *B. bovis* *B. divergens*	Low therapeutic index Slow effect against *B. bovis* Side effects associated with the stimulation of the parasympathetic nervous system

Many of these preparations are sold under a variety of trade names; * no longer commercially available;
IM = intramuscular; IV = intravenous; SC = subcutaneous; AM = application method;
[1] May & Baker Ltd., Dagenham, England. [2] Hoechst AG, Frankfurt, Germany. [3] Burroughs Wellcome & Co., London, England.
[4] ICI-, Macclesfield, Cheshire, England

diagnosis the demonstration of the parasite in the bloodsmear or with the QBC method (☞ METHODS, 3.1 and 3.3) is more adequate.

Therapy: Diminazene aceturate (3.5 mg/kg, im.), Imidocarb dipropionate (1.2–2.4 mg/kg, sc.), quinuronium sulfate (1–2 mg/kg, sc. or im.) and amicarbalide diisethionate (5–10 mg/kg, im.) can be used against the pathogenic *Babesia* species of cattle (☞ Table 9).

Two points should be considered: 1) For serious clinical attacks the dose should be split to avoid shock due to massive destruction of *Babesia*. 2) Most babesicidal drugs are toxic to the host, so caution is required in their use. The commonly used babesicidal compounds are listed in Table 9. In endemic areas it is preferable to support immunity within the population, as such animals can withstand repeated infections. The aim of therapy is therefore to reduce but not to eradicate the parasite concentration within the host. In severely affected animals emphasis should also be given to supportive treatment (electrolytes, rehydration, iron-dextran, etc.) and rich nutrition during the convalescence.

Prophylaxis: Several methods are used in endemic areas to control or prevent babesiosis.

- Controlled immunisation, using babe sicidal-drugs:
  Application of a babesicidal drug (e.g. diminazene aceturate, 3.5 mg/kg, im.) following inoculation of a non-attenuated *Babesia* strain.
- Imidocarb (2 mg/kg) is administered to an animal prior to the introduction onto an infected pasture. The delayed action of imidocarb controls clinical infection (up to 60 days for *B. bigemina* and up to 21 days for *B. divergens* and *B. bovis*) without blocking the immune response.
- Immunization with attenuated *B. bovis* and *B. bigemina* strains:
  Inoculation of a attenuated *Babesia* strains. Several research teams are presently working on the development of *Babesia* vaccines in cattle. In some countries vaccines are available.
- Prophylaxis through tick control:
  In tropical Africa and the Mediterranean region tick control is essential (☞ CATTLE, ■ 5) and should be made weekly during periods of adult tick activity.

(Figure 112, Table 9)

Fig. 112 Icterus and hydropericardium caused by *Babesia bigemina* infection [8]

THEILERIIDAE

Theileriosis is caused by protozoan parasites of the genus *Theileria*. In cattle, there are two highly pathogenic species. *Theileria parva* is the cause of East Coast Fever in East and Central Africa. A variant regarded as either a subspecies, *T. parva lawrencei*, or a type, *T. parva* (*lawrencei* type), is a common benign parasite of the African buffalo (*Syncerus caffer*), which, when transmitted to cattle, causes a condition called corridor disease. *T. parva* (*bovis* type) causes the "January disease" in Zimbabwe. *Theileria annulata* causes tropical theileriosis, which is widespread through the Mediterranean basin, the Middle East and Asia. Other species that infect cattle in Africa are *T. mutans*, *T. taurotragi* and *T. velifera*. They are usually benign, although *T. mutans* may be pathogenic under some circumstances. *T. orientalis* is a generally benign species found in the Mediterranean basin, the Middle

East, Asia and Australia which may cause disease in imported cattle.
(Figures 113, 114, 115)

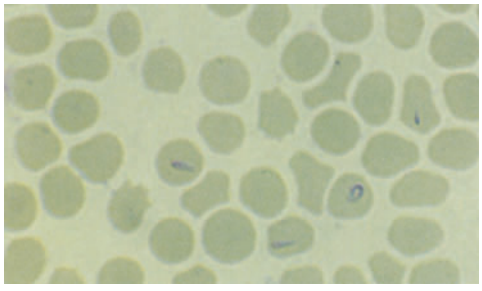


Fig. 113 *Theileria orientalis*; Giemsa-stained blood smear; this species occurs outside of Africa and is lowly pathogenic [4]

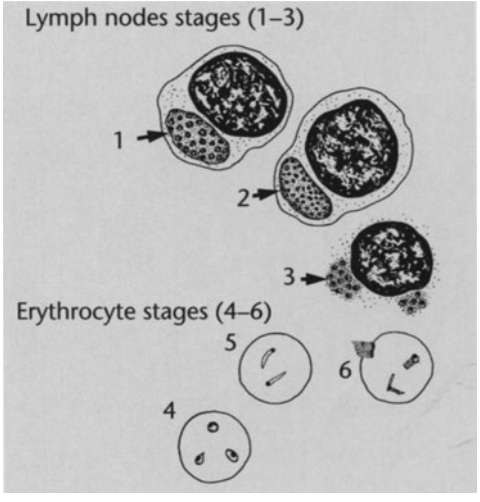


Fig. 114 Morphology of *Theileria* spp. stages in mammals; stages found in the lymph nodes: (1) Macroschizont with medium-sized nuclei (0.4–2 µm; Koch's blue bodies), (2) Microschizont with small nuclei (0.3–0.8 µm) and (3) Merozoites (0.7–1 µm); stages found in the erythrocytes: intra-erythrocytic stages may be (4) circular, oval or piriform (0.8 x1.5 µm; 80%) or (5) comma-shaped (0.5 × 2 µm; 20%); (6) some parasites appear to have a velum [16]

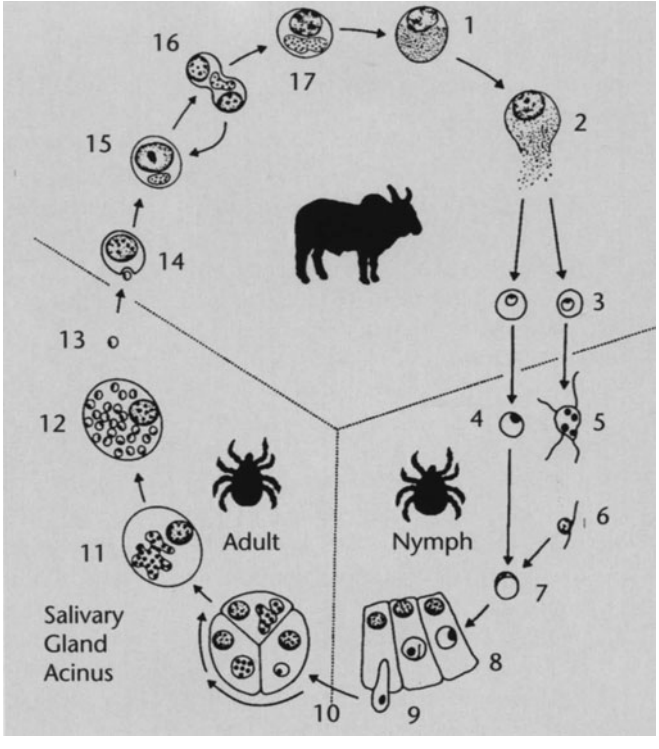


Fig. 115 Life cycle of *Theileria parva* [17]
(1) Merogony, (2) Merozoites (3) Piroplasm in erythrocyte, (4) Macromete, (5) Syngamy, (6) Microgamete, (7) Zygote in gut lumen, (8) Gut epithelial cells, (9) Kinete, (10) Moult, (11) Sporogony, (12) Sporozoites, (13) Sporozoite in saliva, (14) Sporozoite enters lymphocyte, (15) Schizont in lymphoblast, (16) Clonal expansion, (17) Schizont

Theileria parva (syn. *T. bovis, T. lawrencei*)
East Coast Fever, bovine theileriosis, Corridor Disease, Rhodesian tick fever

Hosts: Cattle, water buffalo, African buffalo

Vector: *Rhipicephalus appendiculatus* (equatorial East Africa and southern Africa above 1200 m) and *Rhipicephalus duttoni* (Angola plateau). Other vectors are *Rhipicephalus zambeziensis, Hyalomma excavatum, H. dromedarii, H. truncatum* and some other *Rhipicephalus* spp.

Species description: *T. parva* causes a disease called East Coast Fever (ECF), which is responsible for high mortality among susceptible and imported stock. The zebu in endemic areas has a high natural resistance, but animals imported into endemic areas are highly susceptible. Transmission of the parasite in all is on a stage to stage basis (trans-stadial transmission). There is no transovarial transmission in the tick vector as in *Babesia* spp. The organisms occur both in erythrocytes and in lymphocytes. The forms in the red blood cells are mainly rod-shaped, 1.5–2 × 0.5–1 µm, but round, oval, comma- and ring-shaped forms may also occur (Fig. 114, 4–6). Several parasites may occur in individual erythrocytes but there is no multiplication in the red cells. The multiplying forms of the parasite occur in the cytoplasm of lymphocytes and occasionally in the endothelial cells of the lymphatic glands and the spleen. These are schizonts, being circular or irregularly shaped structures about 8 µm in diameter. Two forms of schizonts are recognized. Those which contain large chromatin granules, 0.4–2 µm in diameter, are termed macroschizonts and produce macromerozoites, 2–2.5 µm in diameter (Fig. 114, 1). The other forms contain smaller chromatin granules, 0.3–0.8 µm in diameter, and are referred to as microschizonts and produce micromerozoites (Fig. 114, 2). The latter invade the red blood cells and may represent sexual stages of the parasite. After the intraerythrocytic stages are ingested by ticks, merozoites are liberated and differentiate into sexual stages. There is a sexual development of *T. parva* in the tick vector which results in infective sporozoites. Cattle are infected when vector ticks engorge on an animal and these infective particles (sporozoites) are transmitted. Most recovered animals remain carriers of infection.

Geographic distribution: East, Central and South Africa according to the distribution of the main vector *Rhipicephalus appendiculatus*.

Symptoms: High fever, swelling of the lymph nodes, dyspnoea and death. Fever occurs 7–10 days after the tick bite and continues throughout the course of the disease and may reach > 42°C. Lymph node swelling becomes pronounced and generalized. Anorexia, loss of condition, lacrimation and nasal discharge may occur. Terminally, dyspnoea is common. Just before death, a sharp fall in temperature occurs and pulmonary exsudate pours from the nostrils. Anaemia is not a major diagnostic sign as it is in babesiosis.

Significance: ECF is a serious disease with high mortality in susceptible stock.

Diagnosis: Lymphoblasts in Giemsa-stained lymph node biopsy smears (☞ METHODS, 3.1) during the acute febrile phase contain multinuclear schizonts. Lymph node enlargement and massive pulmonary oedema and hyperaemia are the most striking post-mortem lesions. Haemorrhages are common on the serosal and mucosal surfaces of many organs.

Therapy: Cattle with clinical ECF may be treated with parvaquone (2 × 10–20 mg/kg, im. at 48 h intervals),buparvaquone (2 × 2.5 mg/kg, im. at 48 h intervals) or with the coccidiostat halofuginone (2 × 1.2 mg/kg, po. at 48 h intervals). Chlortetracycline and oxytetracyline are relatively ineffective. None of these drugs will sterilize infections, and recovered animals may be carriers.

Prophylaxis: Immunization of cattle using an infection-and-treatment procedure is practical and relatively effective. The compo-

nents for this procedure are cryopreserved sporozoite stabilates of the appropriate strains of *Theileria* derived from infected ticks and a single dose of either long-acting oxytetracycline or buparvaquone given simultaneously or of parvaquone given 1 week after infection. Cattle should be immunized 3–4 weeks before being turned out onto infected pasture. The incidence of ECF can be reduced by regular tick control, but in many areas this means biweekly acaricidal treatments. The use of pour-on acaricides is a promising way of tick control in endemic areas (☞ CATTLE, ■ 5.1) (Figures 116, 117, 118, 119, 120, 121, 122, 123)

Fig. 118 Lymph node swelling in a *Theileria parva* infected cattle [4]

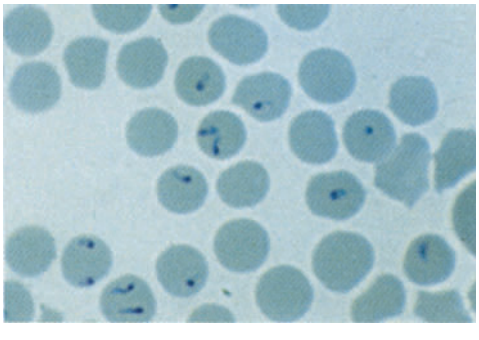


Fig. 116 *Theileria parva*; erythrocyte forms [4]

Fig. 119 Lacrimation and nasal discharges in a *Theileria parva* infected cattle [8]

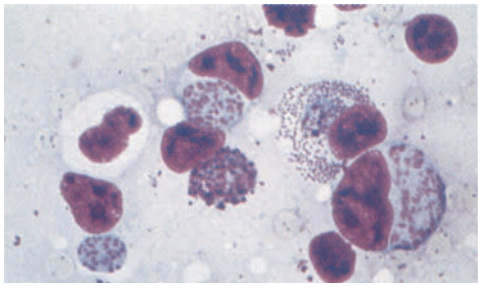


Fig. 117 *Theileria* sp.; macroschizonts ("Koch's blue bodies"and microschizonts in lymph node smears [4]

Fig. 120 *Theileria parva*; petechial haemorrhage on the intestinal serosa [8]

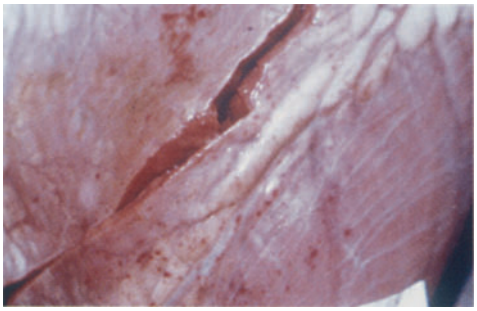


Fig. 121 *Theileria parva*; petechial haemorrhage on the surface (epicard) of the heart [8]

Fig. 123 *Theileria parva*; petechial haemorrhage on the kidneys [15]

Fig. 122 The reported distribution of *Theileria parva* [17]

Theileria annulata Mediterranean Coast Fever, Tropical theileriosis, Egyptian ever

Hosts: Cattle, water buffalo

Vector: *Hyalomma* spp. (*H. detritum, H. truncatum, H. anatolicum* and other *Hyalomma* spp.)

Species description: *T. annulata* produces a highly fatal disease of cattle in North Africa. Mortality rates may be up to 90% in some regions. This species occurs commonly in the lymphocytes and erythrocytes of bovine species. The organisms in the red blood cells are more or less indistinguishable from those of *T. parva*. They occur more commonly as round, oval- or ring-shaped (0.5–1.5 µm) forms. Rod shapes, commas (1.6 µm) and anaplasma-like organisms may also occur. Macroschizonts and microschizonts are found in the lymphocytes of the spleen and lymph nodes. *T. annulata* is transmissible by blood passage, and schizonts are numerous in the circulating blood. The development cycle in the vertebrate host is comparable to that of *T. parva*. The disease may be acute (duration: 3–4 days) or more chronic (duration: 2–3 weeks) in nature. The incubation period is 9–25 days. Animals that recover from *T. annulata* infections are resistant to reinfection. There is no cross-immunity between *T. annulata, T. parva* and *T. mutans*. The multiplication of *Demodex* sp. and *Besnoitia besnoiti* cysts in the subcutis is favoured by the immunosuppression produced by *Theileria* infections.

Geographic distribution: North Africa, Sudan, Mauretania, Ethiopia, southern Europe, southern UIS and Asia.

Symptoms: Fever (40–41.5°C), depression, lacrimation, nasal discharge and swelling of the superficial lymph nodes; emaciation rapidly occurs. A few days after the initial symptoms marked anaemia, jaundice (bilirubinaemia) develop. Haemoglobinuria may occur, but is not always present. In acute cases animals may die within 1–2

days. In chronic infections a very heterogeneous complex of symptoms may develop over the period of 2 months until the animal recovers. Decreased milk production, digestive disturbances (cessation of rumination, diarrhoea or constipation) and infertility (abortion) may be seen. The severity of the disease does not necessarily correspond to the level of parasitaemia. Similarities with babesiosis may occur and must be differentiated.

Significance: *T. annulata* may cause mortalities of up to 90% in certain areas. It causes one of the most important diseases of cattle in endemic regions.

Diagnosis: This is based on the demonstration of parasites in the red blood cells or in stained smears (☞ METHODS, 3.1) taken from lymph node or spleen biopsies. The differentiation between *T. parva* and *T. annulata* organisms is difficult but the geographic spread of these two diseases is quite different. *T. annulata* often occurs together with *Babesia* spp. and/or *Anaplasma* spp. At necropsy the mucosa membranes of the abomasum and the small intestine show characteristic ulcers (2–12 mm in diameter), surrounded by an inflammation. Multiple petechiae may be found on the epi- and endocardium. The spleen, liver and lymph nodes are markedly enlarged.

Therapy: Tetracyclines have both prophylactic and therapeutic activity against *T. annulata*. Rolitetracycline (4 mg/kg, im.) administered daily during 4 days moderated the clinical signs markedly. Similar results were achieved by a single injection of a long-acting oxytetracycline formulation (20 mg/kg).

Prophylaxis: Immunization of cattle using an infection- and -treatment procedure is very effective and widely used. The application of 2×10^6 parasitised lymphoblasts obtained from subcultured *T. annulata* strains were inoculated into animals prior to exposure. No clinical signs developed and the animals were able to withstand heavy natural challenge. Another possibility is to apply a single injection of a long-acting oxytetracycline formulation (20 mg/kg) prior to exposure. Regular tick control of herds in endemic areas may markedly reduce the disease incidence (☞ CATTLE, ■ 5.1 THERAPY AND PROPHYLAXIS OF ECTOPARASITES, p. 141).

(Figures 124, 125)

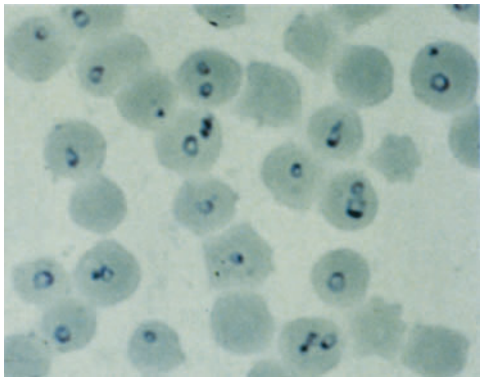


Fig. 124 *Theileria annulata*; erythrocyte forms (experimental infection) [4]

Fig. 125 Abomasal ulcerations caused by *Theileria parva* and *Theileria annulata* [15]

Theileria mutans Benign bovine theileriosis

Hosts: Cattle

Vector: *Amblyomma variegatum* and *Amblyomma hebraeum*

Species description: *T. mutans* causes a mild bovine theileriosis which is usually non-fatal. Morphologically it is not distinguish-

able from the pathogenic *T. parva* and *T. annulata*. The forms in the erythrocytes are round, oval, piriform, comma-shaped or *Anaplasma*-like. The round forms are 1–2 µm in diameter and the oval forms measure 1.5 × 0.6 µm. Binary fission occurs in the erythrocytes. The incubation period is 10–20 days.

Geographic distribution: Throughout Africa, Madagascar, Réunion, Mauritius, southern Europe, Asia, Australia, UIS, Caribbean

Symptoms: Similar to a mild form of *T. annulata* infection. Anaemia is the major clinical sign. Icterus and lymph node swellings may occur.

Significance: *T. mutans* is usually only slightly- or non-pathogenic for indigenous cattle in endemic areas. An acute form may develop in cattle imported into an endemic area. The mortality is generally less than 1%.

Diagnosis: Same as for other *Theileria* species

Therapy: Unknown; the same drugs as for the pathogenic *Theileria* species may be used.

Prophylaxis: Tick control and immunisation as for the pathogenic *Theileria* species.

(Figures 126, 127, 128)

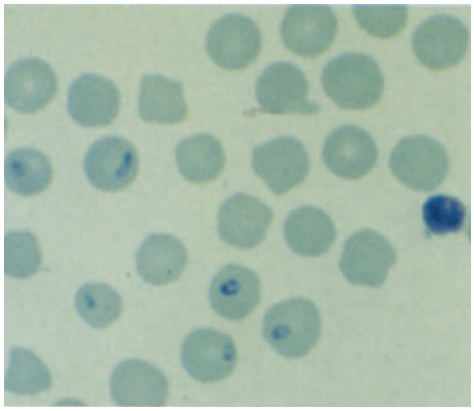


Fig. 126 *Theileria mutans*; erythrocyte forms [4]

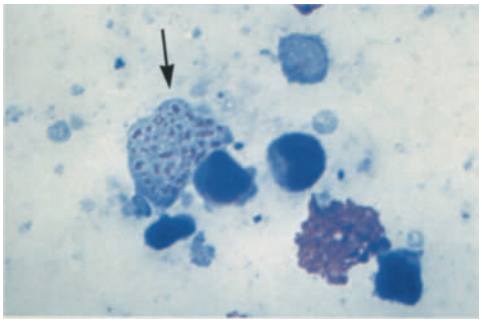


Fig. 127 *Theileria mutans*; macroschizont (rarely encountered) [15]

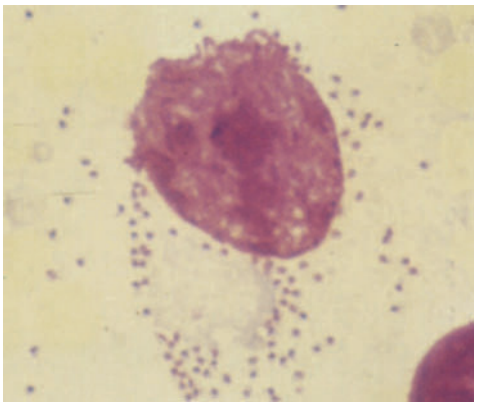


Fig. 128 *Theileria mutans*; microschizonts (rarely encountered) [15]

Theileria velifera

Remarks: This is another mild *Theileria* species of cattle in Africa and in the Caribbean. Its distribution coincides with that of the vector *Amblyomma variegatum* (Africa and Madagascar) and *Amblyomma lepidum* and *Amblyomma hebraeum* elsewhere. The parasites occur as pleomorphic or rod-shaped bodies in the erythrocytes and presumably lymphocytes. Most are 1–2 µm long. The great majority have a rectangular "veil" 1.0–3.5 µm long, extending out from the side. This species is nonpathogenic.

(Figure 129)

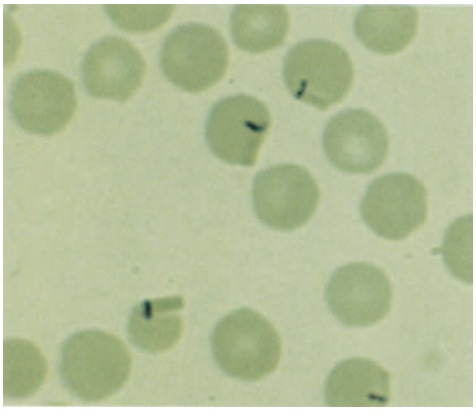


Fig. 129 *Theileria velifera*; erythrocyte forms [4]

Theileria taurotragi

Remarks: This species is found in African antelopes and can occasionally be found in cattle. It can also develop in the vector of *T. parva*. It is of low epidemiological importance.

RICKETTSIALES

ANAPLASMATACEAE

Anaplasma spp.

Anaplasmoses are infectious diseases, virulent, inoculable and not directly transmitted, that affect domestic and wild ungulates. The causative agent is a Rickettsia of the genus *Anaplasma*, usually transmitted by ticks, but which may also be transmitted mechanically by biting Diptera (*Tabanidae, Stomoxys*). The pathological signs are progressive anaemia (acute or slow) ending in cachexia and death. *Anaplasma* are exclusively found within erythrocytes. They are located intracellularly and surrounded by a vacuolar invagination of the host cell. The infection starts with an initial body that grows to become an elementary body. This multiplies by doubling or binary fission to produce new initial bodies. After several binary fissions, initial bodies accumulate in the vacuole to leave the host cell in order to parasitize other erythrocytes. The different *Anaplasma* species are morphologically indistinguishable. The criterion used is the location of the organism in the erythrocyte (marginal or central). (Figure 130)

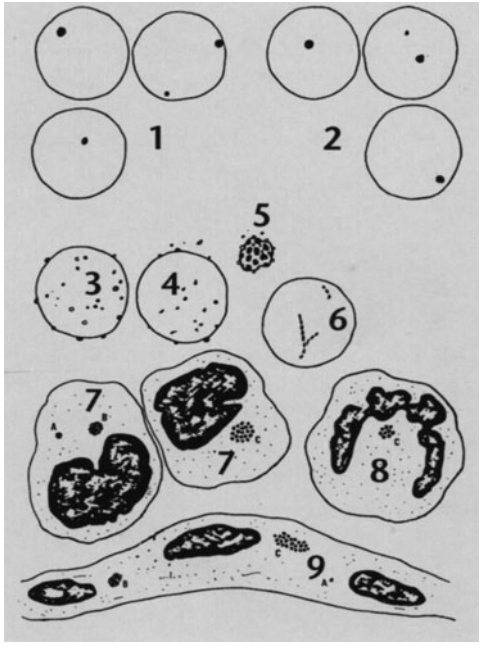


Fig. 130 Morphology (schematic) of various Rickettsiales found in ruminants;
Anaplasmataceae: (1) *Anaplasma marginale* (80–90% parasites marginal or peripheral); (2) *Anaplasma centrale* (80–90% of parasites central); (3) *Eperythrozoon wenyoni*, (on the erythrocyte surface); (4) *Eperythrozoon teganodes* (on the surface and near the erythrocyte); (5) *Eperythrozoon tuomii* (on the thrombocyte surface) and (6) *Haemobartonella bovis*;
Ehrlichiaceae: (7) *Ehrlichia bovis* (in monocytes); (8) *Ehrlichia phagocytophila* (in granulocyte) and (9) *Cowdria ruminantium* (in the vascular endothelium);
development stages: A = elementary body, B = initial body amd C = mass of elementary bodies [16]

Anaplasma marginale The malignant anaplasmosis of cattle, Gallsickness

Remarks: 80–90% of the organisms are peripheral. *A. marginale* is distributed throughout the tropics corresponding to the distribution area of *Boophilus decoloratus* and *Boophilus microplus* usually considered as the main vectors. Transplacental infection occurs.
(Figures 130, 131)

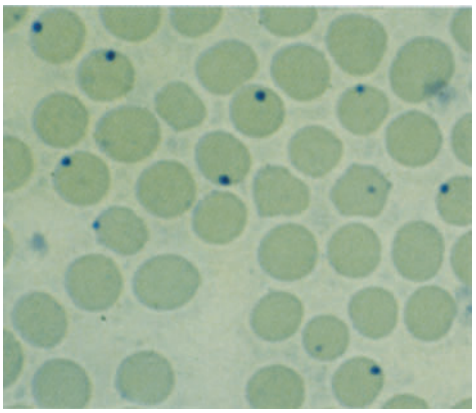


Fig. 131 *Anaplasma marginale*; Giemsa-stained bloodsmear [4]

Anaplasma centrale Mild anaplasmosis of cattle, Gallsickness

Remarks: *A. centrale* is predominantly located in the centre of the erythrocytes. The distribution and vectors are the same as in *A. marginale*. Anaplasmosis due to *A. marginale* is generally mild and often clinically inapparent.
(Figures 130, 132, 133)

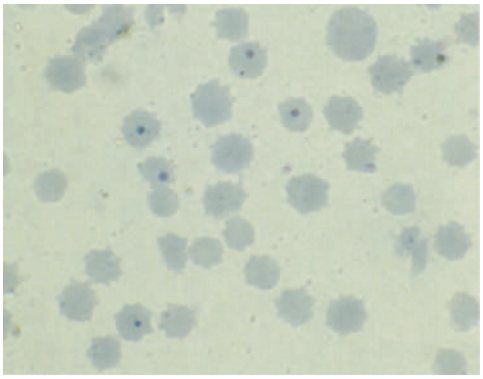


Fig. 132 *Anaplasma centrale*; Giemsa-stained bloodsmear [4]

Fig. 133 Icterus associated with anaplasmosis (yellow abdominal fat) [15]

- **General features of bovine anaplasmosis**

Symptoms: Calves undergo mild infections, with little or no mortality. In yearlings the disease is more severe but most animals recover. In adult cattle, the disease is more severe, anaemia is marked and mortality may reach 50%. The disease starts with general depression, indolence, fever (40–41°C). Milk production falls rapidly. Weight loss and progressive anaemia, dehydration and icterus occurs. Affected animals often succumb to hypoxia when moved or handled for treatment. Recovered animals often remain carriers for life.
Significance: *Anaplasma marginale* causes severe losses in endemic areas.

Diagnosis: In endemic areas, anaplasmosis should be suspected in adult cattle showing chronic anaemia without haemoglobinuria, leading to cachexia. Icterus is an important sign. Anaplasmosis often follows an acute form of babesiosis or theileriosis and appears to be a prolonged convalescence. Demonstration of the organisms in Giemsa-stained blood smears confirms the diagnosis (☞ METHODS, 3.1). Serological tests such as complement fixation and the IFAT and DNA probes are useful tools for diagnostic purposes. Anaemia due to helminth infections should be excluded by coprological examination.

Therapy: Acute anaplasmosis is most effectively treated with tetracyclines (oxytetracycline, 5–10 mg/kg, im. or iv.) or chlortetracycline (1.5 mg/kg, po.), especially if administered early in the course of infection. Long-acting oxytetracycline formulations may give sustained blood levels. Imidocarb dipropionate (1.2–2.4 mg/kg., sc.) may also be used for *Anaplasma* infections. Symptomatic and supportive treatment is important. Transfusion of 4–6 l of normal blood is often indicated and should be repeated in 48 h intervals, until the animal appears stronger. Oral and parenteral rehydration with isotonic saline and glucose solution is vital for dehydrated animals. Handling and disturbances should be avoided, since even mild exertion can produce hypoxia and death. Animals should be kept in shade with free access to fresh water.

Prophylaxis: Regular dipping, spraying of animals during the vector season drastically reduces the incidence of the disease. Several methods exist to immunize animals in endemic areas. Inoculation of blood containing *A. centrale* which gives rise to a mild infection that protects against a subsequent infection with the virulent and very pathogenic *A. marginale*. The use of virulent and attenuated *A. marginale* isolates to induce immunity or a chronic carrier status in calves is a widely accepted technique throughout the tropics where anaplasmosis is endemic. The use of virulent organisms in adult cattle is hazardous, and treatment at the onset of the patent infection with tetracyclines is recommended to temper the course of infection.

Eperythrozoon spp.

Organisms found on the surface of erythrocytes or near thrombocytes, occasionally they are located near erythrocytes. They multiply by binary fission. In general the size of *Eperythrozoon* is 0.4–1 µm. The most important vectors of *Eperythrozoon* spp. are sucking lice, infected through trans-stadial transmission. *Hyalomma anatolicum* possibly transmits *E. wenyoni*. *Eperythrozoon* spp. are generally not very pathogenic in spite of sometimes high infection levels. They may assume increased significance together with other protistan infections (*Babesia* spp., *Theileria* spp., *Anaplasma* spp. or *Trypanosoma* spp.). The only pathogenic *Eperythrozoon* species which produces a disease entity is *E. suis*. The disease is characterised by a slow development of anaemia, comparable to anaplasmosis. Oxytetracyclines (5–10 mg/kg, im. or iv.) are effective against all *Eperythrozoon* spp. Prophylaxis requires lice and tick control.

In cattle the following species are present in tropical Africa: *Eperythrozoon wenyoni* occurs on the erythrocyte surface; *Eperythrozoon teganodes* occurs on the erythrocyte surface or near to it and *Eperythrozoon tuomii* occurs on the thrombocyte surface.

(Figures 130, 134)

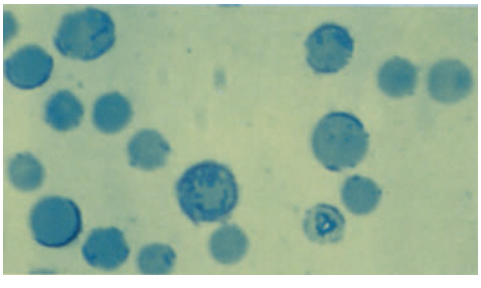


Fig. 134 *Eperythrozoon wenyoni*; Giemsa-stained bloodsmear [13]

Haemobartonella spp.

These are organisms found on the surface of erythrocytes which form branched chains and multiply by binary fission. The organisms are coccoid (0.1–1 µm) or bacilliform (1–5 × 0.7–1.5 µm). They cause a defined disease entity in dogs and cats and rats. *Haemobartonella* spp. are often detected as resurgent parasites during concomitant infections or following splenectomy. Tetracyclines are the drugs of choice for treating *Haemobartonella* infections, but therapy is rarely indicated (☞ also above ANPLASMATACAE, Fig. 130).

Haemobartonella bovis

Remarks: It occurs on the erythrocyte surface. These coccoid or bacilliform organisms occur on the erythrocyte surface of cattle in Mediterranean regions. Vectors are sucking lice and ticks (species unknown). *Haemobartonella bovis* is relatively non-pathogenic. In rare cases the parasite may be associated with slow anaemia and symptoms similar to anaplasmosis. *Haemobartonella* spp. and *Eperythrozoon* spp. are difficult to distinguish reliably by light microscopy (☞ above ANPLASMATACAE, Fig. 130).

EHRLICHIACEAE

Ehrlichia bovis Tropical bovine ehrlichiosis, "Nofel" or "Nopel"

Hosts: Cattle

Vector: Ticks of the genera *Amblyomma, Hyalomma* and *Rhipicephalus*

Species description: *Ehrlichia bovis* occurs in mononuclear cells of cattle. The syndrome corresponds to the disease called "Nofel" (Fulani/Peule in West Africa; ear = nopi in peul) or "Nopel" (Bororos in Central Africa), because of the ears being kept low at the beginning of an acute infection. The clinical signs vary greatly ranging from inapparent forms to serious fatal forms, dominated by nervous signs, ataxic gait, stiff legs, walking in circles, phases of excitement followed by somnolence, epileptic crisis with falls, rolling eyes and salivation. Death may occur in an epileptic attack. The disease is always serious in imported cattle. The nervous signs are similar to those of cowdriosis.

Geographic distribution: North and Central Africa, Middle East, Ceylon

Symptoms: Anorexia, fever, incoordination and enlargement of lymph nodes

Significance: *Ehrlichia bovis* is of low significance for indigenous cattle. However, it is a serious problem for imported or newly introduced cattle in many tropical areas.

Diagnosis: Microscopic examination of peripheral blood smears demonstrates *E. bovis* in monocytes or macrophages. For differential diagnosis infections with *Cowdria ruminantium* have to be excluded. *C. ruminantium* is located exclusively in the endothelial cells (brain and other tissues) and not in the peripheral blood leucocytes, whereas *E. bovis* is found in monocytes and macrophages.

Therapy: Oxytetracyclines (5 mg/kg, im., for 4 days) or streptomycin-penicillin (3 g and 3 mio. units per day, im.); other tetracyclines may be used in emergencies.

Prophylaxis: This consists of regular tick control. There are no immunization procedures described.

(Figures 130, 135)

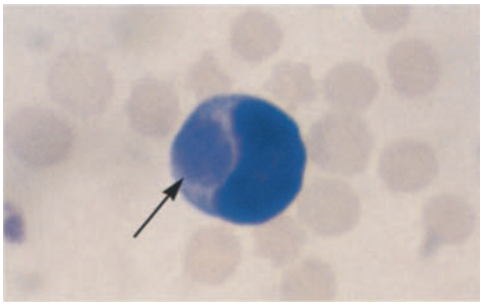


Fig. 135 *Ehrlichia bovis*; mass of elementary bodies in a monocyte [15]

Ehrlichia phagocytophila
European ehrlichiosis

Remarks: *E. phagocytophila* occurs in the neutrophilic and eosinophilic granulocytes of cattle, sheep and other domestic and wild ruminants in Europe. Goats are not very susceptible. *Ixodes ricinus* transmits the disease by trans-stadial infection. The disease is characterized by fever which occurs after an incubation period of 4–11 days. The infection causes a state of immunosuppression and is therefore a predisposing factor to a variety of secondary infections. The animals usually recover after this febrile phase. However, the most characteristic problems are abortion in pregnant ewes and cattle, and progressive weight loss following infection may occur. At necropsy hypertrophy of the spleen and lymph nodes may be seen. The diagnosis is made by demonstrating the organisms in stained blood smears (☞ METHODS, 3.1). Serological tests such as IFAT (☞ METHODS, 5.1) may be used for epidemiological studies.

Therapy: Long acting oxytetracyclines (5 mg/kg, im.) have a certain curative effect.

Prophylaxis: ☞ above *Ehrlichia bovis*

(Figures 130, 136)

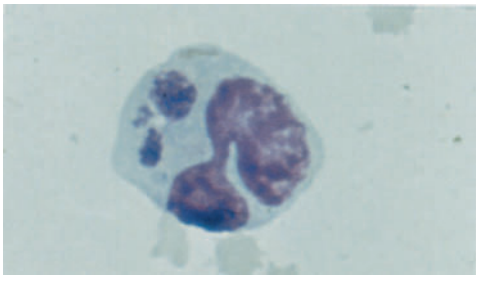


Fig. 136 *Ehrlichia phagocytophila*; mass of elementary bodies in a granulocyte [4]

Ehrlichia ondiri

Remarks: This parasite occurs in granulocytes of cattle in high-altitude grassland regions of East Africa. Members of the genus *Haemaphysalis* and other genera are suspected to be vectors of the disease. The incubation period is 1–2 weeks. The disease starts with a fever attack which is accompanied by a petechial exanthema of the mucosae of the mouth, nose, vulva, eyes (poached egg eye), digestive tract, urinary bladder, pericardium and endocardium. Extended haemorrhage in the gastrointestinal tract and the pulmonary oedema cause death.

Diagnosis is made by microscopic examination of blood smears. Organisms of *E. ondiri* are found in granulocytes.

Therapy and Prophylaxis: ☞ above *Ehrlichia bovis*

Cowdria ruminantium Heartwater, Tyewde

Hosts: Cattle, sheep, goat and other ruminants

Vector: Several species of the tick genus *Amblyomma* transmit the disease: *Amblyomma variegatum* in open savannas from equatorial Africa to Madagascar; *Amblyomma gemma* in East Africa (Massai and Somalian steppes); *Amblyomma pomposum* has limited geographic distribution and occurs in the Angolan plateau, Zambia, southwestern Tanzania; *Amblyomma lepidum* in East Africa (Massai steppes, Sahelian steppes of the Nile in Sudan) and *Amblyomma tholloni* in the Zambezi region. *C. ruminantium* is also present on the Caribbean islands.

Species description: Cowdriosis is specific to ruminants of the family Bovidae and is most severe in sheep and goats but also causes great losses in cattle. Imported ruminants are much more susceptible to cowdriosis than indigenous breeds. They may suffer heavy losses. But also indigenous ruminants are affected especially when they are in poor general condition (endoparasitism, malnutrition, chronic infections, etc.) or with weakened defence (lactation, gestation). This applies especially to the early rainy season in the Sahel-Sudanese region when animals are weakened by the long food shortage of the dry season and when there is a drastic

proliferation of the *Amblyomma* ticks. Cowdriosis can then become a great problem. The incubation period is 8–15 days. Endothelial cells are the preferred sites of the proliferation of this pathogen, especially of the nervous system, kidney, spleen, lymph nodes, salivary glands and heart muscle. Young calves (< 6 weeks), lambs and kids (< 1 week) are fairly resistant and may recover spontaneously.

Geographic distribution: The distribution of heartwater corresponds to that of all its vectors.

Symptoms: The symptoms are almost identical in both cattle and small ruminants, except that the nervous symptoms are rarer in cattle and not as distinct (e.g. posture of pushing against a wall, ataxia, haggard eye, aggressiveness). Digestive signs are more constant in cattle than in sheep and goats. Diarrhoea may occasionally be seen. Several forms of cowdriosis can occur, ranging from a peracute form (death within 2–3 hours; tyewde of the Fulani) to inapparent infections. There are no pathognomonic signs. In the peracute form an animal may abruptly drop to the ground, struggle, start to pedal, indicating serious nervous disorders. Death follows rapidly. The acute form can last for up to 5 days and is accompanied by initial hyperthermia, breathlessness and dyspnoea. Nervous signs may occur, often at the end of the disease, suggesting tetanus or poisoning. Fluttering of the eyelids and acute gastroenteritis may also occur. The subacute form is rare (12–15 days), developing sometimes pulmonary complications. Attenuated forms are frequent. Animals recover after a short febrile phase. Sometimes, hyperthermia is the only clinical sign.

Significance: Cowdriosis is a serious problem in areas infested by the ticks *Amblyomma* spp.

Diagnosis: In acute forms diagnosis can be based on clinical signs. Demonstration of colonies of the organisms in the cytoplasm of capillary endothelial cells is necessary for definitive diagnosis. This is done with Giemsa-stained "squash" smears of cerebral gray matter. An indirect IFAT (☞ METHODS, 5.1) test may be used to detect antibodies of animals that have recovered from infection. In sheep and goats these antibodies persist for several years, and their presence correlates well with their resistance to reinfections. Seropositive cattle are resistant to challenge, although antibodies disappear within 12 months after infection.

At necropsy hydropericardium is the predominant sign. The exudate is clear, usually amber or yellow. It is a consistent sign of heartwater. It may be as much as 700 ml in small ruminants. Hydrothorax, ascites and splenomegaly are often found. The gall bladder is usually distended. Extensive congestion of the viscera and petechiae on the serous membranes and mucosae of the digestive tract may be seen. Microscopically the deformation of endothelial cells by rickettsial masses is the most striking finding. Smears are made either with material scraped from the internal wall of a major artery, or with a fragment of cerebral cortex crushed between two slides. May-Grünwald/Giemsa staining usually reveals masses of elementary bodies, appearing as blue granules in the cytoplasm of endothelial cells. The initial bodies are dark blue.

Therapy: Oxytetracycline (5–10 mg/kg, im. or iv.) usually effects a cure if administered early. Later in the febrile phase, when clinical signs appear, a higher dose level (10–20 mg/kg) is required.

Prophylaxis: There is no vaccine yet. Several immunization schedules have been applied successfully ("controlled immunization": infection with a laboratory-maintained strain followed by antibiotic treatment) but they require a very careful monitoring of the infected animals and laboratory maintenance of parasite strains.

These methods are expensive and should therefore be reserved for valuable animals (e.g. breeding stock, drought animals, etc.). Tick control is a substantial part of heartwater prophylaxis.

Remarks: Merozoites of *Toxoplasma gondii*

and *Sarcocystis* spp. may occur in the blood stream during the acute phase.
(Figures 130, 137, 138, 139, 140)

Fig. 137 Nervous symptoms associated with *Cowdria ruminantium* [15]

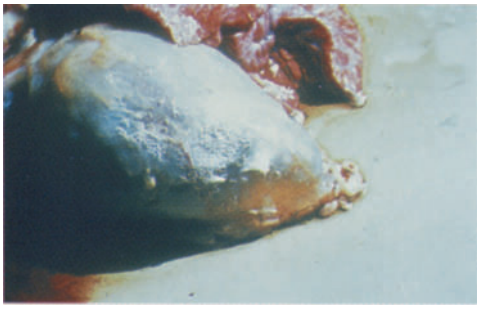


Fig. 138 Hydropericardium (heart water) caused by *Cowdria ruminantium* [15]

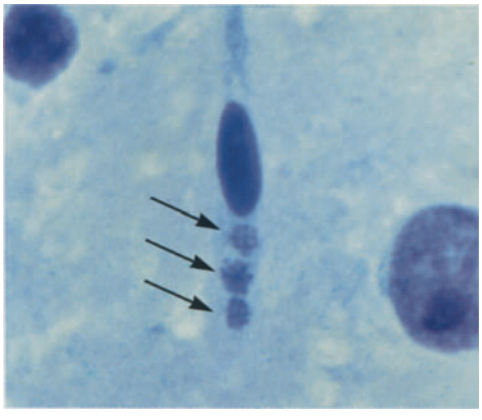


Fig. 139 *Cowdria ruminantium* organisms in the capillary endothelial cells [4]

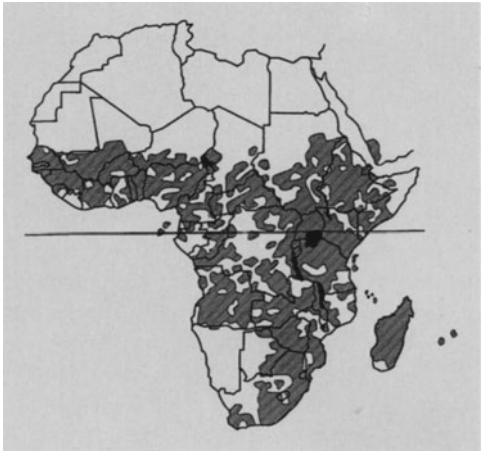


Fig. 140 The known distribution of the known vectors of heartwater in the African region [13]

HELMINTHS

- Trematoda found in the blood and circulatory system

Schistosoma bovis Blood fluke, Bilharziosis

Location: Mesenteric veins
Hosts: Cattle, sheep, goat, equine and dromedary
Species description: *S. bovis* occurs in the portal and mesenteric veins of cattle, sheep, goats, equines, camels and rarely in man. The males of *S. bovis* are 9–22 mm long and 1–2 mm wide. The females are 12–28 mm long. The eggs are spindle-shaped and passed in the faeces. The size of the eggs is 132–247 µm × 38–60 µm.
Geographic distribution: Central, East and West Africa
(Figures 141, 142)

Fig. 141 *Schistosoma bovis*

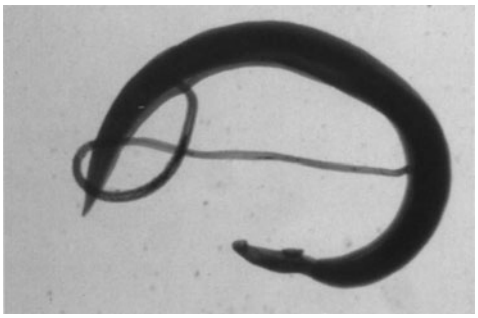


Fig. 142 *Schistosoma bovis*; male (thick) and female (slender)

Schistosoma mattheei

Location: Portal and mesenteric veins and less frequently cystic and lung veins

Hosts: Cattle, sheep, goat, wild ruminants, equine and man

Species description: Females measure 18–25 mm and males 9–14 mm. The eggs measure 170–280 × 70–85 µm and have a terminal spine. The prepatent period is 7 weeks. The life cycle is similar to *Schistosoma bovis*. Intermediate hosts are *Bulinus africanus*, *Bulinus globosus* and other *Bulinus* spp.

Geographic distribution: Southern Africa, Mozambique, Zambia, Malawi, Zimbabwe, Tanzania; Central Africa (Tchad)

Schistosoma intercalatum

Remarks: This species occurs mainly in man and primates in Central Africa. Sheep and goats and other domestic and wild ruminants may accidentally acquire infection. *S. intercalatum* is found in the portal and mesenteric veins. The eggs measure 140–240 µm × 50–85 µm.

Schistosoma curassoni

Location: Portal and mesenteric veins

Hosts: Cattle, sheep and goat

Species description: Intermediate hosts are snails of the genus *Bulinus*. Eggs are similar to those of *S. mattheei*.

Geographic distribution: West Africa (Senegal, Mauretania, Mali)

- **General features of *Schistosoma* spp. infections**

Life cycle: Aquatic snails (*Bulinus* spp.) act as intermediate hosts in the life cycle of *Schistosoma* spp. In the case of *S. bovis*, *S. mattheei* and *S. intercalatum* snails of the genus *Bulinus* spp. act as intermediate hosts. The eggs hatch after contact with water. The miracidia infect aquatic snails and cercariae emerge 38–126 days after infection from the snail and actively penetrate the skin or the rumen of the definite host. Schistosomosis (bilharziosis) occurs near permanent fresh water bodies (pools, backwaters, ponds, lakes and marshy pastures). To become infected, the final host needs the contact with water. This might occure during drinking in these areas, passing through water or grazing in swamps.

Symptoms: These are rarely seen even in heavy infections. Symptoms are mainly caused by the eggs which are deposited by the adult flukes in the wall of the intestines. Intermittent diarrhoea which may contain specks of blood, anaemia and progressive weakness may occur. Both diarrhoea and constipation can be seen and blood and mucus are sometimes found in the faeces together

with the eggs. A chronic hepatic syndrome has been described with neurological signs like ataxia, hypermetria, disorientation, leaning against walls, coprophagy, etc. Sheep are more susceptible than cattle and can die in large numbers while cattle survive, unless they have very heavy burdens.

Significance: Although specific clinical signs are often overlooked, blood flukes may constitute a serious problem in endemic areas.

Diagnosis: This is made by faecal examination. Spindle-shaped eggs are found in the sediment. In chronic cases, it may not be possible to find eggs in the faeces and the diagnosis must be confirmed by a post-mortem examination. At necropsy adult flukes can be found in the mesenteric veins or in the portal system.

Therapy: The therapy of schistosomosis is not easy. Highly efficient anthelmintics may have fatal consequences because dead worms may cause massive thrombus formation in the liver. Therapy should aim to kill the worms over a long period of time rather than risk the massive damage caused by the simultaneous death of all worms. In general treatment of schistosomosis is uneconomical since a large number of repeated doses at intervals of 2–3 days is required. Praziquantel at 25 mg/kg body weight is effective, although two treatments, 3–5 weeks apart are required. Other drugs which have some schistosomicidal properties are stibophen (7.5mg/kg, im. 6 ×), lucathone hydrochloride (50 mg/kg for sheep and 30 mg/kg for cattle; both every other day until three treatments have been given), hycanthone (6 mg/kg, im.) and trichlorfon (10–12 mg/kg, im. 11 × at intervals of 3–5 days).

Prophylaxis: In areas where schistosomosis is of great importance, grazing in swamps, rice fields, ponds (habitat of the intermediate host) should be avoided. Water from bore holes should be used for drinking purposes. Infection can be reduced by fencing off contaminated bodies of water and providing clean drinking water. These measures not only reduce the incidence of schistosomosis, but they also control other trematodes such as *Fasciola* spp. and paramphistomes which frequently occur in the same localities as schistosomes. If the drinking water is contaminated with intermediate snail hosts the use of molluscicides may be indicated. An ecologically justifiable way will probably be the use of molluscicidal plants which can be cultured in water bodies containing the snail-intermediate host.

(Figures 31, 35, 36, 143, 144)

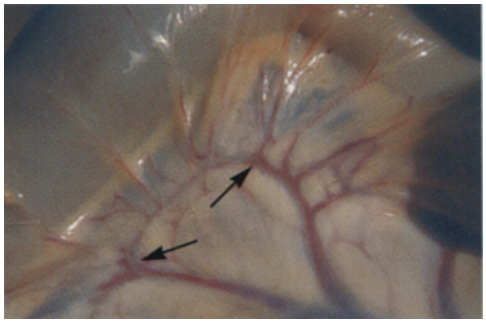


Fig. 143 *Schistosoma bovis* in the mesenteric veins

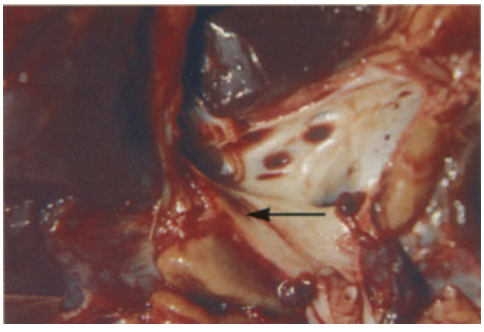


Fig. 144 *Schistosoma bovis* in the portal vein of the liver

- Nematoda larvae (microfilariae) found in the blood and adult nematodes living in the circulatory system

Onchocerca armillata Aortic filariosis

Location: Adult worms are found within tunica media of the aorta. Microfilariae are found in the blood stream (transiently) and in the skin of the dorsal parts of the body (definitively).

Hosts: Cattle, rarely small ruminants and camel

Species description: Adults are found in the aorta. Males are about 7 cm long and females up to 70 cm. The microfilariae are unsheathed, measure 346–382 µm × 5.5–6.8 µm and are mainly found in and under the skin on the dorsal parts of the animal (hump, wither, neck, rarely dewlap and lower parts). In chronic infections the aortic wall is thickened and the intima shows tortuous tunnels and there are numerous nodules containing yellow caseous fluid and coiled worms. Infection is transmitted by bites of insects of the families Simuliidae and Ceratopogonidae. The infection is very common (up to 90%) in some areas.

Geographic distribution: Throughout Africa

Symptoms: Clinically mostly inapparent; calcification of the aortic wall and aneurysm may cause cardiovascular symptoms.

Significance: Weakly pathogenic but prevalent in some regions (80–90% of all animals examined)

Diagnosis: Microfilariae appear in the blood stream and in the skin. Typical nodular lesions in the aortic wall may be found at necropsy.

Therapy: This is rarely indicated. Diethylcarbamazine is microfilaricid (5–8 mg/kg daily for 21 days). Ivermectin (200 µg/kg) was found to be highly effective against the microfilariae of many *Onchocerca* spp.

(Figures 145, 146, 159)

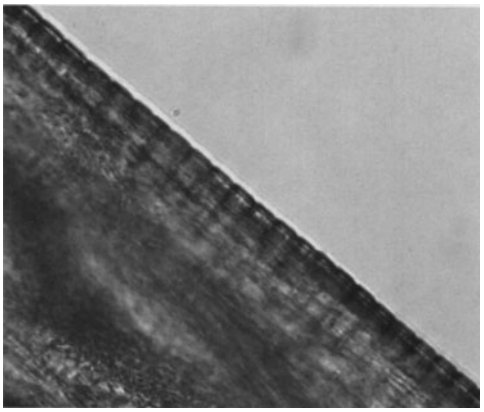


Fig. 145 *Onchocerca armillata*; typical striated cuticula

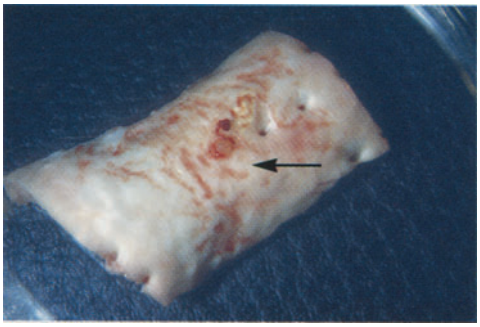


Fig. 146 *Onchocerca armillata*; aortic nodules containing the coiled adult worms (arrow)

Onchocerca spp., *O. gutturosa*, *O. dukei* and *O. ochengi*

Remarks: These species are found in the nuchal ligament or in/under the skin on several parts of the body (☞ CATTLE, ■ 4.1.2 and ■ 5.1). Microfilariae may occasionally be found in the circulating blood during their migration to their predilection site.

Elaeophora poeli Large aortic filaria

Location: Thoracic portion of the aorta

Hosts: Cattle, water buffalo

Species description: Males are 45–70 mm long and females 40–300 mm. The microfilari-

ae are 340–360 µm long and 7.0–7.5 µm wide. The male occurs in nodules in the wall of the aorta, while the female is fixed in the nodules with its anterior extremity and the rest of its body hangs free in the lumen of the vessel. The females are 350 µm wide in the intranodular part of the body and 1.5–1.8 mm wide in the free parts of the body. The life cycle is unknown. Affected vessels are swollen and less elastic. The intima is uneven and rised by nodules which are 8–13 mm in diameter.

Geographic distribution: Central and East Africa, South East Asia, Philippines

Symptoms: There is no evidence that the parasite causes clinical signs.

Significance: Unknown

Diagnosis: Nodules in the aorta, unsheathed microfilariae may occur in the blood stream.

Therapy and Prophylaxis: Not indicated

(Figure 147)

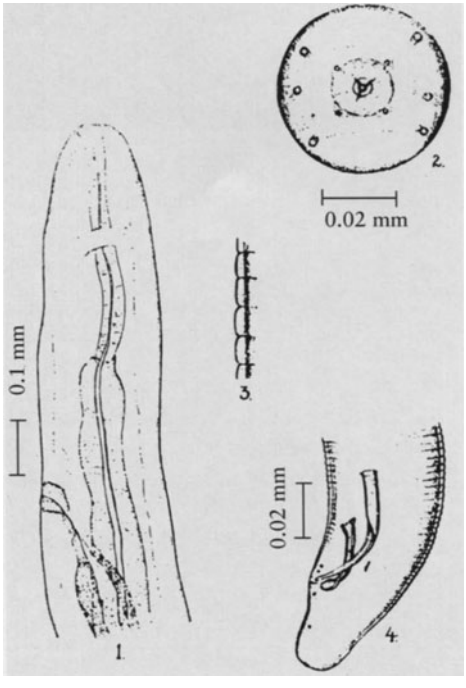


Fig. 147 *Elaeophora poeli*; anterior end of a female (1); anterior end (2), cuticular structure (3) and tail end (4) of a male [18]

Setaria labiatopapillosa

Location: Adult worms occur in the abdominal cavity (☞ CATTLE, ■ 4.4).

Microfilariae are sheathed, 140–230 µm long and appear in the peripheral blood.

(Figure 148)

Fig. 148 *Setaria labiatopapillosa*; sheathed microfilariae are 140–230 µm long; Giemsa-stained blood-smear

3 Stages in the urogenital system

PROTOZOA

Tritrichomonas foetus (syn. *Trichomonas foetus*) Bovine trichomonad abortion

Location: In the bull the parsites are found in the preputial cavity. In cows trichomonads are found in the vagina and uterus.

Hosts: Cattle

Species description: This is a venereal protozoal disease of cattle characterized by early foetal death and infertility, associated with greatly extended calving intervals. It is reported from many tropical countries. The organism is ordinarily 10–15 × 5–10 µm, but there is considerable pleomorphism. At the anterior end there are three flagella about the same size as the parasite. An undulating membrane runs the full length of the body and is bordered by a filament which continues beyond the membrane as a posterior flagellum. Multiplication is by longitudinal binary fission. Under natural conditions the infection is transmitted during coitus from the bull to the cow or vice versa. It may also be transmitted mechanically, e.g. by gynaecological examination of cows with contaminated tools. The organisms are found only in the genital tract of the cow and bull. Most bulls remain permanently infected after a primary infection. The bull is usually the source of initial and continuous infection within a herd. Infected cows usually recover spontaneously after mean durations of 20 weeks (primary exposure) and 10 weeks (secondary exposure). Cows can remain infected throughout pregnancy and discharge trichomonads from the genital tract following calving.

Geographic distribution: World-wide

Symptoms: Purulent vaginitis, metritis, placentitis and abortion are commonly found in infected cows and can cause enormous losses. Prolonged sterility and extended calving intervals are predominant features (*cave:* differential diagnosis: *Brucella abortus*!). There is a persistent uterine discharge containing large numbers of the parasites. Bulls are usually carrier of the parasite without clinical symptoms.

Significance: Venereal disease of cattle characterised by abortion and infertility in cows. *T. foetus* can cause considerable losses in infected herds. In many countries the incidence has greatly been reduced by the artificial insemination using a bull known to be free of the disease.

Diagnosis: History of abortions in a herd and demonstration of the organism in the vaginal or uterine discharges or in the foetus (mainly stomach). In bulls the organisms are in the prepuce, frequently in small numbers. Microscopical examination of the preputial smegma for trichomonads is the most common method to confirm a herd diagnosis. Preputial fluid may be collected with a pipette (e.g. AI pipette) which is introduced into the prepuce, and smegma is collected with a combination of scraping and aspiring via an attached rubber bulb or syringe. The same procedure may be used to collect vaginal fluid. It is important to avoid contamination with faecal material, as such material contains masses of protozoa similar in appearance to *T. foetus*. The organisms may not be numerous and careful, systematic examination is necessary. Diagnosis is based on the size and shape of the organisms as well as the characteristic aimless, jerky motion on a warmed slide. Only living organisms are useful for diagnostic purposes. Confirmation depends on finding the organisms in at least one animal in a suspected herd. The organisms may be cultured in special media (e.g. Diamond's Trichomonad Medium). The diagnosis can be confirmed by the Polymerase Chain Reaction (PCR) which is the most sensitive and specific diagnostic method nowadays. Serological examinations on a herd level may be used for epidemiological purposes but are of little value for individual animals.

Therapy: This is extremely difficult and does not eliminate the parasites. Compounds which have been reported to be effective against trichomonads are dimetridazole, ipronidazole and metronidazole. Thorough rinsing out of affected genital organs with acridine and iodine preparations may reduce the number of parasites but it does not clear the infection. The only effective and sustainable way to control bovine trichomonosis is strict prevention.

Prophylaxis: Control measures are based on the assumption that transmission occurs only during coitus and that infected cows that undergo 3 months of sexual rest after calving with normal uterine involution are free of infection. Animals with pyometra or genital abnormalities should be culled. Artificial insemination (AI) with semen free of trichomoads is the most effective way of controlling the disease. However, if AI is not possible, the exposed animals should be treated repeatedly for recognizable uterine disease and allowed 3 months of sexual rest. For breeding, a young, not infected bull should be used. Bulls and cows should be examined for reinfection. Control may be supported by eliminating all bulls > 3 years old and using younger bulls for mating. This is based on the relative lack of susceptibility of young bulls to trichomonad infection. Slaughter, rather than treatment, of bulls is generally recommended.

(Figures 149, 150)

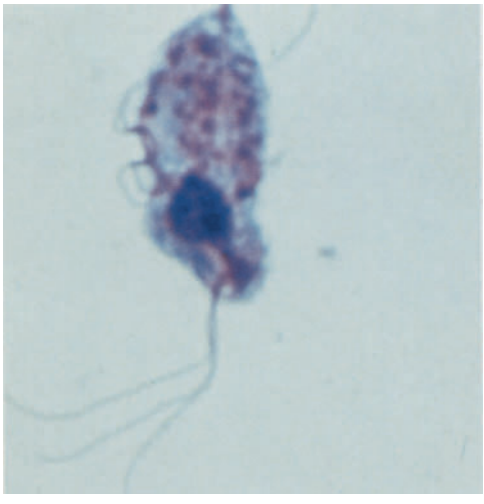


Fig. 149 *Tritrichomonas foetus* (12–18 × 6–10 µm); Giemsa-stained bloodsmear [4]

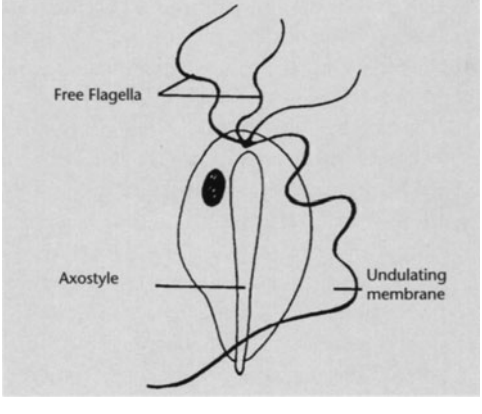


Fig. 150 Morphology of *Tritrichomonas foetus* (schematic) [19]

4.1 Locomotory system

4.1.1 Muscles

PROTOZOA

Sarcocystis bovicanis (syn. *S. cruzi*), ***Sarcocystis bovifelis*** (syn. *S. hirsuta*) **and** ***Sarcocystis bovihominis*** (syn. *S. hominis*)
Bovine Sarcosporidiosis

Location: Cysts, containing the infective stage, called bradyzoites, occur in the striated musculature of cattle.

Hosts: Cattle are intermediate hosts of three *Sarcocystis* species of which the dog (*S. bovicanis*), the cat (*S. bovifelis*) or man (*S. bovihominis*) are final hosts.

Species description: Cysts of several *Sarcocystis* species are found in the muscles of cattle. Cattle always act as intermediate hosts. *S. bovicanis* is the most pathogenic species for cattle. Infection is acquired orally by ingestion of sporocysts from the faeces of infected hosts. Tissue cysts in cattle are infectious for at least 1 year. The life cycle of *Sarcocystis* spp. is as follows: infective sporocysts, excreted by the final host (cat, dog, man) are ingested, sporozoites are released in the intestine and invade many tissues via blood stream. Schizogony occurs in the endothelial cells of blood vessels in most organs, preceding the development of typical cysts in the striated musculature. Cysts may occasionally also be found in the brain. Cysts vary in size, depending on the species, from a few mil-

Table 10 *Sarcocystis* species found in muscles of cattle

Species	Synonym	Definite host	Pathogenicity IH*	DH**
S. bovicanis	*S. cruzi*	Dog, coyote, wolf	+++	0
S. bovifelis	*S. hirsuta*	Cat	0	0
S. bovihominis	*S. hominis*	Man, rhesus monkey, baboon, chimpanzee	0	+

*IH = Intermediate Host; **DH = Definitive Host; 0 = non-pathogenic; + = mildly pathogenic; +++ = severely pathogenic

limetres to several centimetres in length. The peripheral region of a cyst contains globular forms (metrocytes), which produce two daughter cells by endodyogeny and these after further replication give rise to banana-shaped bradyzoites. Infection of the final host is by ingestion of muscle cysts, containing bradyzoites. *S. bovifelis* is nonpathogenic for cattle and produces microscopic cysts of 12 × 1 µm. *S. bovihominis* has man and some primates as definitive hosts and the sarcocysts are compartmented, with a wall of about 6 µm tick that appears radially striated by light microscopy. The pathogenicity of *S. bovihominis* for cattle is still in debate. The following description refers to this species. Following ingestion of sporulated oocysts or sporocysts by cattle (excreted by dogs, wolves, coyotes, raccoons, foxes, hyenas) several generations of schizonts occur in the endothelial cells of blood vessels and metrocytes are found in the striated musculature about 1 month after infection. Fully developed muscle cysts, containing the infective bradyzoites occur 2–3 months after infection.

Geographic distribution: World-wide

Symptoms: Anorexia, intermittent fever attacks, anaemia, weight loss were observed after experimental infection of calves. Deaths occurred about 30 days after a heavy infection with 10^5–10^6 sporocysts. Reduced milk yield, loss of condition, dyspnoea and abortion were observed in adult cattle.

Significance: *Sarcocystis* infection occurs throughout the world. Economic losses during a fresh infection may be higher than expected. Once muscle cysts are formed the infection is inapparent.

Diagnosis: This is very difficult in the acute phase (1 month post infection). During this period schizonts may be demonstrated in vascular endothelial cells by means of stained-scrapings taken from the blood vessels or by histopathological examination. Detection of meronts in Giemsa-stained blood smears (☞ METHODS, 3.1) or biopsy for detection of schizonts. At necropsy artificial digestion of affected muscles might reveal the muscle cysts. Serological tests (IFAT, ELISA; ☞ METHODS, 5.1 and 5.2) are indicated after the acute phase. The PCR (☞ METHODS, 6.3.2) may be used as a highly sensitive method to detect *Sarcocystis* infections.

Therapy: This is extremely difficult in cattle and rarely indicated. Amprolium (100 mg/kg, po., daily during 30 days) was effective to avoid clinical signs in cattle (endothelial schizogony) during experimental infections. Amprolium and halofuginone (0.66 mg/kg, po., 2 × on consecutive days) may be used in sheep and goats to avoid clinical disease after infection.

Prophylaxis: The contamination of cattle food with faeces of dogs, cats and man as well as the feeding of raw cattle meat to dogs should be avoided.

(Figures 151, 152, 153, Table 10)

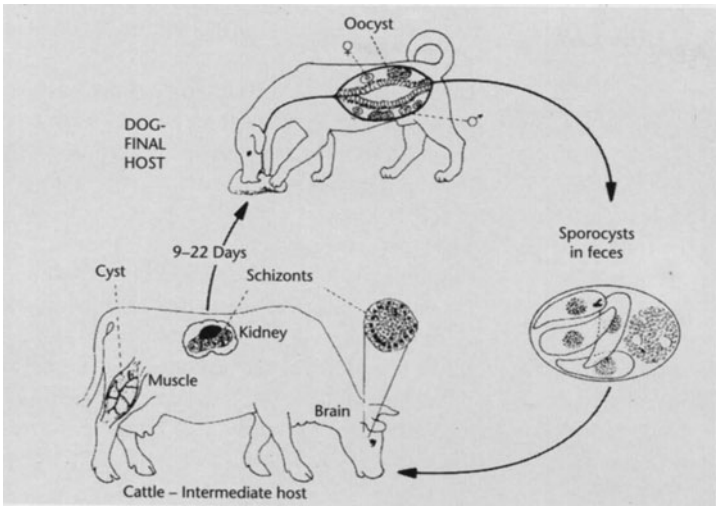


Fig. 151 Life cycle of *Sarcocystis bovicanis* [3]

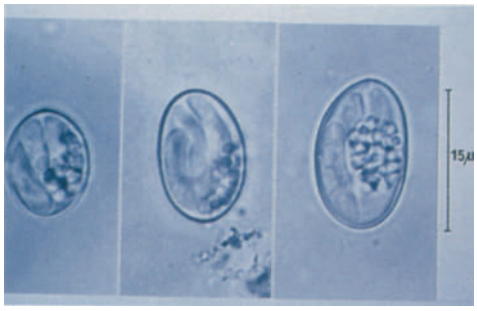


Fig. 152 Sporozoites of *Sarcocystis suicanis* (left), *Sarcocystis ovicanis* (middle) and *Sarcocystis bovicanis* (right) [4]

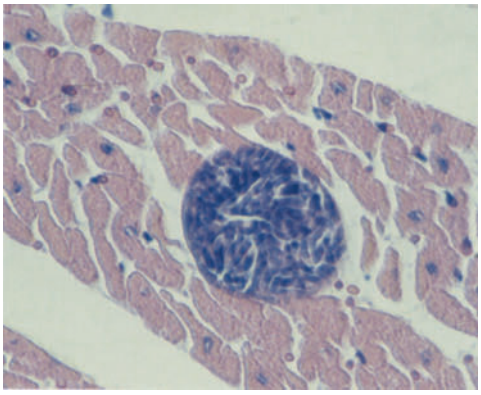


Fig. 153 *Sarcocystis bovicanis* (syn. *S. cruzi*); tissue cyst (70 µm in diameter) [10]

Toxoplasma gondii

Remarks: Tissue cysts of *T. gondii* may also occur in ruminants as they do in pigs (☞ SWINE, ■ 4.1). A diagnosis based on clinical signs is not possible. Cysts may be seen in histopathological examinations. High antibody titers by the Sabin-Feldman-test, IFAT or ELISA (☞ METHODS, 5.1 and 5.2) may indicate an infection. The PCR technique (☞ METHODS, 6.3.2) may be used for the sensitive detection of *T. gondii* infections in all domestic animals species and will thus provide an important epidemiological tool. Tissue cysts of *T. gondii* in cattle may constitute an infection risk of minor importance for man.

Neospora sp.

Remarks: Cysts of *Neospora* sp. are found in the muscles of cattle. The entire life cycle is still unknown. Until 1988 the parasite was diagnosed as *T. gondii*. *N. caninum* causes neuromuscular disorders in dogs and is the main cause of abortion in cattle in the

USA. Tachyzoites and tissue cysts are the only stages so far known. For diagnosis and treatment ☞ CATTLE, ■ 4.6.

HELMINTHS

• Cestoda larvae found in the muscles

Cysticercus bovis Larvae of the human tapeworm *Taenia saginata* cysticercosis, "beef measles"

Location: Cysticerci (larval stage) are found in striated and non-striated muscles of cattle, anywhere in the body. Adult tapeworms are found in the small intestine of man.

Intermediate hosts: Cattle

Species description: The final host of this parasite is man. Cattle serve as intermediate hosts. In cattle the parasite appears as small, fluid-filled cysts (10 mm × 4.5 mm) which give a spotty or measle-like appearance to the beef muscle. These cysts contain 1 protoscolex and occur predominantly in the heart muscle, diaphragm, tongue and masseters. In infected man proglottids are passed in the faeces. Infection of cattle occurs by ingestion of proglottids or eggs. The larvae (oncospheres) hatch in the intestine and penetrate the intestinal wall and are carried via blood stream to muscles where they become bladder worms 8–20 weeks after ingestion. Some of the cysticerci may become calcified and are no longer infective. Man is infected by eating uncooked measly meat of cattle containing viable cysticerci. Adult tapeworm develop in man in 3–5 weeks.

Geographic distribution: World-wide

Symptoms: Cysticercosis in cattle is usually inapparent, except if vital structures in organs are affected (e.g. heart, diaphragm). Infections with *Taenia saginata* in man may be associated with loss of appetite and diarrhoea but they are usually inapparent.

Significance: Carcasses containing beef measles are condemned at meat inspection. Consumption of infected, inadequately cooked meat may infect man. Therefore consequent inspection of cattle carcasses needs to be done. This is time-consuming and expensive.

Diagnosis: Demonstration of cysticerci in muscles of cattle at meat inspection. Serological tests may be used to detect infections antemortem but some are relatively unspecific.

Therapy: Not indicated

Prophylaxis: Animals should not be exposed to human faeces. Water used for livestock purposes (e.g. drinking, irrigation) should be free of faecal contamination. The disease is spread because pastures are irrigated with human sewage.

(Figures 154, 155, 156, 157)

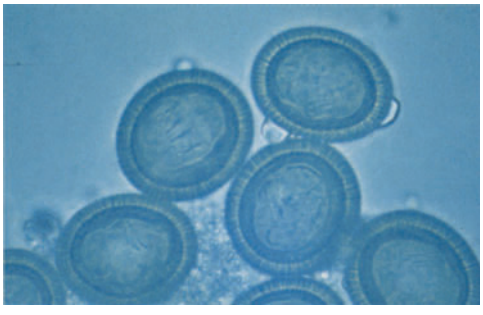


Fig. 154 *Taenia* sp. eggs (34–39 × 31–38 µm) containing oncospheres [4]

Fig. 155 Cysts of *Cysticercus bovis* (10 × 4–5 mm) in the heart of a cattle [4]

Fig. 156 Calcified tissue cyst of *Cysticercus bovis* in the masseter muscle of a cattle

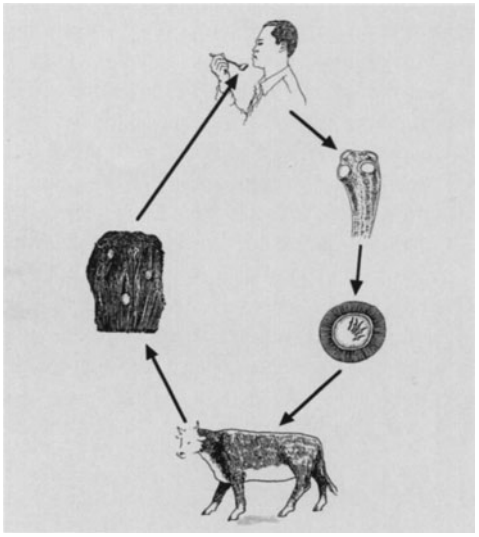


Fig. 157 Life cycle of *Taenia saginata/Cysticercus bovis*

of hooks. Although they are not dangerous to man, their presence is repugnant, and parasitized meat should be condemned and not fed to dogs or other caniidae.

- Nematoda larvae and adult nematodes found in the muscles

Onchocerca dukei Muscular and subcutaneous onchocercosis of cattle

Remarks: Adult worms of this species are found in the subcutaneous, perimuscular and muscular tissue of cattle in tropical Africa (☞ CATTLE, ■ 5.1). It is very frequent in West Africa where sometimes up to 100% of the cattle are infected. *O. dukei* forms intramuscular and subcutaneous nodules. These nodules are fibrous reactions of the host, yellow or grayish-white in colour. They are oval (3–6 mm in diameter) with a raised contour. These nodules are hard to touch, and when sliced one or several worms appear, surrounded by pus. This is the major difference to *Cysticercus bovis*. The intramuscular nodules can be completely embedded in the muscles or only partly covered. The entire musculature may be involved, especially the flank, intercostal and limb muscles. Subcutaneous nodules may be found almost everywhere (☞ CATTLE, ■ 5.1).
(Figures 158, 159)

Cysticercus dromedarii (syn. *C. cameli*)

Remarks: The larva (*Cysticercus dromedarii*) of a hyena tapeworm (*Taenia hyaenae*) is frequently found in the muscles of the dromedary, cattle and goats (☞ DROMEDARIES, ■ 4.1.1). It is rarely found in sheep. *C. dromedarii* cysts are twice as large as *C. bovis*, measuring 12–18 mm in length. They are pearly white and the lateral invaginated protoscolex has a double row

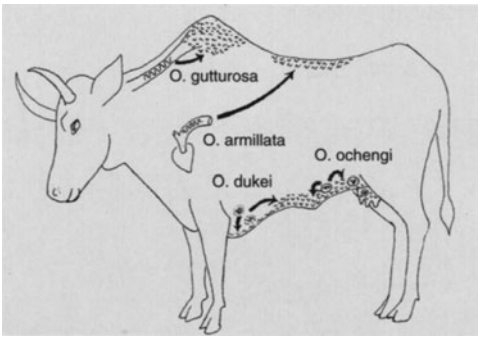
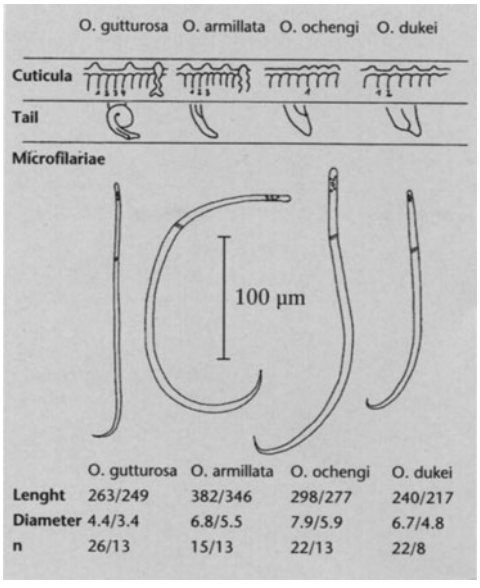


Fig. 158 Sites of occurrence of some *Onchocerca* species found in cattle in Africa [20]



	O. gutturosa	O. armillata	O. ochengi	O. dukei
Lenght	263/249	382/346	298/277	240/217
Diameter	4.4/3.4	6.8/5.5	7.9/5.9	6.7/4.8
n	26/13	15/13	22/13	22/8

Fig. 159 Key for the identification of *Onchocerca* species of cattle in Africa [20]

ARTHROPODS

• Insecta larvae found in the muscles

Hypoderma bovis and *Hypoderma lineatum*

Larvae of the warble flies

Remarks: Larvae of the warble flies may sometimes occur in the muscles during their migratory period. *Hypoderma lineatum* migrates through the wall of the oesophagus (☞ CATTLE, ■ 5.1).

4.1.2 Tendons

HELMINTHS

• Nematoda larvae and adult nematodes found in the tendons

Onchocerca gutturosa

Ligamentary onchocercosis

Location: Adult worms of this species occur in the ligamentum nuchae and also in the ligaments of the hip, elbow, stifle, knee joints and the external side of the scapular cartilage. Microfilariae are found in the skin of the hump and back, sometimes ears and neck of cattle.

Hosts: Cattle

Species description: Males are 2–3 cm long and females are up to 60 cm long or more. The microfialriae are unsheathed and 249–263 µm long and 3.4–4.4 µm wide. The intermediate hosts are members of the family *Simuliidae*.

Geographic distribution: Probably worldwide, extremely common throughout Africa.

Symptoms: Usually inapparent infections. Microfilariae may cause a slightly itching dermatitis, resembling a mild mange.

Significance: Allergic skin reactions against the microfialriae and massive nodule formation may reduce the quality of the skin.

Diagnosis: This is based on the identification of microfilariae in skin biopsies or adult worms at slaughter.

Therapy and Prophylaxis: This is usually not indicated. If allergic dermatitis due to microfilariae are suspected treatment with ivermectin (200 µg/kg, sc.) may be indicated.

Onchocerca lienalis

Remarks: Adults are found in the ligamentum abomaso-lienale. Microfilarieae occur in the skin. The infection is asymptomatic.

4.2 Liver

HELMINTHS

• Trematoda found in the liver

Fasciola gigantica Giant liver fluke

Location: Bile ducts

Hosts: Cattle, sheep, goat, dromedary, horse, pig and many other animal species

Species description: *F. gigantica* is the common liver fluke of livestock in Africa and South

Asian countries. *F. gigantica* resembles *F. hepatica*. Its size is larger, being 25–75 mm in length and up to 12 mm in breadth. The size of the eggs is 156–197 µm × 90–104 µm. The most frequently involved intermediate hosts are *Lymnaea auricularia* and *L. natalensis*. These are aquatic snails living in fairly large permanent bodies of water. The snail vectors can survive an amphibious existence but can only aestivate for very short periods. Metacercariae (the cyst stage of cercariae formed after the tail is cast off) encyst on plants under water such as rice plants, etc. Metacercariae may survive for up to 4 months on stored plants and thus infection may be transmitted by feeding rice straw. *F. gigantica* adults reach the bile ducts 12 weeks after infection. The immature stages migrate through the liver parenchyma. Infections with *F. gigantica* can occur extremely focal, revealing high prevalences in some regions and low prevalences in others. Infection is acquired by eating herbage which is contaminated with metacercariae. The prepatent period is 9–12 weeks.

Geographic distribution: Throughout Africa and Asia

Symptoms: In sheep an acute and a chronic form can occur whereas in cattle only the chronic form seems to play a role. The pathogenesis is essentially the same as in *F. hepatica*.

Significance: *F. gigantica* causes mainly a chronic fasciolosis in cattle and an acute, often fatal, syndrome in sheep.

Diagnosis: Detection of typical operculated eggs with the sedimentation method. *Cave: F. gigantica* eggs are similar to the eggs of some rumen fluke species! *F. gigantica* eggs only appear 15 weeks after infection! Adult flukes are found in the bile ducts at necropsy.

Therapy: ☞ *F. hepatica*

Prophylaxis: ☞ *F. hepatica* in many parts of Africa it is not possible to avoid grazing around lakes, swamps especially if these places are used for watering. The use of bore holes for watering cattle is an effective means to reduce infections with *F. gigantica*.

(Figure 160)

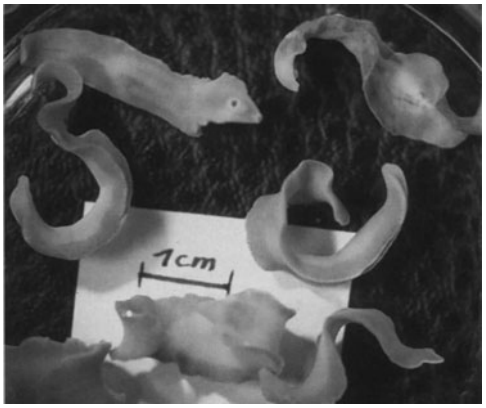


Fig. 160 *Fasciola gigantica*; the giant liver fluke

Fasciola hepatica Common liver fluke

Location: Bile ducts of the liver, sometimes gall bladder

Hosts: Cattle, sheep, goat, horse, donkey, pig and many other animal species

Species description: *F. hepatica* is occurs world-wide – except in Africa and South Asia where it is replaced by *F. gigantica* – and affects especially cattle and sheep. Its size is 30 by 15 mm. The eggs measure 130–150 × 65–90 µm. *F. hepatica* eggs hatch within 10–12 days after deposition and the miracidium, the first larval stage, penetrates actively into the intermediate host which is generally an amphibious snail of the genus *Lymnaea*. Cercariae leave the snail 4–7 weeks after infection and settle on plants just below water level. After casting off the tail they form a cyst about 0.2 mm in diameter (metacercariae). The metacercariae are infective. Ingested metacercariae penetrate the small intestinal wall and reach the liver via abdominal cavity. The duration of the migration within the liver parenchyma is 6–8 weeks after which the young flukes reach maturity in the bile ducts. Infection occurs orally by ingestion of metacercariae on herbage. The incubation period is 2–4 weeks. First symptoms may be seen 5–7 days after infection in acute fasciolosis.

Geographic distribution: Temperate areas world-wide and high altitude regions in East and South Africa.

Symptoms: *F. hepatica* causes a wide range of clinical symptoms, depending on the number of metacercariae ingested but none of the symptoms is pathognomonic. Chronic fasciolosis is the most common form in cattle, sheep and other hosts. The symptoms of chronic fasciolosis are generally associated with hepatic fibrosis and hyperplastic cholangitis. Anaemia, oedema (bottle jaw), digestive disturbances (constipation, diarrhoea) and cachexia develop gradually.

Acute fasciolosis is less common than the chronic disease and occurs mainly in sheep. It is basically a hepatitis caused by the simultaneous migration of large numbers of immature flukes. Sudden death may occur in acute fasciolosis.

Significance: *F. hepatica* is the most important trematode of domestic ruminants and the most common cause of liver fluke disease in temperate areas.

Diagnosis: The oval, operculated, golden-brown eggs (130–150 × 65–90 µm) appear in the faeces 10 weeks after infection. The sedimentation is the most reliable method for the detection of *Fasciola* spp. eggs (☞ METHODS, 1.5). Eggs are expelled intermittently, depending on the evacuation of the gall bladder. *Fasciola* spp. eggs are very similar to eggs of the rumen flukes (family Paramphistomidae). Rumen flukes are very prevalent in ruminants in most parts of Africa whereas fasciolosis is rather focal. The differentiation between *Fasciola* spp. eggs and eggs of Paramphistomidae is not easy. The detection of the adult flukes in the liver at necropsy or slaughter is the most reliable method to confirm fasciolosis. Prevalence studies should be based on abattoir surveys rather than on coproscopic investigations.

Therapy: A number of compounds is available to treat fasciolosis in cattle. These are oxyclozanide (10 mg/kg, po.), rafoxanide (7.5 mg/kg, po.), nitroxynil (10 mg/kg, sc.), albendazole (10 mg/kg, po.), closantel (5 mg/kg, po.), triclabendazole (12 mg/kg, po.), netobimin (20 mg/kg, po.) and clorsulon (7 mg/kg, po.). Some of these diamphenethide (100 mg/kg, po.), nitroxynil (15 mg/kg, sc.), closantel (10 mg/kg, po.), triclabendazole (12 mg/kg, po.) and clorsulon (7 mg/kg, po.) are active against immature flukes. The treatment interval for strategic control should be chosen according to the local epidemiological situation.

Prophylaxis: The snail intermediate host may be controlled by drainage of land, fencing off water pools to exclude animals from the snail habitats. The use of plant molluscicides offers new prospects for future snail control.

(Figures 30, 31, 32, 161, 162, 163, 164, 165)

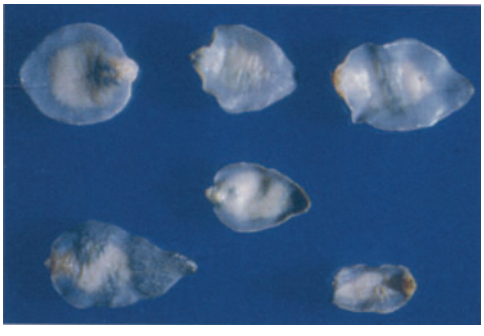


Fig. 161 *Fasciola hepatica*; the common liver fluke (30 × 15 mm)

Fig. 162 *Lymnaea truncatula*; the intermediate host of *Fasciola hepatica* [10]

Fig. 163 Life cycle of *Fasciola hepatica* [6]

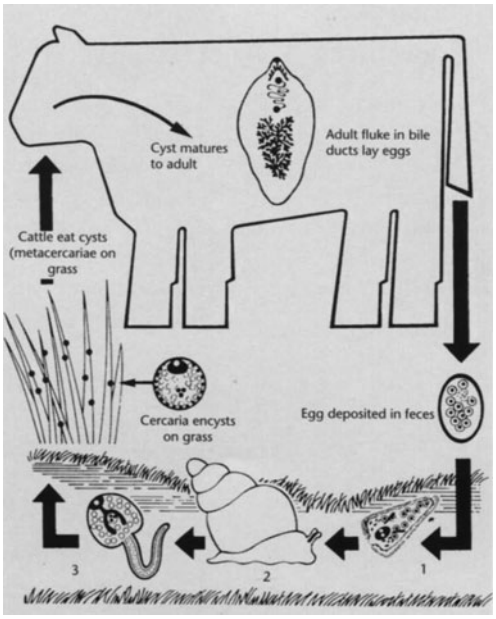


Fig. 164 *Fasciola hepatica* infection; cholangitis and calcification of the bile ducts [4]

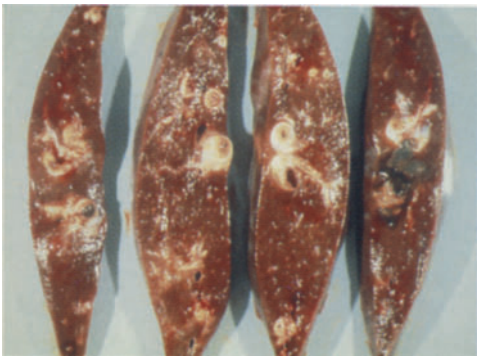


Fig. 165 *Fasciola hepatica* infection causing cholangitis and calcification of the bile ducts

Dicrocoelium hospes African lancet fluke

Location: Bile ducts and gall bladder
Hosts: Sheep, goat, cattle and other ruminants
Species description: *D. hospes* is 6–10 mm long and 0.8–1 mm wide. The eggs measure 36–45 µm × 25 µm. The life cycle involves two intermediate hosts. The first is a land snail (*Limicolaria* spp., *Achatina* spp. and probably others) and the second an ant (*Dorylus* spp., *Cematogaster* spp. and other genera). *D. hospes* is closely related to *D. dendriticum*. Infection is acquired by ingestion of infected ants (containing metacercariae) via herbage. Migration of immature flukes from the intestine via ductus choledochus into the biliary system. The prepatent period is up to 97 days.
Geographic distribution: North, Central and West Africa
Symptoms: Generally clinically inapparent; heavy infections cause diarrhoea, cholangitis and weight loss.
Significance: In some regions a high percent-

age of animals is infected. Losses occur due to poor growth and condemnation of infected livers at slaughter.

Diagnosis: Adult *D. hospes* in the bile at necropsy; detection of parasite eggs in the sediment of faeces.

Therapy: ☞ below *D. dendriticum*

Prophylaxis: ☞ below *D. dendriticum*

Dicrocoelium dendriticum (syn. *D. lanceolatum)* Common lancet fluke

Location: Bile ducts or gall bladder

Hosts: *D. dendriticum* occurs mainly in sheep, goat, cattle but also in pig, dog, donkey, rabbit and rarely in man.

Species description: The fluke is 6–10 mm long and 1.5–2.5 mm wide. The eggs measure 36–45 × 20–30 µm. The life cycle involves two intermediate hosts, a land snail as the first (*Zebrina* spp., *Cionella* spp. and 29 other species are described) and ants of the genus *Formica* and *Lasius* as the second intermediate hosts. Ants infected with metacercariae attach to herbage overnight and are available to grazing animals in the early morning. Infection occurs by ingestion of infected ants (containing metacercariae) via herbage. Migration of immature flukes from the intestine via ductus choledochus into the biliary system. The prepatent period is 47–54 days. Cirrhosis of the liver and thickening of the bile ducts may occur in heavy infections.

Geographic distribution: Europe, Asia, the Americas, North Africa, occasionally in imported ruminants in other parts of Africa; autochthonous infections seem not to occur in Africa.

Symptoms: Often without clinical symptoms. Heavy infections may produce weight loss, anaemia and hypoproteinaemia.

Significance: Lancet flukes may cause extensive liver damage, causing the host to "do poorly". Condemnation of livers at slaughter may cause severe economic losses among cattle herds.

Diagnosis: Demonstration of typical eggs in the sediment of faeces. The eggs are small (40 × 25 µm), thick walled, yellowish-brown and contain a miracidium. Adult parasites may be found in the bile ducts at necropsy.

Therapy: Albendazole (20 mg/kg, po.), fenbendazole (50 mg/kg, po.), netobimin (20 mg /kg, po.) thiophanate (50 mg/kg, po.), thiabendazole (200 mg/kg, po.) and praziquantel (50 mg/kg, po.) are effective against the lancet fluke.

Prophylaxis: Elimination of the intermediate hosts is not feasible.

(Figures 32, 33, 166, 353)

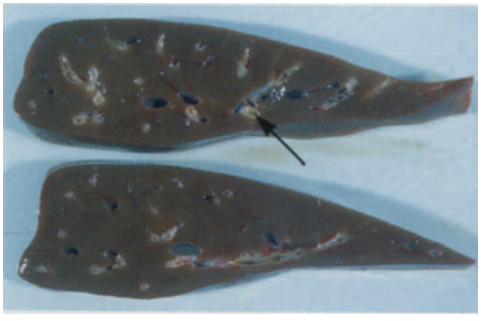


Fig. 166 *Dicrocoelium dendriticum* found in the bile ducts

***Schistosoma* spp.**

Remarks: Schistosomes may often be found at necropsy in the portal veins of the liver (☞ CATTLE, ■ 2).

• Cestoda found in the liver

Echinococcus granulosus (syn. *E. unilocularis*) Hydatid tapeworm, hydatidosis

Location: Larvae (hydatid cysts) of *E. granulosus* are found in the liver and the lungs of cattle, sheep, goats, swine, horse, dromedary and other domestic animals and man (= intermediate hosts). Adult tapeworms are found in the small intestine of the dog and other related carnivores (= final hosts).

Hosts: Canids are the final hosts of *E. granulosus*. Intermediate hosts are ungulates and man.

Species description: *E. granulosus* is a small tapeworm with 3–4 proglottids and a total length of 2–6 mm. It occurs in the small intestine of the dog and other canids (hyaena, coyote, fox, etc.). Adult tapeworms in the dogs pass proglottids or eggs in the faces. When ingested by cattle or other intermediate hosts, these eggs hatch in the intestine. The oncospheres (hexacanths) penetrate the gut wall, enter the portal vein and reach the liver, which is the first capillary filter for the larvae and subsequently the lungs, which are the second capillary filter. The remaining oncospheres may reach via the arteries other organs. In all these organs hydatid cysts (bladder worms) develop. These are large cysts filled with fluid and tapeworm heads (protoscolices). The hydatid cysts develop slowly over several months. They are commonly 5–10 cm in diameter and contain a liquid. The hydatid cyst is composed of a thick outer, concentrically laminated membrane. About 5 months after infection brood capsules, each containing several protoscolices develop from the inner part of the capsule (germinal membrane). The brood capsules may become detached and float free in the cyst fluid, being termed "hydatid sand". At this time the cyst is infective for the definitive host. The life cycle is completed when a dog ingests protoscolices. Hydatid cysts are usually found in the lungs of sheep and cattle, but primarily in the livers of horses. In pigs, hydatid cysts are found in both the liver and the lungs. The hydatid cysts may be multilocular (sheep, cattle, pigs) or unilocular (horse). In man hydatid cysts may be found in many organs. The significance of the hydatid cyst depends on the severity of the infection and the organ in which it is situated. In domestic animals clinical signs are not commonly seen despite heavy infections. Human hydatidosis is often associated with clinical signs and the function of the affected organ is often impaired. This is especially true if the heart or the brain are involved. Adult tapeworms are harmless to the dogs and seldom cause clinical symptoms.

Geographic distribution: World-wide

Symptoms: Hydatid cysts do not usually cause clinical symptoms unless the cysts are numerous or become very large.

Significance: Hydatidosis in cattle is not usually a problem, but infected organs are condemned at slaughter. In man hydatidosis is a serious problem. Infected dogs are a reservoir for both infection of domestic animals and man.

Diagnosis: Usually the diagnosis of hydatidosis is made at slaughter or necropsy. Infected dogs pass eggs in the faeces which cannot be differentiated from those of *Taenia* spp. Immundiagnostic tests (ELISA, Immunoblotting; ☞ METHODS, 5.2 and 5.3) are widely used in medical parasitology and may assume significance in epidemiological studies. *E. granulosus* eggs, excreted by dogs are very similar to those of *Taenia* spp. The differentiation may be carried out by means of monoclonal antibodies.

Therapy: Treatment of hydatidosis in cattle and other intermediate hosts is rarely indicated. Control of hydatidosis is based on prophylaxis.

Prophylaxis: Dogs should not be fed with uncooked meat in general and infected organs in particular. In endemic areas where human hydatidosis is of great importance special attention should be paid to the safe destruction of affected organs, the reduction of stray dogs and the anthelmintic treatment of domestic dogs. Praziquantel (5 mg/kg, po. or 5.7 mg/kg, sc. or im.), bunamidine hydrochloride (25–50 mg/kg, po.) and the combination of febantel/praziquantel/pyrantel are sufficiently effective against adult *E. granulosus* tapeworms in dogs.

(Figures 167, 168, 169, 170)

Fig. 167 *Echinococcus granulosus*; hydatid cyst in the lungs of a cattle [4]

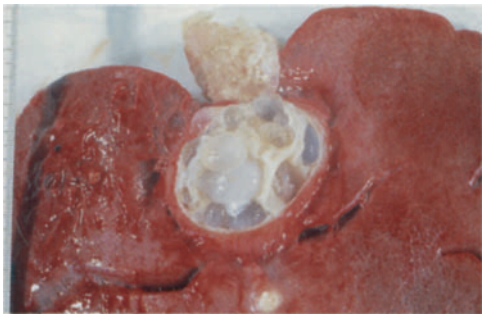


Fig. 169 *Echinococcus granulosus*; hydatid cyst [42] opened [4]

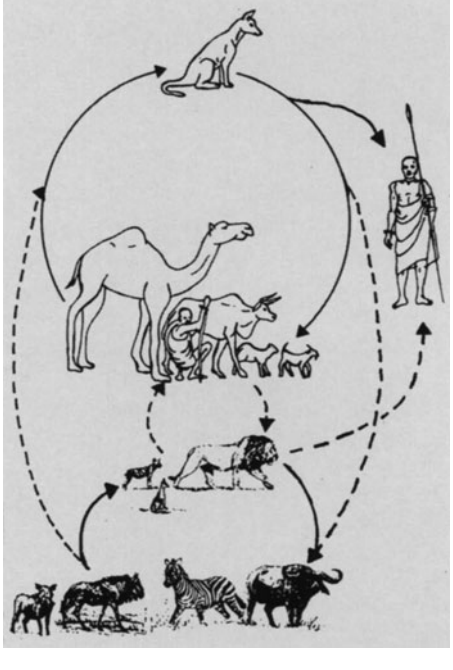


Fig. 168 Life cycle of *Echinococcus granulosus* in sub-Saharan Africa [21]

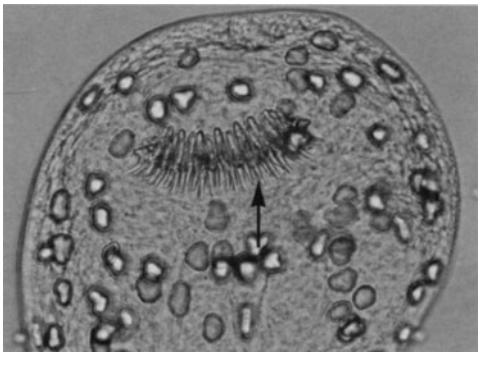


Fig. 170 *Echinococcus granulosus*; protoscolex (100 × 160 in diameter) with typical hook collar

Stilesia hepatica

Remarks: This parasite occurs in the bile ducts and small intestine of sheep and goats (☞ SHEEP AND GOATS, ■ 4.2). In endemic areas wild ruminants and rarely cattle may also be affected. This parasite is very prevalent in tropical and southern Africa. *S. hepatica* is non-pathogenic but extremely prevalent (in 90–100% of sheep) in many parts of Africa. It is non-pathogenic and does not require treatment.

Cysticercus tenuicollis

Remarks: Migrating post-oncospheral stages may occasionally be found in the liver parenchyma and thin-necked cysts may be found on the serosa of the liver (☞ CATTLE, ■ 4.4 and SHEEP AND GOATS, ■ 4.4).

POROCEPHALIDA

Linguatula serrata "tongue worm"

Remarks: This is a cosmopolitan parasite and it occurs in the nasal and respiratory passages of the dog and other canids, snakes, very rarely in man, horse, goat and sheep. The parasite is tongue-shaped and the cuticle is transversely striated. Males are 1.8–2 cm, females are 3–13 cm long. The eggs measure about 90–70 µm. The eggs are ingested by a herbivorous intermediate host (horse, sheep, goat, cattle, rodents, rabbit, etc.) and hatch in the alimentary canal and the larvae migrate to the mesenteric lymph nodes, in which they develop to the infective nymphal stage. The larva is up to 500 µm long and undergoes about six to 9 moults. It usually lies in a cyst surrounded by a viscid fluid. These cysts may be found at necropsy in the intestinal lymph glands, the liver or in other organs. Dogs become infective by eating the infective viscera, especially of sheep and cattle. Infected dogs show sneezing and discharge from the nostrils. The infection in cattle is clinically inapparent.
(Figures 171, 172)

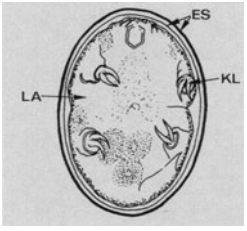


Fig. 171 *Linguatula serrata*; embryonated egg (90 × 70 µm); [47]; ES = egg shell; KL = claw; LA = larva [7]

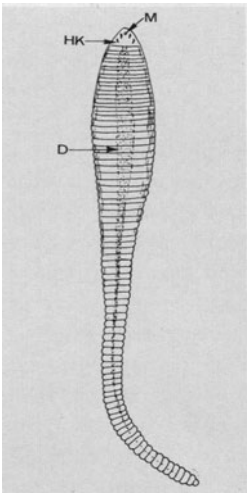


Fig. 172 *Linguatula serrata*; adult female (up to 13 cm long); M = mouth opening; HK = hooks; D = intestine [7]

4.3 Respiratory system

HELMINTHS

- Cestoda found in the lungs and trachea

Echinococcus granulosus (syn. *E. unilocularis)* Hydatid tapeworm, hydatidosis

Remarks: Larvae (hydatid cysts) of *E. granulosus* are often found in the lungs and liver of cattle and other domestic animals (☞ CATTLE, ■ 4.2).

- Nematoda found in the lungs and trachea

Dictyocaulus viviparus Cattle lungworm, parasitic bronchitis

Location: Trachea, bronchi and bronchioles
Hosts: Cattle, camel and some deer species
Species description: Males are 4–5 cm long and the females 6–8 cm. The eggs measure 82–88 × 33–38 µm. The adult worms live

in the airways and produce eggs which contain larvae. These eggs are moved with respiratory secretions towards the larynx. They are then coughed up and swallowed. Hatching occurs in the intestine and first-stage larvae are passed in the faeces. On the pasture the larvae moult twice to reach the third stage which is infective for cattle. When swallowed the infective larvae penetrate the gut wall and move to the local lymph nodes, where they moult to become fourth-stage larvae. Then they migrate via the thoracic duct to the jugular vein, after that to the right side of the heart and then to the lungs where they are arrested in the capillaries and break through to the air passages. Development to maturity in the bronchi of the host takes about 4 weeks. Larval stages remain inhibited for several months. Irritation of the respiratory mucosa by larvae and adult worms cause increased respiratory secretions and lung congestion with blockage of air passages. Aspiration of eggs and larvae into the alveoli leads to consolidation of lobules. Severe epithelialization and peribronchial fibrosis usually occur a few weeks after the infection has started. These chronic lung alterations may be the cause of the unthriftiness, commonly observed in animals after a heavy infection. Immunity is built up as quickly as 10 days after an initial infection but it wanes in the absence of reinfection.

Geographic distribution: World-wide

Symptoms: Parasitic bronchitis is characterized by severe coughing, rapid breathing, dyspnoea and rapid loss of condition. Severe cases lead to emphysema and pneumonia. Death may occur in heavy infections.

Significance: Parasitic bronchitis due to *D. viviparus* may cause great losses in endemic areas. Even animals after a moderate initial infection show retarded growth for prolonged periods of time. In Africa *D. viviparus* has been frequently found in imported animals. Autochthonous infections occur sporadically.

Diagnosis: This is based on the clinical signs, rapid and heavy breathing, coughing, nasal discharges and the demonstration of larvae in the faeces by the Baermann method (☞ METHODS, 1.7 and CATTLE, ■ 1). However, coughing may occur in the prepatent period before larvae are found in the faeces. Usually parasitic bronchitis is a herd problem, seen especially in young calves which have recently been exposed to an infected pasture.

Therapy: Levamisole (5 mg/kg, sc. or 7.5 mg/kg, po.), the benzimidazoles (fenbendazole, 7.5 mg/kg, po.; oxfendazole, 4.5–5 mg/kg, po.; albendazole, 7.5 mg/kg, po.; febantel, 7.5 mg/kg, po.) netobimin (12.5 mg/kg, po.) and ivermectin (200 µg/kg, sc.) are highly effective against all stages of *D. viviparus*. These drugs are also effective against lungworms in sheep, horses and pigs. In calves, aggravated coughing a few minutes after treatment (especially with levamisole, sc.) is characteristic for the infection and often regarded as a confirmation of the diagnosis. Heavily affected calves should be moved inside and supportive treatment should be administered.

Prophylaxis: Pastures with a recent history of lungworm infection are highly dangerous for young calves. Lungworm infections may be controlled in several ways. Calves may be vaccinated with X-radiated *Dictyocaulus* larvae (Dictol®), in countries where the vaccine is available, twice (4 weeks apart) prior to exposure. The animals should be housed during the vaccination period and for another 2 weeks after the second dose to allow time to build up an adequate level of immunity before release on pasture. Another approach is the strategic control of infections. In first-season cattle, a first treatment is applied 2–3 weeks after turn-out and, depending on the infection risk and the duration of the drug, repeated treatments are required during the period of high challenge (benzimidazoles monthly, ivermectin 3 and 10 weeks after turn-out). A sustained release device (anthelmintic with a prolonged activity)

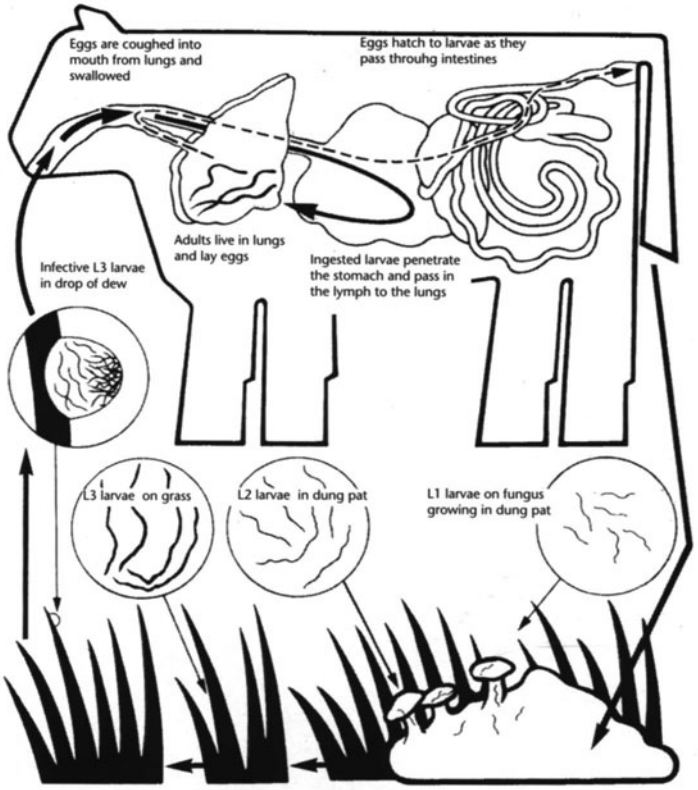


Fig. 173 Life cycle of *Dictyocaulus viviparus*; the third-stage larvae penetrate the intestinal mucosa and not the mucosa of the stomach [6]

may also be applied about 2–3 weeks after turn-out or prior to the period with the highest infection risk.
(Figures 83, 173, 174)

Fig. 174 *Dictyocaulus viviparus*; adult worms in trachea

Mammomonogamus laryngeus

Location: Larynx
Hosts: Cattle, water buffalo, occasionally sheep, goat and rarely man
Species description: *M. laryngeus* is not very pathogenic for cattle. The worms are attached to the mucosa of the larynx. The males and females are found in permanent copulation. The life cycle is unknown.
Geographic distribution: Caribbean Islands, South America, Asia, Central Africa (Cameroon)
Symptoms: Affected animals may cough and sometimes lose condition. Calves may develop bronchitis. Pneumonia due to respiratory secretions which are aspirated, causing pulmonary reactions have been observed.

Significance: Heavy infections in endemic areas may cause losses due to massive irritation of the larynx by the parasites. Bronchitis and pneumonia may occur.
Diagnosis: This is made by finding the eggs in the faeces or adult worms at necropsy.
Therapy: Unknown. Nitroxynil (10mg/kg, sc.), which is used against *Syngamus* spp. of poultry may also be used against *Mammomonogamus laryngeus*. Modern benzimidazoles and ivermectin (200 µg/kg. sc.) may be used in heavily infected cattle.
Prophylaxis: Unknown
(Figures 175, 176, 177)

Fig. 175 *Mammomonogamus laryngeus* (males are 3–3.5 mm long, females are 8.5–10 mm long) [8]

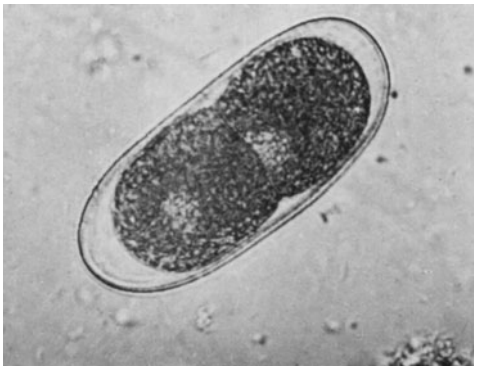


Fig. 176 Egg of *Mammomonogamus laryngeus* (323 × 50 µm) [8]

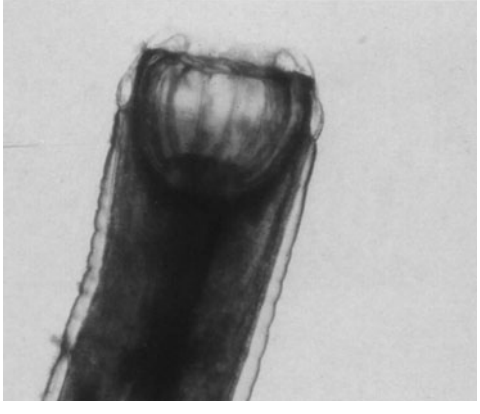


Fig. 177 *Mammonogamus laryngeus*; head end [8]

Mammomonogamus nasicola

Location: Nasal cavities
Hosts: Cattle, sheep and goat
Species description: The males and females of this parasite are permanently joined in copulation. Males are 4–6 mm long and females 11–23 mm. Eggs are 54 × 98 µm and have only a few blastomeres. Life cycle and pathogenesis are unknown. An optional reservoir host (e.g. earthworm or snail) is being suspected. After oral ingestion of infective larvae the parasite reaches the respiratory tract through the blood stream. The parasites suck blood and are bright red in fresh samples.

Geographic distribution: Central and South America, West Indies, Central Africa.
Symptoms: Heavy infections cause irritation of the nasal mucosa, sneezing and nasal discharges. *M. nasicola* may be differentiated from *Schistosoma* infection of nasal passages.
Significance: ☞ above *M. laryngeus*
Diagnosis: ☞ above *M. laryngeus*
Therapy: Unknown
Prophylaxis: Unknown
(Figure 178)

Fig. 178 *Mammomonogamus nasicola* [18]

4.4 Abdominal cavity

HELMINTHS

- Cestoda found in the abdominal cavity

Cysticercus tenuicollis Larval stage of the canine tapeworm *Taenia hydatigena*

Remarks: The thin-necked larvae (*Cysticercus tenuicollis*) of *Taenia hydatigena* are often found attached to the omentum, the intestinal mesentery and to the serosal surface of abdominal organs, especially the liver of cattle, sheep and other herbivores. Cysticerci are often found at meat inspection without any previous clinical signs. The feeding of condemned material to dogs should be avoided (☞ SHEEP AND GOATS, ■ 4.4).
(Figures 179, 180)

Fig. 179 *Cysticercus tenuicollis*; thin-necked cyst attached to the liver of a sheep. The protoscolex can be seen through the cyst wall

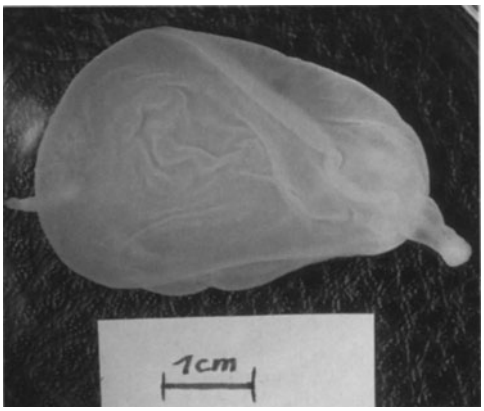


Fig. 180 *Cysticercus tenuicollis*; thin-necked stage found in cysts

- Nematoda found in the abdominal cavity

Setaria labiatopapillosa Bovine abdominal filariosis

Location: Peritoneal cavity
Hosts: Cattle, deer, giraffe and other ruminants
Species description: Males are up to 4–6 cm long and females 6–12 cm. There is a distinct peribuccal ring with dorsal and ven-

tral prominences. The tail of the female terminates in a marked button which is divided into a number of papillae. The microfilariae are sheathed, measure 240–260 µm and appear in the peripheral blood (☞ CATTLE, ■ 2). Several species of mosquitoes act as vectors (*Aedes* spp., *Culex* spp. and *Anopheles gambiae* and other *Anopheles* spp.). Infective larvae are produced in the vector in 12–16 days. Adult worms in the peritoneal cavity are non-pathogenic. The major pathogenic effect occurs when immature stages migrate erratically in the central nervous system of abnormal hosts (e.g. *Setaria digitata* or *S. labiatopapillosa* microfilariae introduced by vectors in horses, sheep and goats). The affected animals suffer from an acute, focal encephalomyelomalacia. The lesions are usually single tracks left by migrating larvae and may be found in any part of the CNS.

Geographic distribution: World-wide

Symptoms: Adult worms in the peritoneal cavity do not cause clinical signs. Erratic larvae in the CNS may cause nervous signs, depending on the location of the lesions. Muscular weakness, ataxia, paralysis and death may occur.

Significance: Adult worms in the peritoneal cavity are non-pathogenic. Erratic larvae in the CNS of an abnormal host may cause nervous symptoms and even death.

Diagnosis: This is made by demonstrating the microfilariae in stained blood smears or with the dark ground/buffy coat method (☞ METHODS, 3.1 and 3.4) or by finding the adult worms in the abdominal cavity. The antemortem diagnosis of immature worm-associated CNS disturbances under field conditions is impossible. Histopathological examination of stained brain sections may result in an aetiological diagnosis.

Therapy: Chemotherapy is difficult because adult worms are very resistant to most drugs. Ivermectin (200–500 µg/kg, sc.) and diethylcarbamazine (25–100 mg/kg/day during several days, sc.) are effective against the microfilariae.

Prophylaxis: Unknown

(Figures 148, 181, 182)

Fig. 181 *Setaria labiatopapillosa*; adult worm on the intestinal serosa; males are 4–6 cm long and and females are 6–12 cm long

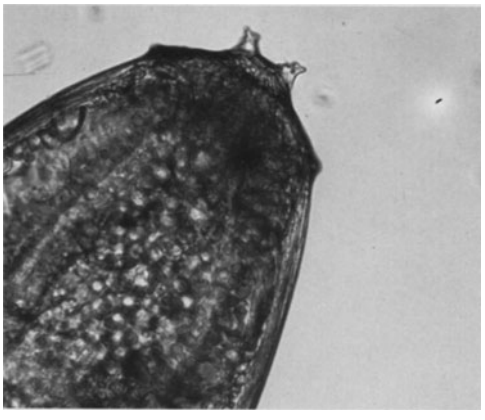


Fig. 182 *Setaria labiatopapillosa*; anterior end

4.5 Pancreas

HELMINTHS

- Trematoda found in the pancreas

Eurytrema pancreaticum Pancreatic fluke

Remarks: This parasite occurs in the pancreatic ducts, bile ducts, occasionally duodenum of sheep, goats (☞ SHEEP AND GOATS, ■ 4.5) and occasionally cattle in Asia, Brazil,

Madagascar and Réunion. There are no obvious clinical signs unless heavy infections are present. However, recent reports suggest that in areas with a high prevalence and intensity of infection, *Eurytrema pancreaticum* may be responsible for chronic wasting and mortality, especially in sheep.
(Figures 34, 183)

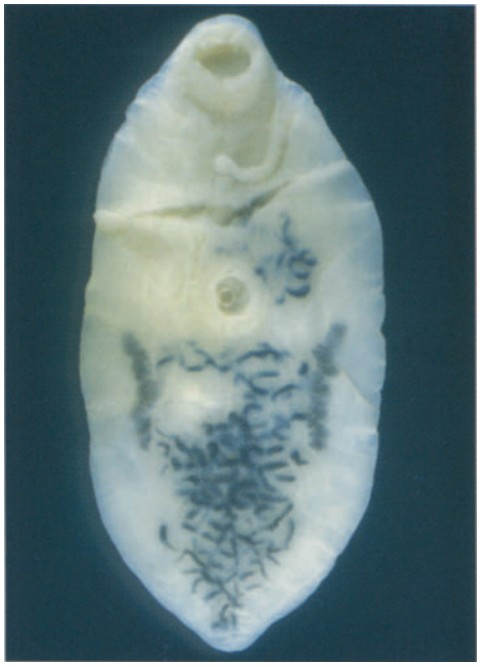


Fig. 183 *Eurytrema pancreaticum*; (8–16 mm long and 5–8. 5 mm wide) [8]

4.6 Central nervous system

PROTOZOA

Toxoplasma gondii

Remarks: Tissue cysts of this parasite may occasionally be found in the brain of sheep and cattle. These cysts contain merozoites (6–8 µm long) and are infective for the final host (cat) (☞ also SWINE, ■ 4.1 and 4.6).

Neospora sp.

Remarks: *Neospora caninum* is a recently recognized new parasite species. It resembles *T. gondii* and causes neuromuscular disorders (polyradiculoneuritis, myositis, paralysis) in dogs and abortion in cattle. *Neospora* sp. is suspected to be responsible for up to 20% of cattle abortion in some parts of the USA. The entire life cycle is unknown. No final host has been found so far in which the sexual development occurs. The only stages of this parasite are tachyzoites and tissue cysts. These are thick-walled (1–4 µm) as compared to *T. gondii* which produces thin-walled (< 0.5 µm) cysts. *Neospora*-like organisms were found in the central nervous system of dogs, cats, lambs, calves and foals. Transplacental transmission has been demonstrated in all these cases. The diagnosis is based on the demonstration of parasites in stained tissue sections or isolation from freshly aborted foetuses. Positive IFAT titres (☞ METHODS, 5.1) in neonatal calves prior to colostrum application is a strong indication of a prenatal infection. The main location of tissue cysts in cattle is the central nervous system. Sulfonamids combined with trimethoprime, pyrimethamine (1mg/kg, daily po. for 4 weeks) and clindamyzine (13.5 mg/kg, 3 × daily po. during 10 days) are used in dogs for treatment. No specific treatment is yet available for ruminants.
(Figures 184, 185)

Fig. 184 A weak-born calf with neuromuscular disorders due to a congenital *Neospora caninum* infection [22]

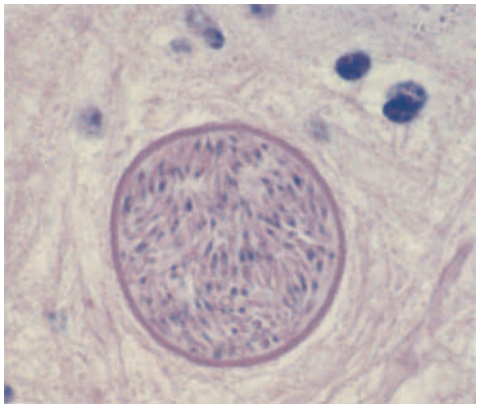


Fig. 185 *Neospora caninum*; thick walled cyst (1–4 µm thick; 70–120 µm in diameter) in the brain of a calf [22]

HELMINTHS

- Cestoda cysts found in the central nervous system

Coenurus cerebralis Larval stage of the canine tapeworm *Taenia multiceps* (syn. *Multiceps multiceps*) "gid", "stuggers", "sturdy"

Remarks: The intermediate stage of the canine tapeworm *Taenia multiceps*, a coenurus, develops in the brain and spinal cord mainly of sheep and goats and less commonly in cattle (☞ SHEEP AND GOATS, ■ 4.6).

5 Stages on the body surface

5.1. Skin and coat

5.1. Skin and coat

PROTOZOA

Besnoitia besnoiti (syn. *Sarcocystis besnoiti*)
Elephant skin disease

Location: *Besnoitia* cysts are found in the dermis, subcutaneous tissue, fasciae, laryngeal, nasal and other mucosae.

Hosts: Domestic and wild cats act as definitive hosts. Intermediate hosts are cattle, goat, wildebeest, impala and kudu. Sheep, rabbit and some rodents may be experimental intermediate hosts.

Species description: This is a protozoan disease of the skin, subcutis, blood vessels and mucous membranes. These *Toxoplasma*-like organisms multiply in endothelia, histiocytic and other cells and produce characteristic large, thick-walled cysts filled with bradyzoites. The *Besnoitia* cysts may reach up to 600 µm in diameter. They are usually spherical and packed with crescentic trophozoites (bradyzoites) each 2–7 µm in length. Parenteral application of blood, taken from an infected animal may transmit the disease to other animals. Unsporulated oocysts (15 × 13 µm) are shed in the faeces of the final host (Felidae). The mode of transmission is not completely known. In particular the transmission from infected cattle to cats remains to be substantiated. Biting flies (e.g. *Glosssina palpalis* and other biting flies) and ticks may transmit *B. besnoiti* mechanically to cats. Needle inoculation of tissues that contain cysts can transmit some *Besnoitia* spp. to other hosts. It has also been suggested that contaminated water troughs may be an important source of infection. The mortality is usually below 10% although animals may lose condition. Pregnant animals may abort. Bulls may become sterile and hides are of little value for leather-making purposes. Animals of all ages, from 6 months upwards may be infected.

Geographic distribution: Southern Europe, Africa, Asia, South America

Symptoms: The initial stage of the disease starts with fever after an incubation period of 6–10 days. Cyst formation in the skin starts 1–4 weeks after the start of the temperature rise. Inappetence, photophobia, enlargement of the lymph nodes and oedematous swellings on the limbs and the lower parts of the body, orchitis and rhinitis may accompany the febrile stage. Animals are reluctant to move, respiration is rapid and diarrhoea and abortion may occur during this phase. In mild infections recovery may occur in this stage. In the second stage of the disease, the skin becomes hard, thick and wrinkled and develops cracks that allow secondary bacterial infections and myiasis to develop. Movement is painful. A serosanguineous fluid oozes from the cracks. The skin is scurfy and folded and the whole appearance is one of extensive mange. There is hair loss over the swollen skin. Severe infections cause emaciation and death may occur. Cysts may appear in the scleral conjunctiva and nasal mucosa. Although mortality is low, conva-

lescence is slow in severe cases. Severely affected bulls may remain permanently sterile. Previously infected animals may be carriers for life. The hairless condition may remain for several months.

Significance: Besnoitiosis may be a severe problem in endemic areas. Although the mortality is low, affected animals may be emaciated and sick for months.

Diagnosis: This is based on the clinical signs with the typical skin lesions following a febrile phase. Microscopical examination of affected skin by means of stained biopsies may reveal the typical cysts, containing the bradyzoites. Spherical, encapsulated pseudocysts are pathognomonic. The best method of diagnosis is the examination of the scleral conjunctiva. The cysts can be seen in the scleral conjunctiva with the naked eye, revealing many chronic cases without signs.

Therapy: There is no satisfactory treatment. Affected animals should be separated and treated symptomatically (antibiotics, insect-repellants, etc.). Sulfonilamide application prevented cyst development in experimental studies. Antimony (1%, 0.6 ml/kg, po.) cured besnoitiosis in a goat.

Prophylaxis: This is difficult until the exact mode of transmission is known. In some countries, a tissue-cultured vaccine is available and quite effective. Separation of cattle from cats, and of domestic cattle from wild ruminants, and the elimination or isolation of infected animals should help to prevent transmission of this parasite.

(Figures 186, 187, 188)

Fig. 186 Thickened skin ("elephant hide disease") following a *Besnoitia besnoiti* infection [4]

Fig. 187 *Besnoitia besnoiti*; cysts can be seen in the scleral conjunctiva with the naked eye [4]

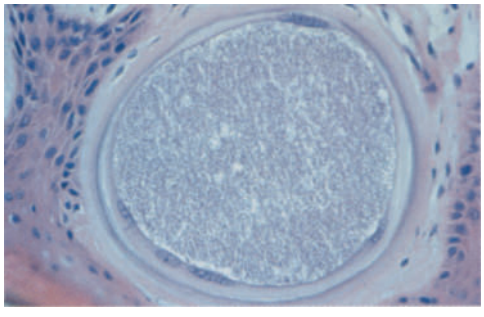


Fig. 188 *Besnoitia besnoiti*; thick-walled cyst found in the subcutaneous tissue, the cysts may be up to 600 µm in diameter [4]

HELMINTHS

• Nematoda found in the skin

Parafilaria bovicola "Verminous nodules", "verminous haemorrhagic dermatitis"

Location: Adults are found in subcutaneous nodules on the upper side of the body. Microfilariae are found in the bloody excretions of the skin nodules.

Hosts: Cattle

Species description: Males are 2–3 cm and females are 4–5 cm in length. The eggs measure 45 × 30 µm and contain microfi-

lariae. Development occurs in *Musca* spp. which become infected when they feed on the skin lesions. When feeding on lacrimal secretions or wounds they transmit the microfilariae to the next definitive host. The verminous nodules are likely to break and ooze blood, causing a haemorrhagic dermatitis.

Geographic distribution: World-wide, especially many parts of Africa

Symptoms: Subcutaneous nodules on the upper side of the body; these nodules are painful and contain the worms. Nodules are likely to break when the gravid female starts with the excretion of eggs. These haemorrhages and nodules are typical signs of the infection with *P. bovicola*.

Significance: Nodules are painful and irritating, and the carcasses at slaughter are downgraded.

Diagnosis: Verminous nodules, haemorrhage, microfilariae in the exudate

Therapy: Ivermectin (0.2 mg/kg, sc.) is fully effective against adults. Nitroxynil (20 mg/kg, sc.) is also effective but must be repeated 3 days later. High doses of levamisole and fenbendazole (50 mg/kg, po.) daily for 5 days were effective.

Prophylaxis: Fly (and tick) control may reduce the entrance points of infective larvae.

(Figure 189)

Fig. 189 *Parafilaria bovicola* causing "bleeding spots" and nodules on the skin of cattle; "bleeding spots" are markedly seasonally

Onchocerca dukei Muscular onchocercosis

Location: Adult worms of this species are found in the subcutaneous, perimuscular and muscular tissue of cattle in Africa.

Hosts: Cattle

Species description: The nodules are found in the ventral thorax region, abdomen, diaphragm and thighs. These nodules may be confused with the cysts of *Cysticercus bovis* (*Taenia saginata*). Microfilariae are 240–217 µm long and 4.8–6.7 µm wide and their predilection site is the subcutis of the lower thorax and the umbilical region. The parasite is transmitted by species of the genus *Simulium*.

Geographic distribution: Tropical Africa and also in sub-Saharan West Africa

Symptoms: Infections are usually clinically inapparent.

Significance: Losses occur mainly by condemnation of carcasses when a lot of subcutaneous and intramuscular nodules are seen during meat inspection. Such meat is repugnant.

Diagnosis: This is often made at meat inspection. Nodules are found particularly in the thorax, abdomen and diaphragm and may be confused with the cysts of *Cysticercus bovis* (☞ CATTLE, ■ 4.1). Skin biopsies soaked for 12 hours in physiological saline may be investigated after staining with Giemsa (☞ METHODS, 3.1). Typical microfilariae may be seen.

Therapy: This is not usually indicated.

Prophylaxis: This is generally not feasible in endemic areas (☞ Cattle, ■ 4.1.1).

Onchocerca gibsoni

Location: The adult worms are found in subcutaneous nodules on the brisket, shoulders and external surfaces of the hind-limbs. Microfilariae are found intradermally around the nodules with a predilection to the brisket region.

Hosts: Cattle

Species description: Adult worms cause nodular swellings in the skin but infected ani-

mals are not clinically ill. Infected carcasses must be trimmed to remove the nodules. The adults lie in groups or "worm nests" in the subcutaneous tissue and a nodule is formed around them. The worm nests may be up to 5 cm in diameter. There is a fibrous capsule around the nodules which becomes thicker as the nodule ages. This capsule may eventually become calcified. The males are 30–53 mm and the females 140–190 mm long (sometimes up to 500 mm). The tail of the male is curved and it bears lateral alae and 6–9 papillae on either side. The spicules are unequal in size and measure 0.14–0.22 and 0.047–0.094 mm, respectively. The microfilariae are not sheathed and 240–280 µm long. The intermediate hosts are members of the genus *Culicoides* (e.g. *Culicoides pungens* and probably others).

Geographic distribution: Asia, Australia, southern Africa

Symptoms: The infections do not usually cause clinical signs. Nodules may be found at the predilection sites.

Significance: Infected carcasses may be trimmed or even condemned at slaughter.

Diagnosis: This is based on finding the adult worms in subcutaneous nodules or microfilariae in the skin of the brisket. Microfilariae are not evenly distributed in the skin, but occur in irregularly distributed "nests". A number of small skin biopsies (2 mm in diameter) may be placed in a drop of physiological saline solution for 1–2 hours. Microfilariae then migrate into the solution and can be examined.

Therapy: ☞ below *Onchocerca ochengi*

Prophylaxis: Unknown; insect repellents may reduce the attacks by the vectors.

Onchocerca ochengi (syn. *Onchocerca dermata)* "Intradermal onchocercosis of cattle"

Location: This species is found in subcutaneous and intradermal nodules on the ventral regions and flanks, primarily the udder and scrotum.

Hosts: Cattle

Species description: In endemic areas up to 50% of the cattle are infected. The intermediate host has not been identified yet but a biting insect is suspected. Small nodules occur deep in the hide. Microfilariae occur intradermally around the nodules. The microfilariae of *O. dukei* and *O. ochengi* are concentrated in the skin of the posterior and anterior belly.

Geographic distribution: East and West Africa

Symptoms: Intradermal nodules may be formed mainly in the abdominal region, on the udder and scrotum and sometimes in other parts of the body. Microfilariae can cause allergic reactions and local hyperkeratosis.

Significance: The value of leather, which is often perforated by these nodules, is markedly decreased by this parasite.

Diagnosis: Intradermal nodules can be detected by palpation. At slaughter they are visible on the internal surface of the hide.

Therapy: This is generally not indicated. However, the microfilariae may be killed by diethylcarbamazine (5–8 mg/kg, po. during 3 weeks), ivermectin (200 µg/kg, sc.), but also levamisole at increased dosage rates.

Prophylaxis: Unknown; insect repellents may reduce the attacks by the vectors.

(Figures 159, 190)

Fig. 190 *Onchocerca ochengi*; skin nodules [23]

Dipetalonema dermicola and *Dipetalonema ruandae*

Remarks: These filariid worms are rarely found in cattle. The former occurs in the skin and the latter in the connective tissue of the oesophagus. They are non-pathogenic and the life cycle is unknown.

Setaria labiatopapillosa Bovine abdominal filariosis

Remarks: Microfilariae of this filariid worm which occurs in the abdominal cavity of cattle (☞ CATTLE, ■ 4.4) may occasionally be found in the skin. The microfilariae are sheathed, measure 240–260 µm and appear usually in the peripheral blood. Several species of mosquitoes act as vectors (*Aedes* spp., *Culex* spp. and *Anopheles gambiae* and other *Anopheles* spp.).

Stephanofilaria spp. (*S. stilesi, S. assamensis* and other *Stephanofilaria* spp.)

Remarks: *Stephanofilaria* spp. are small filarial parasites responsible for circumscribed dermatitis. *S. stilesi* causes a dermatitis along the ventral midline (between the brisket and the navel) of cattle. Adult worms are 3–6 mm long and usually found in the dermis, just beneath the epidermal layer. Microfilariae are 50 µm long and are enclosed in a spherical, semi-rigid vitelline membrane. The intermediate host for *S. stilesi* is the female horn fly *Haematobia irritans* and a *Musca* sp. for *S. assamensis*. The infective larvae are introduced into the skin as the horn fly feeds. For diagnosis, deep skin scrapings are macerated in isotonic saline and examined microscopically for adults and microfilariae must be differentiated from the microfilariae of *Onchocerca* spp. and *Setaria* spp. which are much larger (200–250 µm). No effective treatment is known yet for *S. stilesi*, but topical application of organophosphates (trichlorfon, 6–10%, daily for 7 days) have proved effective against other species of *Stephanofilaria*. Ivermectin (200 µg/kg, sc.) is effective against adult worms of *S. assamensis*.
(Figure 191)

Fig. 191 *Stephanofilaria* sp., circumscribed dermatitis on the udder [15]

ARTHROPODS

Arthropods are divided into two main groups:

Arachnida
- *Ticks*
- *Mites*

Insecta
- *Lice*
- *Fleas*
- *Dipterida*

• Arachnida found in/on the skin

– Ticks
(Figure 192)

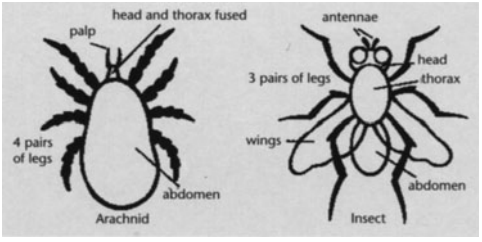


Fig. 192 Principle differences in the morphology of arachnids and insects [6]

Ticks may impair cattle health in 3 different ways:

- **Direct noxious effects**

Attachment to the host causes irritation of the skin with subsequent ulceration and secondary infections. The wounds are attracted by screwworms and other flies and myiasis may develop. Heavy infestations are associated with anaemia, since adult female ticks imbibe up to 10 ml of blood. Furthermore the presence of large numbers causes annoyance and animals become anxious and restless which may be a cause of loss of weight and condition. The life cycle of ticks may involve one, two or three hosts (Figures 193, 194, 195, 196).

In cattle the following ticks have a direct noxious effect:

Fig. 193 Skin wounds: noxious effects of tick infestation

IXODIDAE ("hard ticks")

Amblyomma spp. *(A. variegatum, A. hebraeum)*
Boophilus spp. *(B. decoloratus, B. microplus)*
Dermacentor spp.
Haemaphysalis spp.
Hyalomma spp.
Ixodes spp.
Rhipicephalus spp. *(R. appendiculatus, R. sanguineus, R. evertsi, R. parvus, R. pulchellus, R. sinus)*

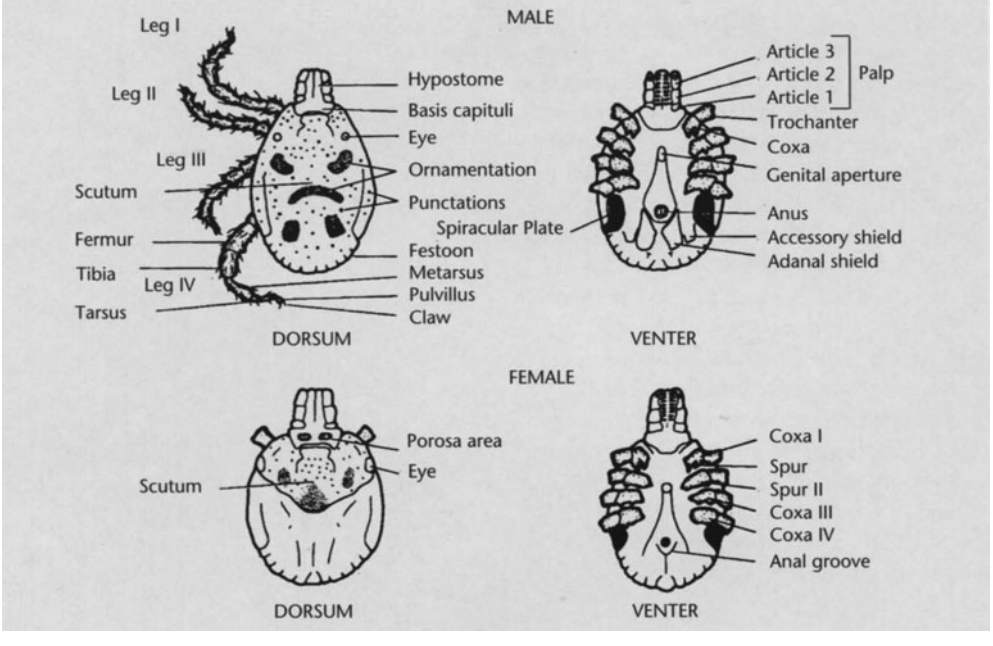


Fig. 194 Characteristics of hard ticks (Ixodidae) [24]

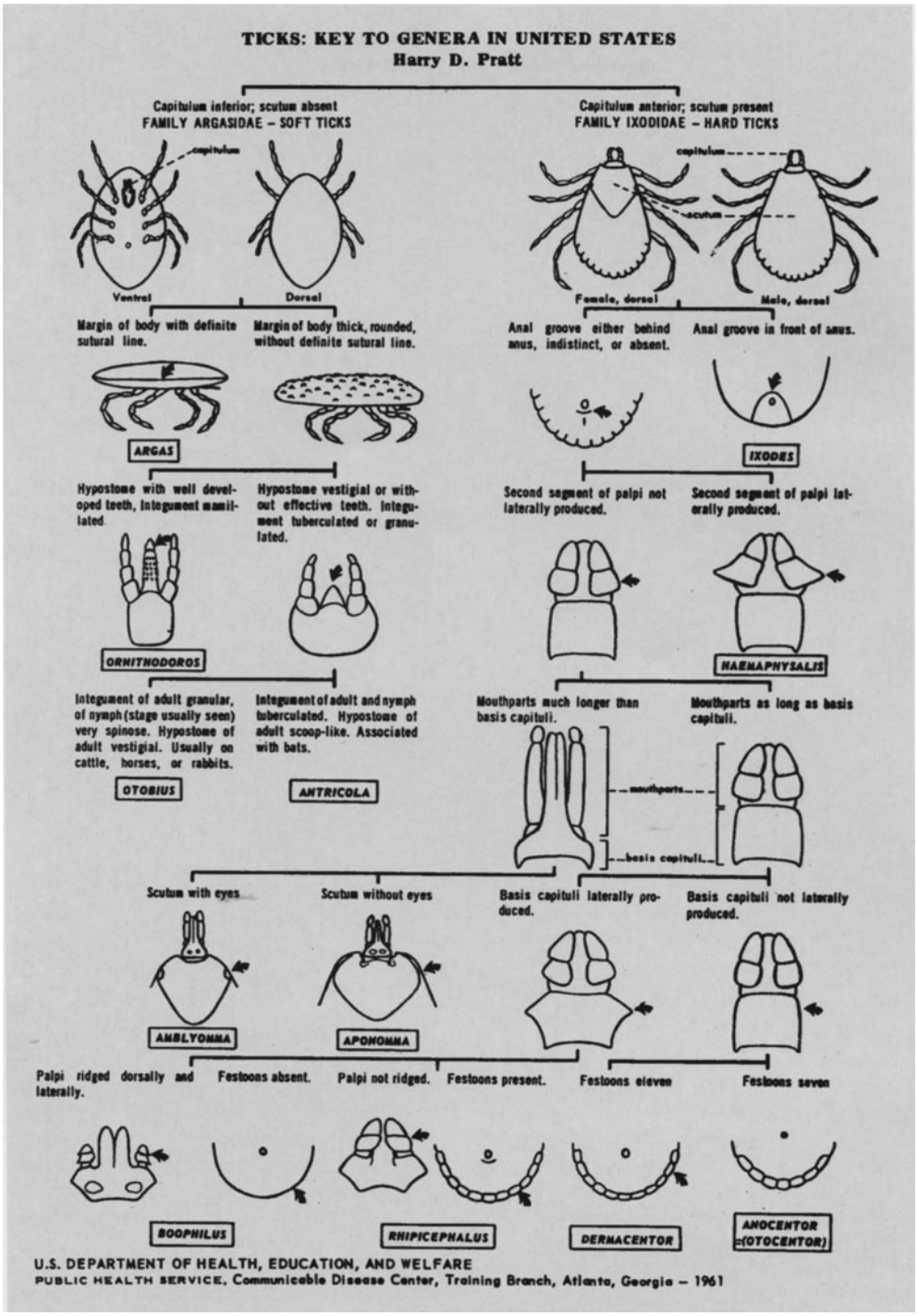


Fig. 195 Key for the identification of tick genera [25]

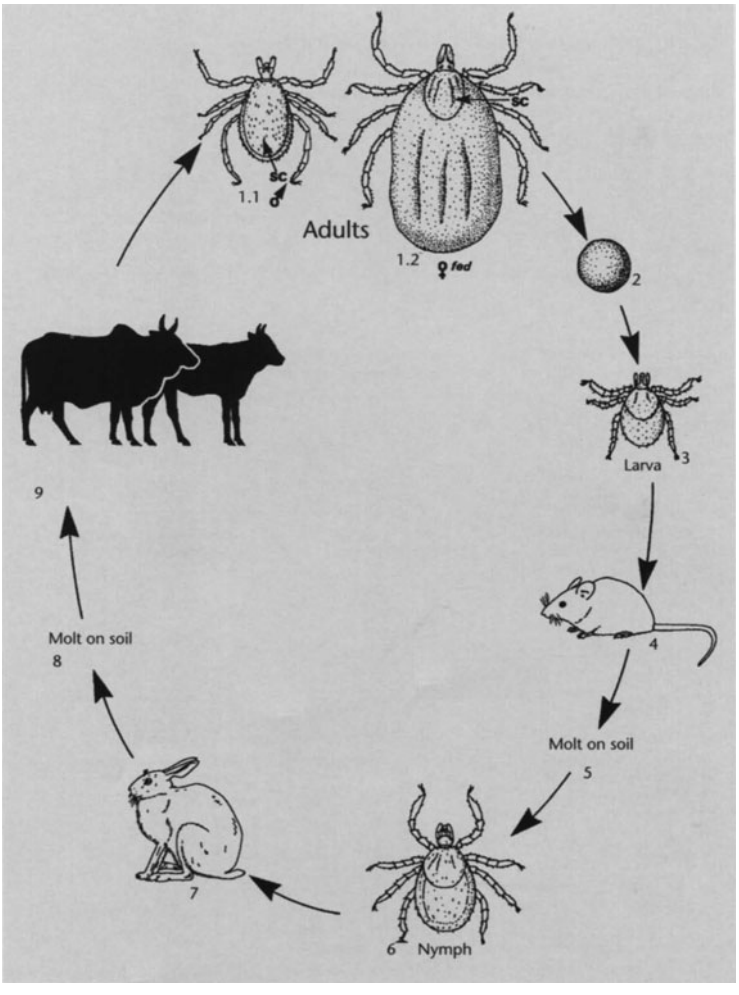


Fig. 196
Life cycle of a three-host tick (*Ixodes ricinus*)
1.1 and 1.2: Eyeless adults on their hosts; fed females (1.2) reach a length of up to 1.5 cm. Their scutum (SC) then appears small. Copulation occurs while the females feed; they then drop down to the soil;
2: Over a period of 1 month females lay about 2000 spherical to ovoid eggs, which become attached to each other and thus appear as clusters on the soil;
3 and 4: Larvae hatch from the eggs after 3–36 weeks (depending on the temperature) and creep onto the tops of grass, from where they attach to passing hosts (mostly small mammals, but also humans);
5 and 6: Fed larvae drop to the soil, and moult within 5–7 weeks (sometimes up to 5 months) to become eight-legged nymphs;
7 and 8: The nymphs attack larger mammals, suck blood for 2–7 days and drop to the soil, where they moult within 2–8 months and become sexually mature adults (1.1 and 1.2);
9: Mostly in spring the adults attack larger mammals including a variety of domestic animals and man, where especially females suck for 5–14 days. The whole development is temperature-dependent and in Europe needs about 3 years [26]

ARGASIDAE ("soft ticks")
– ***Otobius megnini*** Spinose ear tick
(Figures 197, 198)

- **Transmission of diseases**

One of the most damaging effects of ticks is their ability to transmit diseases to their hosts. Some of these are serious with fatal consequences. Transovarian transmission from one tick generation to another via the eggs is possible and contributes to spreading the disease.

The following pathogens are transmitted by ticks:

Babesia bovis Redwater, tropical bovine babesiosis

Remarks: This is transmitted by *Boophilus microplus*, the pantropical blue tick (☞ CATTLE, ■ 2).

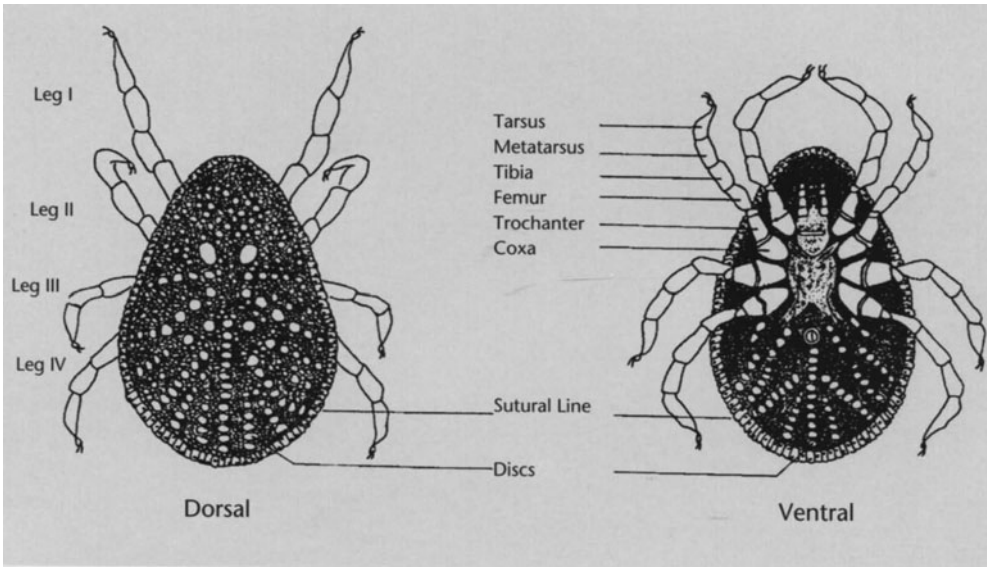


Fig. 197 Characteristics of soft ticks (Argasidae, *Argas* sp.) [26]

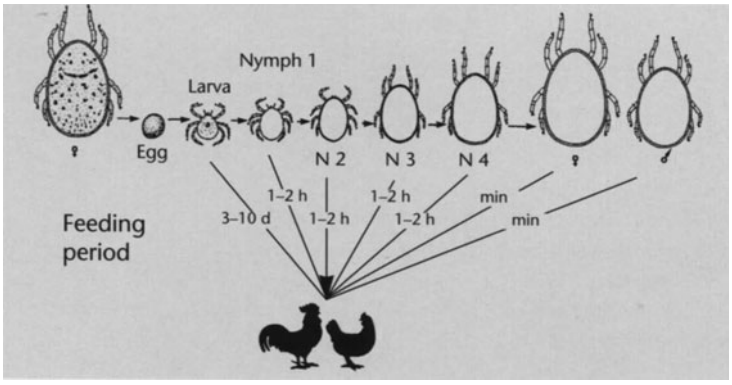


Fig. 198 Example of a typical argasid life cycle; development stages of *Argas* sp., which need about 3–36 months to mature (depending on the temperature); except for larvae, which suck blood for 3–10 days, all stages feed several times but only for a few minutes each time [24]

Babesia divergens
European bovine babesiosis

Remarks: *B. divergensis* transmitted by *Ixodes ricinus* (☞ CATTLE, ■ 2).

Babesia bigemina (syn. *Piroplasma bigeminum*) Redwater, tropical bovine piroplasmosis, tick fever, "Texas fever"

Remarks: This parasite is transmitted by *Boophilus microplus; B. decoloratus* (the common blue tick), *B. calcaratus, Rhipicephalus* spp. (*Rh. evertsi, Rh. bursa, Rh. appendiculatus*) and *Haemaphysalis* spp. (*H. punctata*) (☞ CATTLE, ■ 2).

Babesia major (syn. *Piroplasma major*)
European bovine piroplasmosis

Remarks: *B. majoris* transmitted by *Haemaphysalis punctata* (☞ CATTLE, ■ 2).

Cowdria ruminantium
Heartwater, Tyewde

Hosts: Cattle, sheep, goat and other ruminants

Remarks: This parasite is transmitted by several species of the tick genus *Amblyomma*, particularly by *Amblyomma variegatum* (the tropical bont tick) and *A. hebraeum* (the South African bont tick). Other species which may be involved are *A. gemma, A. pomposum, A. lepidum* and *A. tholloni* (☞ CATTLE, ■ 2).

Theileria parva (syn. *T. bovis, T. lawrencei*)
East Coast Fever, bovine theileriosis, Corridor disease, Rhodesian tick fever

Remarks: This parasite is transmitted by *Rhipicephalus appendiculatus* (the brown ear tick) and *Rhipicephalus evertsi* (the red-legged tick) and *Rhipicephalus duttoni*. Other vectors are *Hyalomma excavatum, H. dromedarii, H. truncatum* and some other *Rhipicephalus* spp. (☞ CATTLE, ■ 2).

Theileria annulata Mediterranean Coast Fever, Tropical theileriosis, Egyptian Fever

Remarks: This parasite is transmitted by *Hyalomma detritum, H. truncatum* and *H. anatolicum* (☞ CATTLE, ■ 2).

Theileria mutans Benign bovine theileriosis, mild gallsickness

Remarks: This parasite is transmitted by *Amblyomma variegatum, A. hebraeum* and possibly also by *Rhipicephalus appendiculatus* and *R. evertsi* (☞ CATTLE, ■ 2).

Anaplasma marginale Malignant anaplasmosis of cattle, gallsickness

Remarks: This parasite is transmitted by *Boophilus decoloratus* and *B. microplus* (☞ CATTLE, ■ 2).

Anaplasma centrale Mild anaplasmosis of cattle, gallsickness

Remarks: This parasite is transmitted by *Boophilus decoloratus* (☞ CATTLE, ■ 2).

Eperythrozoon wenyoni

Remarks: This parasite is transmitted by *Hyalomma anatolicum*. The pathogen occurs on the erythrocyte surface (☞ CATTLE, ■ 2).

Ehrlichia bovis Tropical bovine ehrlichiosis, "Nofel" or "Nopel"

Remarks: This parasite is transmitted by tick species of the genera *Amblyomma, Hyalomma* and *Rhipicephalus* (☞ CATTLE, ■ 2).

Ehrlichia phagocytophila
European ehrlichiosis

Remarks: This parasite is transmitted by *Ixodes ricinus* (☞ CATTLE, ■ 2).

Ehrlichia ondiri

Remarks: This parasite occurs in granulocytes of cattle in high altitude grassland areas of East Africa. The exact vector is unknown but ticks of the genus *Haemaphysalis* are suspected (☞ CATTLE, ■ 2).

Borrelia theileri Tick Spirochaetosis

Remarks: This is transmitted by *Boophilus decoloratus* and *Rhipicephalus evertsi*. Tick spirochaetosis occurs in cattle, sheep, goats and horses.

- **Tick toxicosis**

Tick paralysis

43 tick species belonging to 10 genera are known to induce tick paralysis in man and a variety of mammals. These ticks are capable of releasing a toxin into the host which causes a condition associated with progressive, ascending, afebrile, symmetrical paralysis, with hind legs being affected first followed by the forelegs.

Fig. 199 *Rhipicephalus evertsi*; the red-legged tick, an important cause of tick paralysis [10]

Animals may die. Paralysis is relieved if ticks are removed in time. Most domestic animal species appear to be susceptible to tick paralysis.
Lambs and calves and to a lesser extent adult cattle are susceptible to tick paralysis. *Ixodes rubicundus* (the karoo paralysis tick) mainly affects sheep and goats in South Africa and *Rhipicephalus evertsi* causes the "spring lamb paralysis" in lambs but also in calves.
(Figure 199)

Sweating sickness

An acute, febrile tick-borne toxicosis characterised by a profuse, moist eczema and hyperaemia of the skin and visible mucous membranes. Watering of the eyes and nose, salivation and a extremely sensitive skin with a sour odour are other typical signs. Eventually the skin becomes cracked and predisposed to secondary infections (incl. screw-worm infections and myiasis). Often the course is acute and death may occur within a few days. In less acute cases recovery may occur.
It is mainly a disease of young calves but also sheep in eastern, central and southern Africa. The causative agents are certain strains of *Hyalomma truncatum* which produce an epitheliotropic toxin. Calf mortality may reach 70%.

Symptoms: Generalized hyperaemia with subsequent desquamation of the superficial layers of the mucous membranes of the upper respiratory, gastrointestinal and external genital tracts and profuse moist dermatitis. For diagnosis it is essential to determine the presence of the vector. Clinical signs appear 4–11 days after the tick bite.

Therapy: Ticks must be removed quickly. Antibiotics and anti-inflammatory agents are useful to combat secondary infections. Immune serum may be used.

Prophylaxis: Control of tick infestations is the only effective measure. Removal of ticks, symptomatic treatment and good nursing are indicated.
(Figures 200, 201)

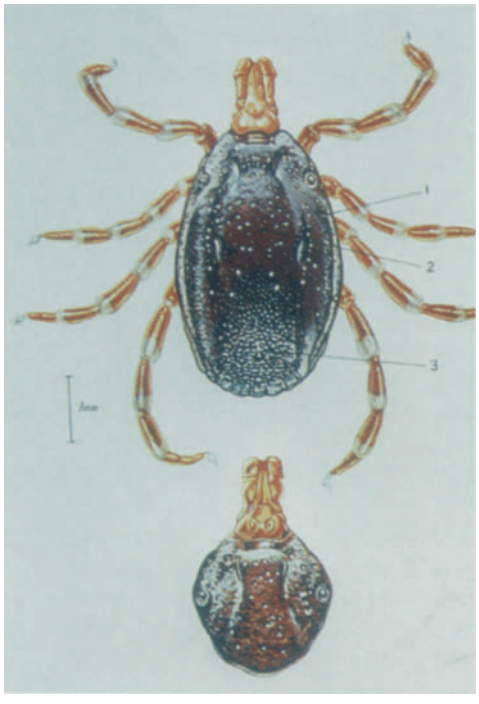


Fig. 200 *Hyalomma truncatum*; an important cause of sweating sickness; (1) marginal groove, (2) scutum and (3) pronounced punctuation [4]

Fig. 201 Sweating sickness, an acute, febrile tick-borne toxicosis characterised by a profuse, moist eczema and hyperaemia of the skin. This condition is often caused by *Hyalomma truncatum* [4]

General toxicosis

Tick toxicosis is a general aggravation of the toxic effect of the parasite's saliva. Certain toxins have a suppressive effect on the animals and occasionally this may reactivate chronic infections. Infections with *Babesia* spp. and *Anaplasma* spp. may occur during massive *Rhipicephalus appendiculatus* infestations. Toxicosis, associated with general disorders, occurs with *Ornithodoros savignyi* (sand tampan) in young calves and lambs, especially when there are many bites. Animals show cutaneous oedema, haemorrhage, rapidly progressing weakness and prostration. Death can occur within 6 hours. Toxicosis may occur in recumbent animals, during rest.
(Figure 202)

Fig. 202 *Rhipicephalus appendiculatus* (the brown ear tick); an important cause of tick toxicosis [10]

- **Description of ticks affecting cattle**

IXODIDAE ("hard ticks")

***Amblyomma* spp.**

Hosts: All domestic livestock species
Species description: 3-host ticks. *Amblyomma*

spp. are large ticks and have ornate (patterned) upper body surfaces. Festoons (= rectangular division of the rear body edge) are present. *Amblyomma* ticks have long, prominent mouth parts, easily distinguished from the short mouth parts of *Dermacentor*. *Amblyomma variegatum* (the tropical bont tick) is the vector of heartwater and produces skin wounds with its large mouth parts. These wounds may become secondarily infected and may develop into abscesses. Tick paralysis may also occur due to the bont tick. The bont tick occurs mainly on the perineum, udder and in the axillae and inguinal areas. Some *Amblyomma* species, notably *Amblyomma hebraeum* (the South African bont tick) are often resistant to chemicals now in use.

Geographic distribution: *Amblyomma* spp. occur in central and southern Africa and many other parts of the world.

(Figures 203, 204, 205, 206, 207)

Fig. 203 *Amblyomma variegatum*; female [13]

Fig. 205 *Amblyomma variegatum*; male [13]

Fig. 204 *Amblyomma hebraeum*; female [13]

Fig. 206 *Amblyomma hebraeum*; male with bright festoons [13]

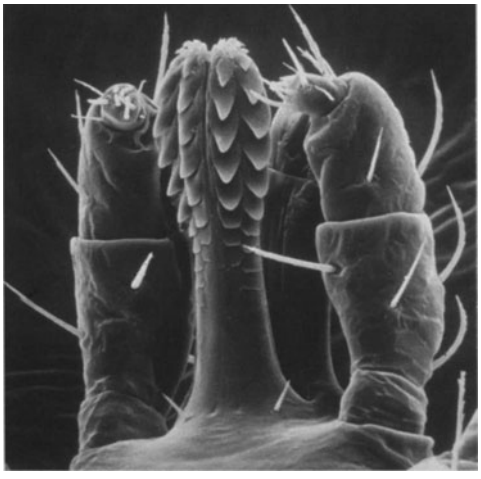


Fig. 207
Amblyomma variegatum; chelicera and palpes

***Boophilus* spp.** Cattle fever tick, tropical cattle tick

Hosts: Horse and cattle

Species description: 1-host ticks. *Boophilus* spp. are plain brown in colour. They are inornate with eyes. Males are small (3–4 mm) and fully engorged females may be up to 12 mm in length. Members of *Boophilus* transmit several diseases and cause skin irritation which leads to licking and scratching and to secondary bacterial infections. Large numbers may cause anaemia. 1-host ticks such as *Boophilus* spp. are often the first to develop resistance to chemicals. Therefore control measures have to be changed frequently. *Boophilus decoloratus* (the blue tick) is one of the most important species of this genus and is found mainly on the neck, thorax, back and udder.

Geographic distribution: Throughout the world in warm climates

(Figure 208)

Fig. 208 *Boophilus* sp.; engorged female (up to 2 cm in diameter) [10]

***Dermacentor* spp.**

Hosts: Many wild and domestic mammals

Species description: Some species are 1-host ticks while others are 3-host ticks. *Dermacentor* ticks have ornate (patterned) upper body surfaces. Festoons are present. The mouth parts are short.

Geographic distribution: Asia, Europe, North and South America and some parts of Africa; *Dermacentor* may damage their hosts by transmitting diseases (e.g. Q fever, tularemia), causing tick worry and anaemia.

(Figure 209)

Fig. 209 *Dermacentor marginatus*; male [4]

***Haemaphysalis* spp.**

Hosts: Dogs, birds and in Africa to a lesser extent cattle

Species description: 3-host ticks which are

small, inornate without eyes. Festoons are present. They may be found on the skin on all parts of the body. In addition to annoying cattle they may transmit cattle tick fever, anaplasmosis, and Q fever. They may also produce paralysis and anaemia in heavy infestations.

Geographic distribution: World-wide

(Figure 210)

Fig. 210 *Haemaphysalis punctata*; female [4]

Hyalomma spp. The bont-legged tick

Hosts: Horse, domestic ruminants and camel

Species description: Usually 2-host ticks, although three hosts may be used by some species. Inornate (sometimes ornate) eyes are present and festoons may be absent or present. Hypostome and palps are long. *Hyalomma truncatum* causes sweating sickness. Predilection sites are the distal parts of the legs, udder, tip of the tail and perianal region.

Geographic distribution: *Hyalomma* spp. occur in many parts of Africa, depending on the particular species.

(Figure 200)

Ixodes spp. *Paralysis ticks*

Hosts: Cattle, horse and many other animal species

Species description: 3-host tick. *Ixodes* ticks are plain brown in colour and the only eyeless species. The paralysis tick (*Ixodes rubicundus*) has a 2-year life cycle with specific requirements of temperature and humidity. *Ixodes* spp. are found anywhere on the skin of their host. *I. rubicundus* prefers lower parts of legs and abdomen. *Ixodes* spp. are a primary cause of tick paralysis in sheep and goats but they may also transmit diseases.

Geographic distribution: Europe, North America, South Africa

(Figures 211, 212)

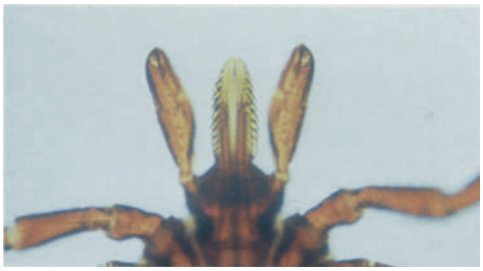


Fig. 211 *Ixodes ricinus*; mouth parts [4]

Fig. 212 *Ixodes ricinus*; female (large) and male (small) [4]

Rhipicephalus spp.

Hosts: Cattle, sheep and goat and many other animal species

Species description: 2- or 3-host ticks; festoons are present. *Rhipicephalus appendicula-*

tus (the brown ear tick) is a 3-host tick, plain brown in colour and occurs in the ears of the host. It is the chief vector of ECF and other diseases. Brown ear ticks are impossible to control by pasture rotation because they can survive up to 2 years on the pasture without feeding and they can feed on a large number of different species of wild and domestic animals.

Rhipicephalus evertsi (the red-legged tick) is a 2-host tick and has red legs. The adults typically occur around the anus and the nymphae are found deep in the ears. The red-legged tick is known to develop resistance to acaricidal drugs very quickly. It transmits ECF and other diseases.

Geographic distribution: Africa south of the equator

(Figures 199, 202, 213)

Fig. 213 *Rhipicephalus appendiculatus*; male (small) and egg excreting female (1 cm in diameter) [8]

ARGASIDAE ("soft ticks")

Otobius megnini Spinose ear tick

Location: Larvae and nymphae feed deep in the external ear canal. Adults are non-parasitic and live on the ground.

Hosts: Horse, donkey, mule, cattle, sheep, goat

Species description: 1-host tick. Free-living adult females lay eggs on the ground which hatch within 3 weeks. Larvae and nymphs live and feed on one host for up to 7 months. Infestations of this species usually build up in kraals and stables, where the host densities are high. *O. megnini* can persist in empty kraals and stables for more than 2 years.

Geographic distribution: Arid and semi-arid areas of South and South West Africa

Symptoms: Infested animals shake their heads. Loss of appetite, debilitation and anaemia may be present. Irritation in the ear associated with secondary infections (incl. myiasis) may dominate the clinical picture. Ulceration (ear canker) may occur and ticks may clog the ears, causing deafness. Waxy and oily material is discharged from the ear. Larvae and nymphs may sometimes be seen in masses. Infested animals hold their head to one side and feeding is impaired. Weight loss may occur.

Significance: Heavy infestations cause otitis externa, great annoyance and blood loss. *O. megnini* may cause severe problems in livestock in many parts of Africa.

Diagnosis: Ticks may be found by swabbing the ear or by direct inspection of heavily infected ears. Larvae and nymphs are found inside the ear. The adult ticks are difficult to find as they breed in hidden cracks of barns, fences and trees.

(Figures 214, 215)

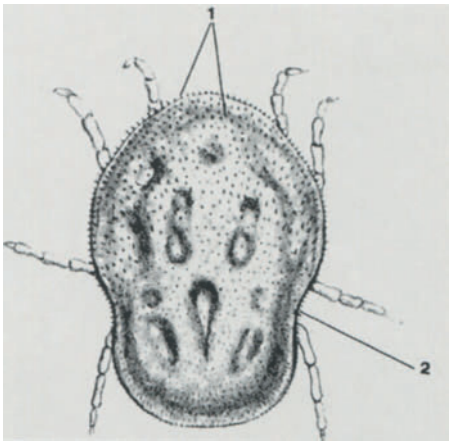


Fig. 214 *Otobius megnini* (the spinose ear tick); nymph (3–8 mm long): (1) integument covered with short, sharp spines and (2) posterior part of the body constricted [27]

Fig. 215 *Otobius megnini*; nymphs (up to 8 mm long) [6]

Ornithodoros savignyi The sand tampan

Remarks: This tick may be a serious pest of cattle. It may cause death in calves and tick toxicosis in adult cattle (☞ SHEEP AND GOATS, ■ 5.1).

- **Tick control in cattle**
  ☞ THERAPY AND PROPHYLAXIS OF ECTOPARASITES, p. 141

– Mites

(Figures 216, 217)

Chorioptes bovis Chorioptic mite, foot mange, leg mite

Location: On the legs, base of tail and upper rear surface of the udder

Hosts: Cattle

Species description: The tarsal suckers have unjointed and short pedicels. Typical mite life cycle. Chorioptic mange feed on skin debris and lymph.

Geographic distribution: World-wide

Symptoms: Scabs or scales develop on the skin of the lower parts of the body. There is some exudation and crust formation on the lower body and legs, but this does not spread over a wide area. Cattle may stamp and scratch infected areas.

Significance: The disease is not as serious as sarcoptic or psoroptic mange but it is very prevalent.

Diagnosis: Demonstration of mites in skin scrapings taken from the edge of the lesions (☞ METHODS, 4.1).

Therapy: These mites are superficial and are therefore not very sensitive to Ivermectin (200 µg/kg, sc.) but it may be an aid in controlling the foot mange. Dips and sprays may be used (☞ below *Psoroptes ovis*). Ivermectin applied topically (500 µg/kg)

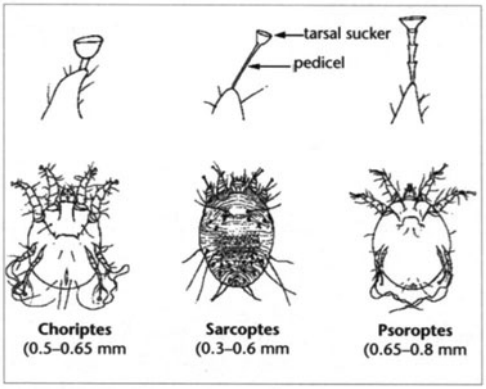


Fig. 216 *Chorioptes*, *Sarcoptes* and *Psoroptes* mites with genus-specific morphology of pedicels and tarsal suckers (schematic)

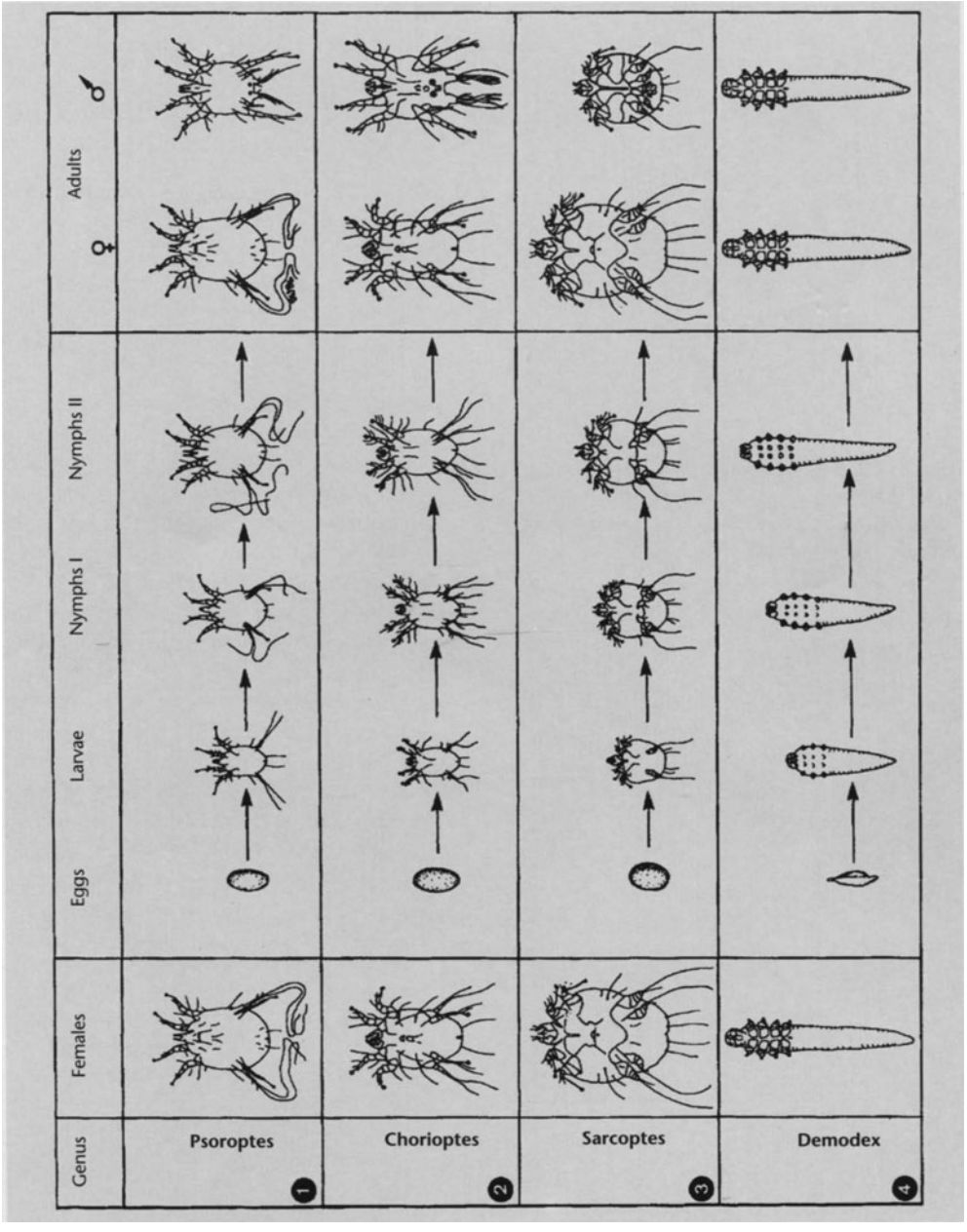


Fig. 217 Developmental stages in the life cycle of important groups of mites. All stages live on/in the skin of their hosts. Larvae have only three pairs of legs. Feeding larvae and nymphs increase in size and moult. In some species there is clear sexual dimorphism; (1) *Psoroptes* spp. feed (as piercing mites) on the lymph fluid and occasionally on the blood of their hosts, (2) *Chorioptes* spp. feed (as chewing mites) on the epidermal products, (3) *Sarcoptes* spp. penetrate the epidermis, forming canals and (4) *Demodex* spp. feed on hair follicles or on sebaceous glands [26]

is effective against chorioptic mange. Crotoxyphos (0.25%) applied as a spray can also be used against the leg mite.

Prophylaxis: ☞ below *Psoroptes ovis* (Figures 218, 219)

Fig. 218 *Chorioptes bovis*, adult female (max. 650 µm long) with short, unjointed pedicels [4]

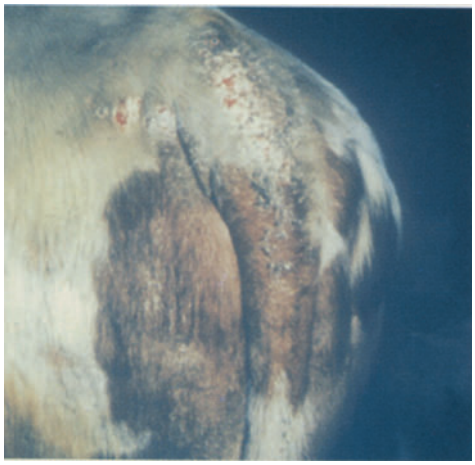


Fig. 219 *Chorioptes bovis* infestation [4]

Sarcoptes bovis Itch mite, mange mite

Location: Neck, the back in front of the tail, inner surface of the thighs and the udder and sometimes the whole body surface

Hosts: Cattle

Species description: This is a minute parasite in outline. The tarsal suckers have unjointed and long pedicels. Females have a number of spines on the upper surface. The life cycle is typical for mites, the entire period of development is spent on the host. (☞ SWINE, ■ 5.1) The mange may occur very seasonally in temperate zones (late winter). *Sarcoptes* mites prefer areas of thin hair but the lesions may spread to other parts. *Sarcoptes* mites puncture the skin to feed on lymph and skin debris.

Geographic distribution: World-wide

Symptoms: Intense itching is caused by irritation. Animals scratch which may result in dermatitis, accompanied by an exudate that coagulates and dries to form crusts. The skin is thickened, wrinkled and hair is lost.

Significance: Irritation to the host causes weight loss and emaciation. Skins of carcasses are of poor quality. Animals in poor condition due to mite attacks are subject to other diseases.

Diagnosis: Demonstration of mites of deep skin scrapings taken from the edge of the lesions (☞ METHODS, 4.1). *Sarcoptes* mites are usually found deep in the skin whereas *Psoroptes* mites are more superficial.

Therapy: This mite is very sensitive to Ivermectin (200 µg/kg, sc.). After one treatment no living mites were recovered. Dips and sprays may also be used to reduce the clinical effects (☞ below *Psoroptes ovis*).

Prophylaxis: ☞ below *Psoroptes ovis* (Figures 220, 221)

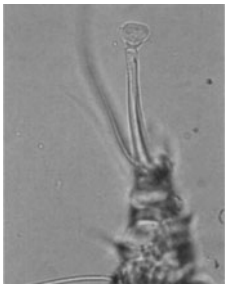


Fig. 220 *Sarcoptes* sp.; mite with unjointed, long pedicels (30–35 µm long) [4]

Fig. 221 *Sarcoptes* sp. infestation of a cattle [4]

Psorpotes ovis (syn. *Psoroptes communis var. bovis)* Psoroptic mite

Location: Any part of the body, especially areas of dense hair such as withers, back and root of tail

Hosts: Cattle, sheep

Species description: The mites are oval in shape and the tarsal suckers have long, jointed pedicels. Typical mite life cycle, taking 9 days. This is a notifiable and quarantinable disease in many parts of the world.

Geographic distribution: World-wide

Symptoms: Affected skin is covered with exudate. This dries to form a scab. Massive loss of hair usually occurs. Lesions may cover the entire body. Deaths in untreated calves are not uncommon. The course may be acute in young calves and chronic nature may also be found. The prognosis is usually favourable following early treatment.

Significance: Psoroptic mange is a widespread and serious disease of cattle. Infested animals lose weight and the skins are of lower quality.

Diagnosis: Demonstration of mites in skin scrapings taken from the edge of the lesions (☞ METHODS, 4.1).

Therapy: Infested cattle should be dipped, not sprayed. The following compounds may be used for dips: toxaphene (0.5–0.6%), coumaphos (0.3%), phosmet (0.2–0.25%), diazinon (0.025%), flumethrine (1 l of a 6% solution in 1500 l of water) and many other compounds. Depending on the product, repeated treatments are required (label instructions should be checked). Ivermectin (200 µg/kg, sc.) is effective against *Psoroptes ovis*. One treatment resulted in clinical healing, but a second treatment is indicated in eradication programs.

Prophylaxis: Newly introduced animals are the main source of infection for a herd. These animals must be checked carefully and possibly treated before being introduced into the new herd. A quarantine may be indicated.

(Figures 222, 223, 224)

Fig. 222 *Psoroptes* sp. female mite (max. 800 µm long) with egg [4]

Fig. 223 *Psoroptes* sp.; mite, jointed, long pedicels (68 µm long) [4]

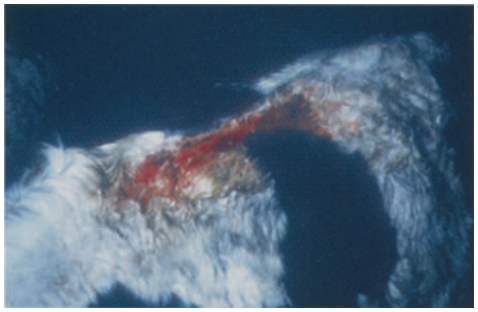


Fig. 224 *Psoroptes* sp. infestation of a cattle [4]

Demodex bovis
Demodectic or follicular mite

Location: Neck, brisket, shoulder, face
Hosts: Cattle
Species description: *Demodex* mites are cigar-shaped, elongated mites, about 0.25 mm long. The thorax bears 4 pairs of stout, short legs and the abdomen is transversely striated. The life cycle is not clearly understood. *Demodex* is transmitted from the cow to the calf while nursing and may cause considerable damage to hides. Lesions are pronounced in young dairy cattle but are rarely visible or palpable on beef cattle. Rarely the lesions may appear over the entire body.
Geographic distribution: World-wide
Symptoms: Small papules and nodules may be seen. They are red and thick and a waxy, white material can be expressed from them. This material contains numerous mites. Nodules may also be filled with pus and abscesses covered with small scales may be seen. The course of bovine demodectic mite infection is usually mild but may extend over many months.
Significance: Damage to skin may affect the production of leather. Demodectic mange is not considered to be a major parasite of cattle but it may open the skin for secondary problems (bacterial and fungal infections, myiasis, etc.).
Diagnosis: Microscopical examination of the cheesy, waxy fluid from the nodules which may contain many mites. Long-standing nodules of the skin are characteristic.
Therapy: There is no satisfactory treatment. Systemic and topical applications of chemical compounds have given some relief.
Prophylaxis: Unknown
(Figures 225, 226)

Fig. 225 Cigar-shaped *Demodex bovis* mite, (250–400 × 70 µm)

Fig. 226 *Demodex bovis* causing multiple skin nodules [8]

Psoregates bos Itch mites of cattle, "Australian itch"

Remarks: Itch mites occur in Canada, Australia and South Africa. These mites are minuscule (189 × 189 µm) and difficult to collect. They are spherical and have paired claws and legs which are arranged radially. Alopecia and desquamation occur, but the lesions lack the scab formation associated with mange mite infestations. Lime-sulfur spray or dip applied twice, with a 2-week interval, is indicated to be the acaricide of choice.
(Figure 227)

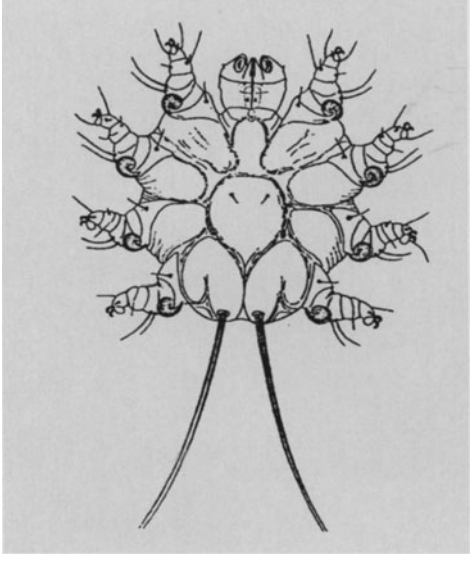


Fig. 227 *Psoregates* sp.; female mite [28]

Raillietia spp. (*R. auris* and *R. caprae*)

Location: Middle and inner ear
Hosts: Cattle, sheep (*R. auris*) and goat (*R. caprae*)
Species description: The mites feed on epidermal cells and wax but not on blood.
Geographic distribution: North America, Australia, East Africa, Europe.
Symptoms: Infestations are usually inapparent but otitis media and interna with nervous signs, including head shaking, head rotation to the affected side, circling, and general incoordination, can be found in a progressive stage of the infestation.
Significance: *Raillietia* spp. infections can cause signs similar to those of other CNS infections and should therefore be excluded.
Diagnosis: It is almost impossible to diagnose *Raillietia* spp. antemortem. Demonstration of the mites in the middle or inner ear at necropsy.
Therapy: Ivermectin may eliminate the mites. Acaricides, applied topically may also be effective.
Prophylaxis: Unknown
(Figures 228, 229)

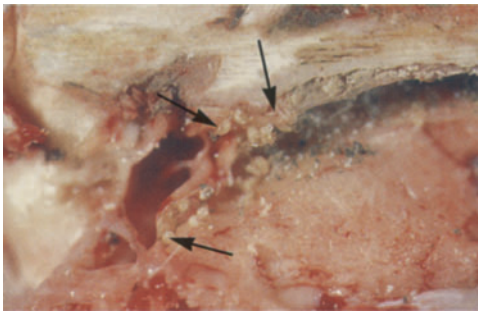


Fig. 228 *Raillietia auris* causing otitis media and interna

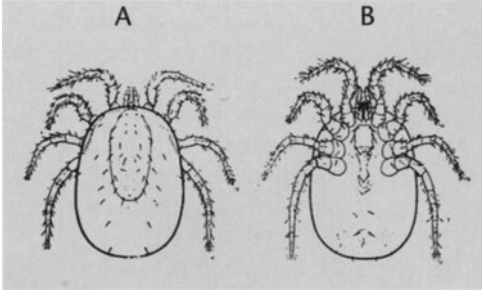


Fig. 229 *Raillietia auris*; dorsal view (A) and ventral view (B) [29]

• Insecta found on the skin

– Lice

(Figure 230)

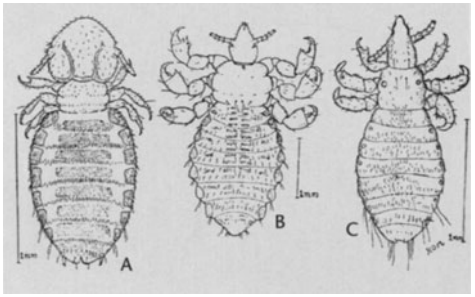


Fig. 230 Cattle lice: *Bovicola bovis* (A), *Haematopinus eurysternus* (B) and *Linognathus vituli* (C) [3]

MALLOPHAGA Chewing lice

Bovicola bovis *(syn. Damalinia bovis)*
Red louse, "chewing louse"

Location: Skin surface, especially the neck, withers and root of tail

Hosts: Cattle

Species description: These lice belong to the Mallophaga and are 1–2 mm long and wingless. They have a broad head with mouth parts adapted for chewing. The entire life is spent on the host. The infestations are heaviest in winter when the coats are dense.

Geographic distribution: World-wide, primarily in cooler areas

Symptoms: Intense itching associated with these lice may be observed. Animals show typical parasite worry (not feeding, not sleeping). Scratching may produce skin wounds or bruises and the coat becomes rough.

Significance: Biting lice are widespread and important parasites. Losses such as reduced growth and secondary skin infections due to intense itching may occur.

Diagnosis: Lice may be seen on skin. The eggs occur as white specks attached to the hairs.

Therapy: ☞ below THERAPY AND PROPHYLAXIS OF ECTOPARASITES

Prophylaxis: ☞ below THERAPY AND PROPHYLAXIS OF ECTOPARASITES, p. 141

(Figure 231)

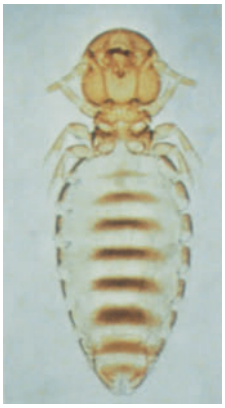


Fig. 231 *Bovicola bovis* (1.5–2 mm long); the cattle chewing louse [4]

ANOPLURA Blood sucking lice of cattle

Haematopinus eurysternus
Short-nosed cattle louse

Remarks: This species occurs world-wide. It is 3.4–4.8 mm long. The louse is fairly broad and the head is short.

(Figures 232, 233, 234)

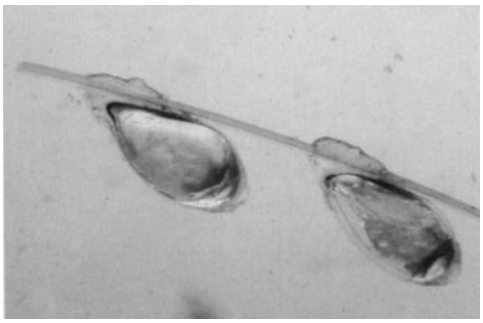


Fig. 232 *Haematopinus eurysternus;* eggs attached to the hair of a cattle

Fig. 233 *Haematopinus eurysternus* (3.4–4.8 mm long); the short-nosed cattle louse

Fig. 235 *Linognathus vituli* (up to 2.5 mm long); the long-nosed cattle sucking louse [4]

Fig. 234 *Haematopinus* sp.; on the skin of a cattle [15]

Haematopinus quadripertusus
Tail louse of cattle

Remarks: This species occurs on cattle in North America, Queensland, Papua-New Guinea and tropical Africa.

Haematopinus tuberculatus Buffalo louse

Remarks: This is a large species (up to 5.5 mm long) and occurs in Asia and the Pacific area. It also occurs on camels in Australia.

Linognathus vituli
Long-nosed cattle sucking louse

Remarks: This species has a long narrow head and a slender body. It is 2.5 mm in length. (Figure 235)

Solenopotes capillatus

Remarks: This is the smallest of the sucking lice of cattle and occurs in conspicuous clusters on the neck, head, shoulders, dewlap, back and tail. (Figure 236)

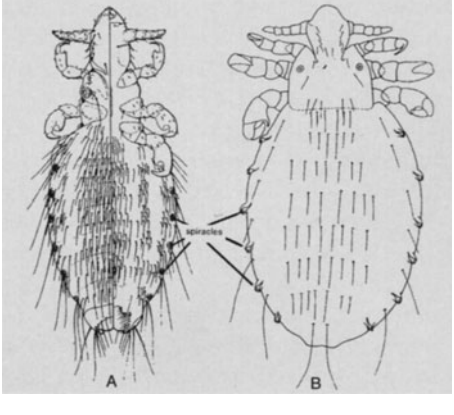


Fig. 236 (A) *Linognathus ovillus* (2.0– 2.5 mm) and (B) *Solenopotes capillatus* (1.3–1.7 mm) [29]

- **General features of blood sucking lice of cattle**

Location: These lice are often found on protected areas of the skin such as side of the neck, brisket, back, head and between the legs.

Hosts: Cattle

Species description: Wingless insects with long mouthparts adapted for sucking. The life cycle takes 1 month. Heavy infestations may occur in immunosuppressed animals (e.g. calves following trypanosome infections).

Geographic distribution: World-wide. Some species are restricted to certain regions.

Symptoms: Louse worry is characterized by licking, scratching and rubbing. The coat becomes rough and secondary infections may occur. Heavy infestations may cause anaemia. Such animals may be more susceptible to other infectious diseases and environmental stress.

Significance: These are common parasites of cattle which can cause severe problems if present in large numbers.

Diagnosis: Lice and their eggs may be found on the skin.

Therapy: A wide variety of insecticides and application modi may be employed. Dipping is being replaced by delivery systems such as "pour-on" and "low-volume spray" for pyrethroid insecticides. Low tolerance for insecticides in milk limits the insecticides that may be used on dairy cattle and goats. Effective compounds include crotoxyphos, crotoxyphos combined with dichlorvos, coumaphos, fenvalerate, stirofos, coumaphos, dioxathion, malathion, methoxychlor, phosmet and permethrin. Label instructions should be considered. Dipping and spraying provides excellent coverage, and usually two treatments 2 weeks apart will effectively control lice. Ivermectin (200 µg/kg, sc.) is effective against sucking lice.

Prophylaxis: This is difficult wherever direct contact between the animals of the herd is possible.

- **Fleas**

No fleas have been found on the body surface of cattle.

- **Dipterida**

CULICIDAE Mosquitoes

Aedes spp., *Anopheles* spp. and *Culex* spp.

Remarks: They belong like flies to the order Dipterida, with a single pair of wings. The main genera are *Anopheles, Culex* and *Aedes.*

They are slender with small spherical heads and large eyes. Both sexes live on fluids which are derived from organic sources, such as jus of fruits and vegetables. Females are capable to suck blood which appears to be necessary for the laying of eggs. Eggs are laid either on water or on vegetation floating on the surface of water. Therefore mosquitoes are found near stagnant pools. Because of their dependence on water their numbers generally become less during the dry season.

Significance: Mosquitoes can cause considerable distress to livestock but their main importance is their ability to act as intermediate hosts or vectors of viral (Rift Valley Fever, Equine encephalomyelitis, African Horse Sickness, Fowl pox, Blue tongue, Lumpy skin disease), bacterial (avian spirochaetosis), protozoan (Avian and human malaria) and filarial (*Setaria equina, Setaria labiatopapillosa*) and probably other diseases.

(Figures 237, 238, 239)

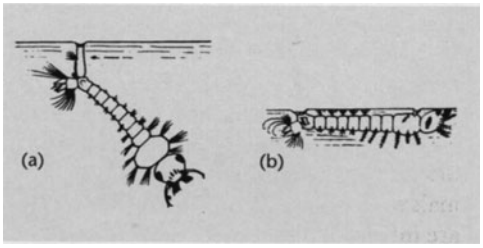


Fig. 237 *Culex* sp. larva (a) and *Anopheles* sp. larva (b) showing their feeding position in water

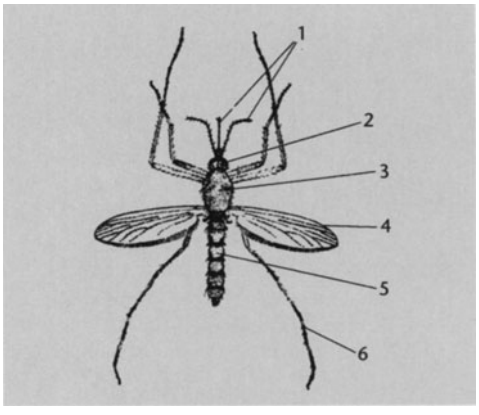


Fig. 238 Culicidae (schematic): adult mosquito with antennae and proboscis long (1), small head with large eyes (2), thorax (3), wings long and narrow (4), abdomen elongate (5) and legs long and slender (6) [27]

Fig. 239 *Culex* sp.; female in feeding position

SIMULIIDAE

Simulium spp. Black flies, midges

Remarks: Small size (1–5 mm), found in swarms near free-running well aerated streams. *Simulids* cause severe irritation to livestock when they occur in large numbers and herds and flock will stampede, often with disastrous results. Man, animals and poultry are liable to attack. Bites are inflicted on all parts of the body, giving rise to vesicles which burst exposing the underlying flesh. Skin wounds caused by simulids heal very slowly. Certain areas of the tropics are rendered uninhabitable by simulids.

Significance: Irritation of livestock; skin wounds with secondary infections and myiasis; transmission of *Onchocerca volvulus* in man

(Figures 240, 241, 242, 243, 244, 245)

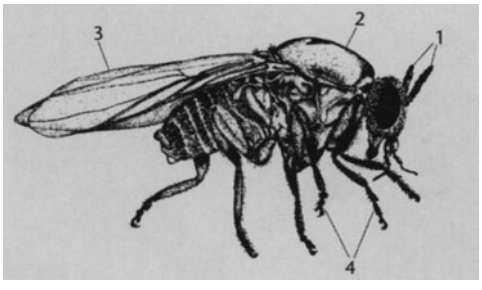


Fig. 240 *Simulium* sp. (blackfly) adult; (1) antennae short and horn-like, (2) humped thorax, (3) wings broad and clear and (4) legs short [27]

Fig. 241 *Simulium* sp., female (5 mm) [4]

Fig. 242 *Simulium* larvae develop in free-running, well-aerated streams [30]

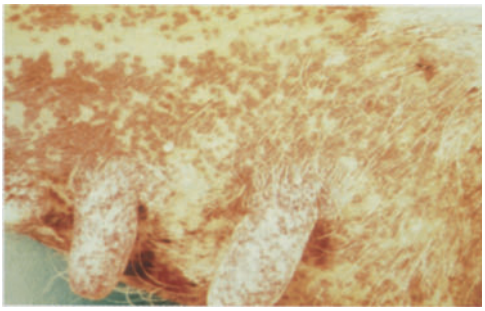


Fig. 244 Erythema and massive skin irritation on the udder due to *Simulium* bites [30]

Fig. 243 *Simulium* sp. larva with typical mouth brushes [30]

Fig. 245 Moist eczema-like skin alterations on the ear of a cattle following *Simulium* bites [30]

CERATOPOGONIDAE

Culicoides spp. Biting midges, seasonal dermatitis, sweet itch

Remarks: They are very small (1–3 mm long). Adult female midges attack cattle, sheep, poultry, horse, man and other species, causing marked irritation by penetration of the skin with their proboscis. The bites cause intense itching. Only the females suck blood mainly during the twilight periods and at night. *Culicoides* occur often in large swarms a few hundred metres around the breeding sites. These are moist areas such as fresh or brackish water or seepages from decaying vegetable or dung heaps.

Significance: 1) Massive irritation of livestock, itching, allergic skin reactions (sweet-itch, seasonal dermatitis) in horses (☞ HORSES AND DONKEYS, ■ 5.1), and 2) transmission of *Onchocerca gibsoni* and other *Onchocerca* spp. in cattle and horses, African Horse Sickness, Blue tongue of sheep. (Figure 246)

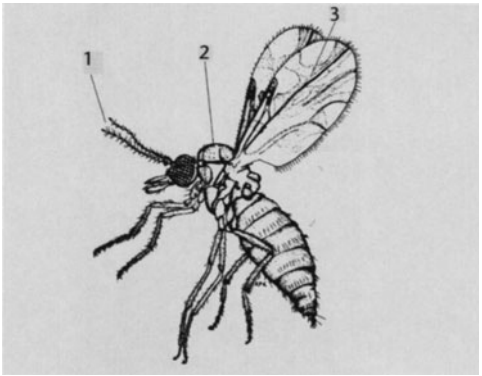


Fig. 246 *Culicoides* sp. (biting midge); adult (1–3mm long); (1) antennae long, (2) humped thorax and (3) mottled wings [20]

TABANIDAE

Tabanus spp. *Haematopota* spp. and *Chrysops* spp. Horse flies

Remarks: These robust flies have powerful wings and breed on leaves of plants in the vicinity of water. Female tabanids attack mammals to suck blood. They cause deep, painful, irritating bites. They generally bite several times for one blood meal because they are disturbed by the host's defense. A number of diseases (besnoitiosis, anaplasmosis, trypanosomosis and anthrax, hog cholera, equine infectious anaemia) are mechanically transmitted by tabanids. This is of special importance especially when horseflies are numerous among a crowded livestock population.
(Figures 247, 248, 249)

Fig. 247 *Tabanus* sp.; adult (17–25 mm) [13]

Fig. 248 *Haematopota* sp.; adult (8–13 mm)

Fig. 249 *Chrysops* sp.; adult (9–12 mm)

MUSCIDAE

Musca spp., *Lyperosia* spp. and *Haematobia* spp. Muscid flies

Remarks: Muscid flies are annoying livestock especially during the summer or rainy season. They are swarming around farm livestock. The resulting irritation is incessant and much of the energy of the animals is lost to defend against fly attacks. In addition to the nuisance the flies often carry pathogens on their feet and bodies. Some also act as intermediate hosts for other parasites. Two genera need to receive special attention: *Musca* and *Haematobia*.

Musca domestica (the common house fly) and other *Musca* spp. are non-biting muscid. *Musca autumnalis* is attracted to wounds and other moist parts of the body, especially the eyes. It may provoke conjunctivitis and an ulcerative dermatitis. The infectious keratoconjunctivitis ("pinkeye") mainly caused by *Moraxella bovis* may be transmitted by muscid flies, especially *M. autumnalis*. *M. domestica* is known to transfer pathogenic bacteria mechanically from one wound to another. It is also capable of transmitting numerous pathogenic agents of medical and veterinary importance (*Salmonella, Shigella, Entamoeba histolytica*, cestodes of poultry, *Habronema* spp., *Thelazia* spp., *Parafilaria bovicola* and others). The preferred breeding place is in the faeces of animals or in decaying organic matter.
(Figures 250, 251, 252)

Fig. 250 *Musca domestica*; adult (6–7 mm) [12]

Fig. 251 *Musca domestica*; larvae [4]

Fig. 252 *Musca autumnalis*; adult flies in situ

Fig. 253 *Haematobia* sp.; adult flies on the back of a cattle

Fig. 254 *Haematobia irritans*; adult flies (5–6 mm) [10]

Haematobia minuta and other *Haematobia* spp. (the horn flies, buffalo flies) are biting muscids and act as vectors of *Stephanofilaria stilesi* in cattle and *Parafilaria multipapillosa* in horses. The adults of this fly live almost permanently on cattle, buffalo, sheep and other animals. They congregate along the backs where their bites cause severe irritation so that the cattle rub themselves raw. The female only leaves her host briefly to lay her eggs in fresh cattle or buffalo dung. The larval development requires a high relative humidity of nearly 100%. The fly is therefore widely distributed in Central, East and southern Africa. The horn flies are obligatory parasites of cattle and a serious pest wherever they occur. *Haematobia* spp. cause intense worry and irritation to animals, the bite being very painful. Serious blood loss may occur when large numbers attack and loss of condition, reduced performance is a common result. The flies cause sores at the base of the horns, on the poll, ears, neck, withers and tail root.
(Figures 253, 254, 255)

Stomoxys calcitrans and *Stomoxys nigra*
Stable fly

Remarks: *S. calcitrans* also belongs to the muscids. It attacks almost all livestock species. *Stomoxys* breeds in manure (preferably horse manure) or in decaying organic matter. They require a very damp situation (heaped-up decaying vegetable matter). It is a biting muscid and occurs world-wide. Both sexes of this fly are bloodsuckers and can become extremely irritating pests of man and domestic animals. On cattle the flies prefer to feed on the legs while on dogs the ears may be so bitten that they become sore and scabby. Their salivary secretions

cause toxic reactions with an immunosuppressive effect, rendering the host more susceptible to diseases.

Significance: *S. calcitrans* acts as intermediate host of *Habronema microstoma* (☞ HORSES AND DONKEYS, ■ 1), *Trypanosoma evansi, Anthrax, Dermatophilus congolensis*, agents of the lumpy wool in sheep and probably many other pathogens. Its painful bite causes intense worry and irritation to animals. It may produce toxic reactions and immunosuppression. Blood loss may be marked following continuous, heavy attacks.

Control: Sanitation is the most important control measure in stable fly control. Manure, straw and decaying matter should be kept away from the environment of cattle, since this provides the development medium for the flies. If good sanitation procedures are practiced, then chemical control is less likely to be needed. Without sanitation chemical control measures are likely to fail.

(Figures 255, 256, 257)

Fig. 257 *Stomoxys calcitrans*; adult flies in situ

Fig. 255 *Stomoxys calcitrans* (the stable fly); adult fly (4–6 mm) with a prominent and rigid proboscis; the maxillary palps are shorter than the proboscis and the thorax has longitudinal stripes [27]

Fig. 256 *Stomoxys calcitrans*; adult fly (4–6 mm) with prominent biting mouthparts (arrow) [10]

GLOSSINIDAE

***Glossina* spp.** Tsetse flies, "flies that are destructive of cattle" from Sechuana

Remarks: Most tsetse flies are active during the daytime and hunt by sight and smell and feed every 2 to 3 days. Both sexes suck blood and are equally capable of transmitting trypanosomes. The female is larviparous, producing one larva at a time and an estimated total of 8–12 larvae during her life. Apart from two species in south-western Arabia, tsetse flies are confined to the African continent, where they infest around 7.5 million square kilometres, mainly tropical regions on either side of the equator. Wherever these bloodsucking flies are, they render the area unsuitable for man and his livestock.

(Figures 258, 259)

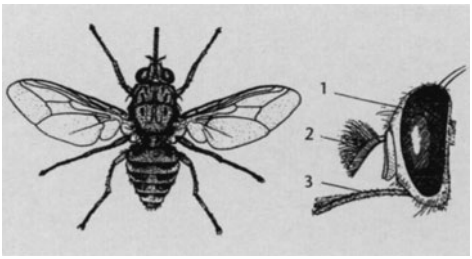


Fig. 258 *Glossina* sp. (tsetse fly); adult flies are robust insects, ranging in size from 6–16 mm and can be distinguished from other flies by their wing venation; the head shows prominent eyes (1), charactersitic antennae (2) and a prominent piercing proboscis [27]

Fig. 261 *Glossina palpalis*; adult in feeding position [4]

Fig. 259 Pupae (6–7 mm long) of tsetse flies (*Glossina* spp.) [13]

Fig. 262 Riverine habitat of *Glossina palpalis* [13]

Some 31 species of tsetse flies are known which can be divided into three groups, each with different habits and requirements: 1. Flies of the *Glossina palpalis* group are riverine species and feed on reptiles and ungulates. 2. Flies of the *Glossina morsitans* group are savannah and dry thorn-bush species which feed mainly on large animals. 3. Members of the *Glossina fusca* group occur in the rainforest and have require-ments between the first 2 groups, preferring dense shade and riverine thickets.

Fig. 260 *Glossina palpalis*; adult [13]

Fig. 263 *Glossina morsitans* with a prominent piercing proboscis [13]

Fig. 264 *Glossina morsitans*; adult (8–11 mm) [13]

Fig. 265 *Glossina fusca*; adult [13]

Fig. 266 *Glossina tachinoides*; adult [13]

Significance: Tsetse flies are vectors of human and animal trypanosomosis. Trypanosomosis of domestic animals is caused mainly by *T. congolense*, *T. vivax*, *T. brucei* and *T. simiae*. (☞ CATTLE, ■ 2). The most important vectors are *Glossina morsitans*, *G. palpalis*, *G. tachinoides*, *G. fusca*, *G. brevipalpis* and *G. pallidipes*.
(Figures 260, 261, 262, 263, 264, 265, 266, 267)

Fig. 267 Biconical tsetse trap [4]

OESTRIDAE

***Hypoderma* spp.** Warble fly, cattle grubs, heel flies

Location: Adult flies lay eggs on hairs of legs and occasionally of the body. Larvae migrate through several tissues of the host's body and appear in the subcutaneous tissue of the back.

Hosts: Cattle

Species description: Adult warble flies are hairy insects like bumble-bees. They do not feed and only live for a few days. The females lay their eggs on the hind legs of cattle and occasionally horses. The eggs of *Hypoderma bovis* are attached singly to an individual hair and the hatched larvae penetrate the skin and migrate along nerves to the spinal cord and then through the dorsal muscles till they come to lie below the skin on the back. *H. lineatum* eggs are attached in rows of 7–20 eggs per hair. Larvae penetrate the skin, migrate first to the oesophageal region and thence to the back. In spring the larvae leave through the holes, drop to the ground and burrow into soil to pupate.

Geographic distribution: Many countries of the northern hemisphere. Warble flies are reported from northern and southern Africa and are not widespread in tropical areas.

Symptoms: Clinical symptoms are rarely seen during the migratory phase, except if larvae are killed during their passage through the spinal cord. Paralysis may then occur. Nodules with an opening are usually seen in the skin of the back. These cysts contain a larva. When the adult flies attack cattle, stampeding may occur.

Significance: The adult flies severely disturb cattle which become apprehensive and attempt to escape by running away, often aimlessly. Consequently feeding and performance is reduced. In addition, warble flies cause extensive damage to the skin of cattle and the commercial value of the hides is markedly reduced. *H. bovis* larvae may cause paralysis when dying or being killed

during their migration through the spinal canal. Severe oedema may occur when larvae of *H. lineatum* are killed during their migration through the oesophageal region.

Diagnosis: Larvae in cysts or lumps under the skin of the back indicate warble infestation. Eggs may be found on hair of the animal's legs.

Therapy: Cattle, especially calves, in areas where grub numbers are high, should be treated as soon as possible after the end of the warble fly season. They should not be treated later than 8–12 weeks before the anticipated first appearance of grubs in the backs, since adverse reactions may occur when migratory larvae are killed in the spinal cord. Pour-on treatments of coumaphos, famphur, fenthion, phosmet, trichlorfon or ivermectin may be used and poured evenly along the midline of the back. Sprays containing coumaphos or phosmet also control cattle grubs. The entire surface of the skin should be wet for sufficient absorption. Coumaphos and phosmet may also be used as dips. Ivermectin (200 µg/kg, sc.) is highly effective against cattle grub. Oral application is also effective.

Prophylaxis: Attacks by adult warble flies are difficult to avoid and entail excessive use of insecticides. Early treatment in endemic areas is indicated.

(Figures 268, 269, 270, 271)

Fig. 268 *Hyporderma bovis* (warble fly); adult (15 mm long) [4]

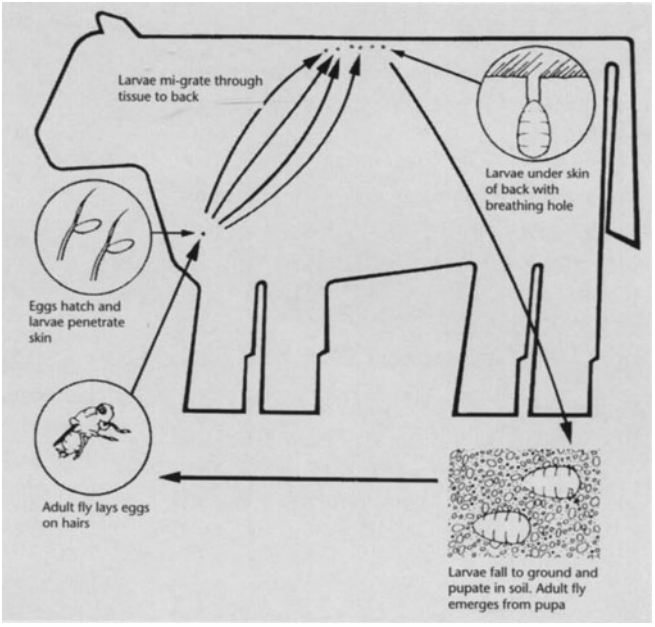


Fig. 269 Life cycle of *Hyporderma* spp. [6]

Fig. 270 *Hyporderma bovis* larvae causing nodules on the back

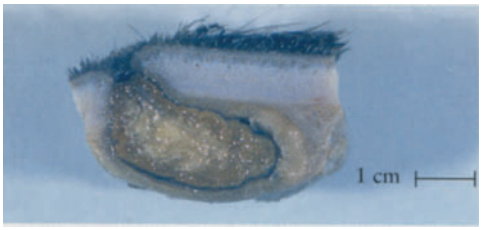


Fig. 271 *Hypoderma bovis*; section through a skin nodule containing a larva

CALLIPHORIDAE The blowflies and their allies

Remarks: They are highly important in many domestic animal species and man. The adults are free-living and the larvae are parasitic maggots which develop in the tissue of their host, causing a condition called myiasis. The larvae may be laid into pre-existing wounds. Myiasis is often a secondary skin problem.
(Figure 272)

Fig. 272 *Calliphora* sp.; adult (12 mm long) [4]

The family of Calliphoridae can be divided into two groups, the **metallic flies** and the **non-metallic flies.**

The **metallic flies** are green, blue or purplish coloured and belong to the genera *Lucilia, Chrysomyia* and *Callitroga*

***Lucilia cuprina* and other *Lucilia* spp.**
"Green-bottle" or "copper-bottle" flies

Remarks: *L. cuprina* is the predominant cause of sheepblow fly strike in South Africa and Australia. It causes myiasis in sheep. It is the most important primary blow fly initiating strikes on living sheep (☞ SHEEP AND GOATS, ■ 5.1).
(Figure 273)

Fig. 273 *Lucilia sericata* (the green-bottle flies); adult (8–9 mm)

Chrysomya bezziana Cattle screwworm, the Old World screwworm, blow fly strike of cattle

Remarks: *C. bezziana* infests cattle but also horses, sheep, dogs and sometimes man. It occurs in tropical and southern Africa and oriental regions. *C. bezziana* causes severe myiasis and toxins produced by the larvae result in retarded healing of wounds. Death may occur in severe cases.
(Figure 274)

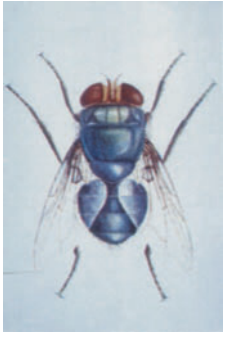


Fig. 274 *Chrysomya bezziana* (the cattle screwworm); adult (8–10 mm) [20]

Callitroga hominivorax (syn. *Cochliomyia hominivorax)* "American screwworm"

Remarks: *C. hominivorax* has recently been found to occur also in North Africa. Cattle, pigs and equines suffer most frequently, but other animals, including fowls and even man may also be affected. Pathology is essentially the same as in *C. bezziana*.
(Figures 275, 276)

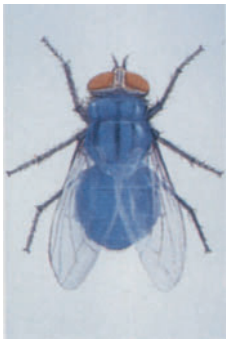


Fig. 275 *Callitroga hominivorax* (syn. *Cochliomyia hominivorax*) the "screwworm"; adult (8–10 mm long) [19]

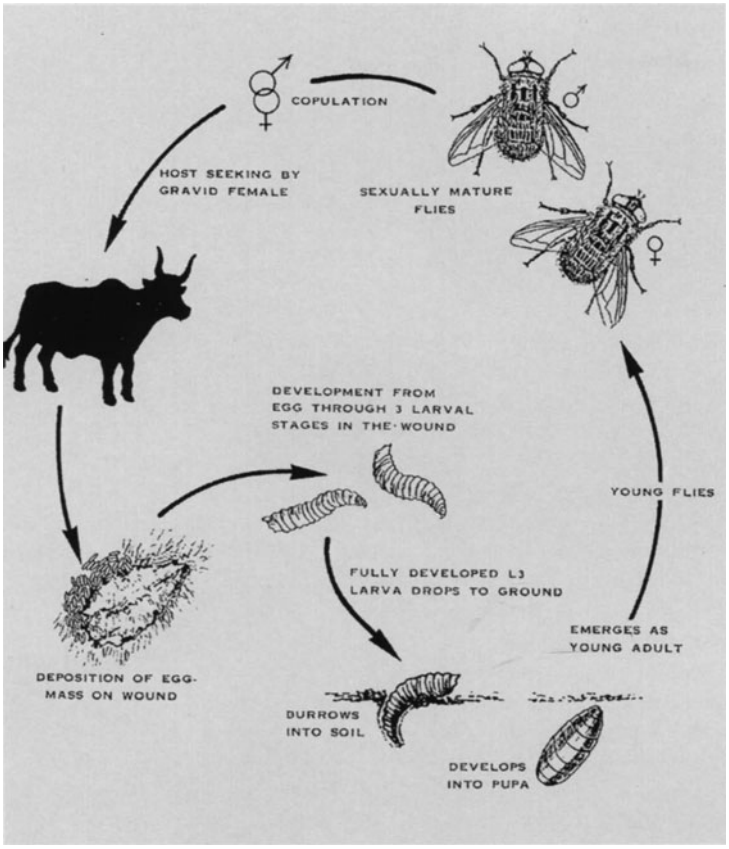


Fig. 276 Life cycle of *Callitroga hominivorax* [31]

The **non-metallic flies** are dull grey, yellow-brown or black and belong to the genera *Wohlfartia*, *Sarcophaga* and *Cordylobia*

Sarcophaga haemorrhoidalis
Red-tailed fleshfly

Remarks: The fly is very common in Africa south of the Sahara and is frequently found around human habitations. Flies of this species are larviparous and may lay their larvae in wounds or sores although larvae may also be deposited on faeces, carrion or fresh meat. Several animal species and man may be affected. The fly may cause myiasis, especially in sheep in some parts of the world.
(Figures 277, 278)

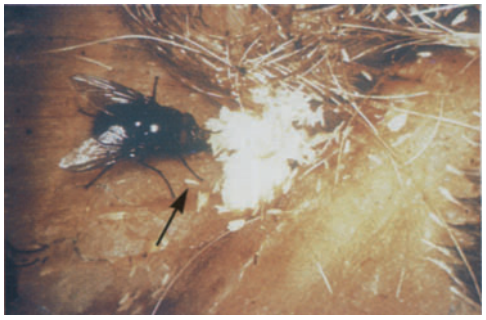


Fig. 277 *Sarcophaga* sp.; adult fly depositing its larvae on the skin of a cattle [8]

Fig. 278 *Sarcophaga* sp.; adult fly (13–15mm long) [4]

Wohlfartia magnifica
Old World fleshfly

Remarks: This species occurs in North Africa. The fly attacks man and other animals. The larvae may be deposited into the external ear of man or in sores around the eyes.
(Figure 279)

Fig. 279 *Wohlfartia* sp.; adult fly (8–14 mm long) [4]

Cordylobia anthropophaga
Tumbu fly or "skin maggot fly"

Remarks: The fly is widely distributed in Africa south of the Sahara. It produces myiasis in man, dogs and other domestic animals. Eggs are laid around places where animals lie. After hatching the larvae penetrate the skin of the host, producing a boil of about 1 cm across with a hole in the centre. When mature the larvae wriggle out of the hole and pupate on the ground. Tumbu boils are found commonly on the ventral parts of the body but also on any other area of the body.
(Figures 280, 281)

Fig. 280 *Cordylobia anthropophaga* (Tumbu fly); stout fly with two black marks on the thorax; the face and legs are yellow (8–12 mm long) [27]

Fig. 281 *Cordylobia anthropophaga*; third-stage larva (12–28 mm long) [27]

HIPPOBOSCIDAE
The louse flies

Hippobosca equina Horse louse fly

Hosts: Horse and cattle
Geographic distribution: World-wide
(☞ HORSES AND DONKEYS, ■ 5.1)
(Figures 282, 283)

Fig. 282 *Hippobosca equina* (horse louse fly; 7–9 mm long)

Fig. 283 *Hippobosca* sp.; adult louse flies on a cattle [4]

Hippobosca variegata

Hosts: Horse and cattle
Geographic distribution: Tropical Africa and oriental regions

Hippobosca rufipes Cattle louse fly

Hosts: Mainly wild and domestic Bovidae, less frequently horses
Geographic distribution: Tropical Africa (arid and semi-arid areas of Africa)
(Figure 284)

Fig. 284 *Hippobosca rufipes* (cattle louse fly); this fly is very hard-bodied and difficult to squash. It has well-developed wings and strong legs ending in well-developed claws (8–11 mm long) [27]

Hippobosca maculata

Hosts: Horse and cattle
Geographic distribution: Tropical and subtropical areas of Africa
(Figure 285)

Fig. 285 *Hippobosca maculata*; adults (8 mm long) attached to the jugular vein region of a cattle [8]

Hippobosca camelina Camel louse fly

Hosts: Camel, horse and occasionally cattle
Geographic distribution: Northern Africa and Middle East

- **General features of *Hippobosca* spp.**

Location: The adult louse flies remain for long periods on their host and cluster in the perineal region, between the hindlegs to the pubic region, but may also bite on other parts of the body.
Species description: The flies live permanently on their host and feed on blood. Mainly cattle and horses are affected. They rarely fly and then usually not more than a few metres. They spend their whole time on the host and are strongly attached to their host and therefore difficult to dislodge. When disturbed they can quickly move sideways.
Symptoms: Infested animals scratch and rub, and skin-trauma are often seen as a consequence of heavy infestations.
Significance: These flies are a source of great irritation. They transmit the non-pathogenic *Trypanosoma theileri*, anthrax and other bacterial infections to cattle.
Diagnosis: Identification of flies located under the tail and between the hindlegs.
Therapy: ☞ below, THERAPY AND PROPHYLAXIS OF ECTOPARASITES, p. 141
Prophylaxis: Regular grooming may be helpful to reduce louse fly infestations.

- **Therapy and prophylaxis of ectoparasites** (for arachnids and insects)

A great number of insecticides is used to control both arachnids and insects (Table 11). Methods of application include whole-body sprays, dips, dusts and topical application to the dermis and ears. Dips are more effective for ticks. Thorough treatment of the infested area is required, especially when ticks infest the ears or underside of the tail or mites infest localized patches on the skin. Impregnated ear tags, containing pyrethroids or organophosphates, are of increasing importance in fly control. Elimination of parasites or stages in the environment is difficult because many ectoprasites are capable of surviving in the environment for prolonged periods (e.g. some ticks can live on the ground up to 300 days without feeding). In areas where many ticks exist reinfection of the host occurs continuously and treatment therefore must be repeated regularly. Some ticks are not strictly species-specific and ticks normally adapted to horses can occasionally also affect cattle or other animals and they must be treated, too, if attempts are made to reduce tick infestations.
In subhumid areas the period of highest tick activity is the wet season and only few ticks are found on animals during the dry season. Con-

sequently tick control is focussed to the wet season. In tropical areas most ticks are active throughout the year and must be controlled continuously.

Table 11 Some common compounds to control external parasites of cattle

Compound	Pest
Organophosphates	
Chlorpyrifos	Lice, horn flies
Coumaphos	Horn flies, lice, ticks, grubs, screw worms, mites
Crotoxyphos and dichlorvos	Horn flies, face flies, stable flies, house flies,lice, ticks
Dichlorvos	Horn flies, face flies, stable flies, house flies
Dichlorvos and tetrachlorvinphos	Horn flies, face flies, lice, ticks
Diazinon	Horn flies (including pyrethroid-resistant flies), spinose ear ticks, lice, mites, *Hypobosca* spp.
Dioxathion	Horn flies, lice, mites
Fenthion	Horn flies, lice, *Hypoderma* spp.
Malathion	Lice, keds, mites
Phoxim	Mites, lice, flies, myiasis, ticks
Phosmet	Grubs, lice, horn flies, ticks, mites
Stirofos	Horn flies, face flies, house flies, stable flies
Tetrachlorvinphos	Horn flies, lice, ticks
Trichlorfon (metrifonat)	Grubs, lice, mites
Carbamates	
Carbaryl	Mites, lice, ticks, flies
Promacyl	Mites, lice, ticks, flies
Chlorinated Hydrocarbons*	
Lindane	Screwworm larvae, mites, lice, ticks, flies
Methoxychlor	Mites, lice, ticks, flies
Toxaphen	Mites, lice, ticks, flies
Pyrethrins and Pyrethroids	
Cyfluthrin	Horn flies, horse flies
Cypermethrin	Horn and face flies, ticks
Deltamethrin	Flies, including tsetse flies
Fenvalerate	Horn and face flies, spinose ear ticks
Flumethrin	Flies, including tsetse flies, ticks
Permethrin	Horn flies, face flies, mites, ticks, lice
Pyrethrin	Horn flies, face flies, mites, lice
Avermectins	
Doramectin	Mites, lice, ticks, *Hypoderma* spp.
Ivermectin	Mites, lice, *Hypoderma* spp.

* some are no longer approved by some governments

5.2 Eyes

Thelazia rhodesi Cattle eyeworm

Location: Conjunctival sac
Hosts: Cattle, rarely sheep and goat
Species description: Milky-white worms, males 8–12 mm long and females 12–18 mm. The cuticle is transversely striated. The spicules are 0.75–0.85 and 0.115–0.13 mm long. Intermediate hosts are *Musca larvipara* and *Musca amica*. Infected flies transmit the infective larvae via saliva to calves. Adult *Thelazia* appeared 20–25 days after infection. In some regions a high percentage of calves is infected but lesions are often absent.
Geographic distribution: World-wide
Symptoms: Conjunctivitis, clouded cornea, marked lacrimation. The affected eyes may be swollen and covered with exsudate and pus. Without treatment progressive keratitis and ulceration of the cornea may occur.
Significance: Infections with eyeworms may be very prevalent in some regions. Heavy infections may cause marked irritation, keratitis and weight loss of affected animals.
Diagnosis: This is made by the detection of worms in the conjunctival sacs. Examination of the lacrimal secretions may reveal eggs or first-stage larvae.
Therapy: Levamisole (5 mg/kg, sc.) and ivermectin (200 µg/kg, sc.) are active against *Thelazia* spp. Concurrent use of antibiotic ointment for secondary invaders is recommended.
Prophylaxis: Fly control measures against the face fly aid in the control of thelaziosis in both cattle and horses.
(Figures 286, 287, 288)

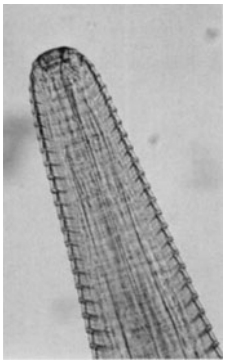


Fig. 286 *Thelazia rhodesi* (eyeworm); anterior end with typical cuticular striation

Fig. 287 *Thelazia rhodesi* in the eyes of a cattle

Fig. 288 N'Dama cattle with lacrimation due to *Thealzia rhodesi* infection