

Pathology and diagnosis of internal parasites in ruminants

Stephen C. J. Love and Gareth W. Hutchinson

1. Introduction

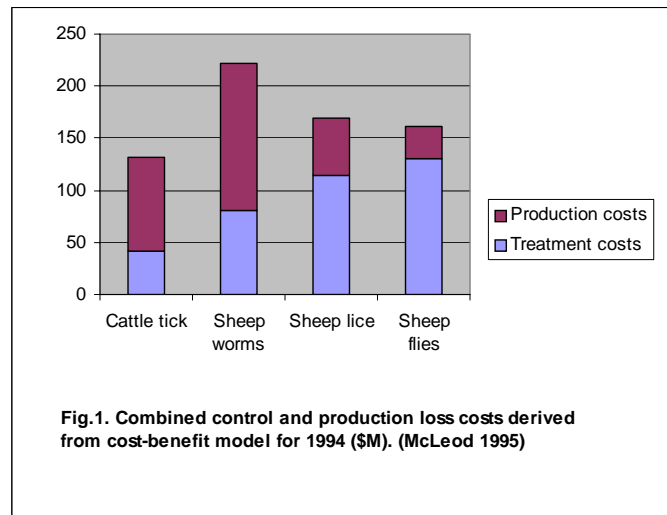
Parasitic infections are generally regarded as the most prevalent and important health problems of grazing ruminants in Australia, with losses associated with nematodes, and ectoparasites causing a combined annual loss of approximately a billion dollars (McLeod 1995). Liver fluke, although having a restricted distribution in temperate regions has been estimated to cost upwards of \$100 million (Boray 1999).

1.1. Scope of paper

The purpose of this paper is to overview the gross pathology and diagnosis of gastrointestinal and other parasites in ruminants, with particular emphasis on the economically important parasites of sheep, goats and cattle.

2. Economic importance of parasites

McLeod (1995) modelled the costs of various parasitic diseases of grazing livestock in Australia. His findings are summarised in Figure 1. The economic impact of these diseases is significant, and production costs, including subclinical parasitism, are often a major component of the total costs.



3. Distribution of important parasites

3.1. Sheep & Goats.

The three most important sheep/goat roundworms in Australia are *Haemonchus contortus* (barber's pole worm), *Trichostrongylus* spp (black scour worm) and *Ostertagia (Teladorsagia) circumcincta* (brown stomach worm). Worms of lesser or occasional importance include *Nematodirus* spp, *Oesophagostomum* spp and *Chabertia ovina*. Liver fluke (*Fasciola hepatica*) is also important in some locations. Sheep worm infections in Australia are often mixed, with dominant species varying according to climatic zone. *H.contortus* is most important in regions with summer dominant rainfall, especially northern New South Wales (NSW) and south eastern Queensland, and in coastal areas of south western Australia (WA). *Trichostrongylus* and *Ostertagia* spp are more cold- and desiccation-tolerant, and hence dominate in areas with non-seasonal rainfall (eg, central and southern NSW), and in winter rainfall areas (Victoria, Tasmania, southern areas of South Australia, and south-west WA). (Besier and Love 2003).

3.2. Cattle

Ostertagia ostertagi is the most important nematode of extensively grazed cattle in temperate regions of the world, including the southern half of Australia. However, in the temperate non-

seasonal to winter rainfall areas of Australia, *Ostertagia* is usually found in mixed infections, including species such as *Trichostrongylus axei* and *Cooperia oncophora*. In sub-tropical to tropical summer rainfall areas of Queensland and the North Coast of New South Wales, important helminths include species such as *Haemonchus placei*, *C.pectinata*, *C.punctata*, *Bunostomum phlebotomum* and *Oesophagostomum radiatum*.

3.3. Alpaca

Although not strictly ruminants, we include alpaca here because they have become more common in Australia and because of their use in animal

husbandry either in their own right, or as guardians for lambing-ewe flocks. Alpaca are susceptible to both cattle and sheep parasites including liver fluke. Because of their use of dunging “latrines” this helps to control internal parasites, and worm burdens are not usually of pathogenic proportions. Occasional heavy *Haemonchus* burdens are reported, especially in high rainfall coastal areas.

4. Diagnosis – general comments.

In diagnosing helminthiasis, the three pillars of veterinary diagnosis apply:

- ✚ History,
- ✚ Clinical signs and gross pathology, and
- ✚ Laboratory aids.

Also knowledge of the local nuances of parasite epidemiology and control is invaluable.

Faecal worm egg counts (FECs) in particular (preferably with speciation by way of larval culture and differentiation), and total worm counts are the tests most commonly employed in the diagnosis of helminth infections in ruminants. See Table 2 for a summary of laboratory tests for worms available through NSW Agriculture and other laboratories.

FEC does not always correlate well with the number of adult worms present, particularly in cattle over 9-12 months. ‘Diagnostic drenching’ may be a useful tool in such cases. FECs may also be low or zero in the presence of large numbers of immature worms. An example of this may be seen with acute *Nematodirus* infections in young sheep after drought breaking rains in south western NSW. Type 2 ostertagiosis in cattle is another example. Also, *Ostertagia* burdens in small ruminants do not always correlate well with FECs.

Table 1. Harmful helminths and their distribution (adapted from Cole 1986)

Sheep and goats	Cattle
Causing common outbreaks of disease	
Summer-rainfall areas	
<i>Haemonchus contortus</i>	<i>Haemonchus placei</i> <i>Ostertagia ostertagi</i> / <i>Cooperia punctata</i> / <i>C.pectinata</i> (as a complex)
<i>Ostertagia spp</i>	<i>Bunostomum phlebotomum</i>
<i>Trichostrongylus spp</i>	<i>Oesophagostomum radiatum</i>
<i>Fasciola hepatica</i>	
Non-seasonal to winter rainfall areas	
<i>Ostertagia spp</i>	<i>Ostertagia ostertagi</i>
<i>Trichostrongylus spp</i>	<i>Trichostrongylus axei</i>
<i>Fasciola hepatica</i>	<i>Cooperia oncophora</i>
Occasionally significant or mainly subclinical effects or sometimes present in large numbers	
<i>Nematodirus spp</i>	<i>Fasciola hepatica</i>
<i>Cooperia spp</i>	<i>Paramphistomum spp</i>
<i>Chabertia ovina</i>	<i>Calicophoron calicophorum</i>
<i>Strongyloides spp</i>	<i>Strongyloides spp</i>

Ova of the ruminant nematodes *Nematodirus*, *Bunostomum*, *Strongyloides* and *Trichuris* are distinctive, but differentiation of the more common species requires examination of third-stage larvae produced by faecal cultures.

Necropsy is the most direct method to diagnose gastrointestinal (GI) parasitism. *Haemonchus*, *Bunostomum*, *Oesophagostomum*, *Trichuris* and *Chabertia* adults can be easily seen. However, important infections with *Ostertagia*, *Trichostrongylus*, *Cooperia* and *Nematodirus* are difficult to see (particularly those species spread over metres of intestine), except by their movements in fluid ingesta. These smaller nematodes can be better seen in GI tract washings, particularly against a white background, by staining for 5 minutes with strong iodine solution followed by decolourising background gut material with 5% sodium thiosulphate ('hypo'). Unfortunately the relatively high cost of total worm counts in the laboratory often precludes the use of this test, but it is highly recommended to confirm difficult diagnoses or where anthelmintic resistance is of major concern.

Multifactorial causation should be considered when evaluating the evidence. Mixed infections are the rule.

For an overview of diagnostic techniques, see Smeal (1995).

5. Anthelmintic resistance

Resistance in sheep and goat worms to most anthelmintics is now fairly common in Australia (Besier and Love 2002, Love 2002) and should be considered in the diagnosis and management of GI parasitism. Confirmed drug resistance in cattle worms in Australia has not been reported. In New Zealand, however, a number of isolates of macrocyclic lactone-resistant *Cooperia* have been found in cattle.

6. Summary tables

Information on gross pathology and other aspects of various parasites is summarised in Tables 4 and 5 at the end of this paper.

7. Parasites of the forestomachs

Trematodes

7.1. *Paramphistomum* spp and *Calicophoron calicophorum* ('stomach flukes')

Paramphistomosis occurs occasionally in cattle and rarely in sheep, with significant disease mainly due to duodenitis caused by migrating immature fluke. Paramphistomes occur commonly in cattle throughout the sub-tropical and wet tropical areas of eastern Australia and the Kimberley region of Western Australia, although infections have been reported elsewhere, including Victoria and the south coast of NSW.

Paramphistomes or stomach flukes are conical shaped trematode parasites. Adult flukes are found mainly in the reticulum but also in the rumen. They have a fleshy, pear-shaped body, 5-12 mm by 2-4mm in diameter, and are pink or light red. Juvenile fluke are small (1-2mm long).

Most infections of adult fluke are harmless although large numbers of fluke can cause a chronic ulcerative rumenitis with atrophy of ruminal papillae. Peak conical fluke numbers are usually seen in late summer or early winter following prolonged inundation of pasture (Rolfe *et al.* 1991).

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Clinical paramphistomosis is usually diagnosed in cattle 4-18 months of age and is associated with invasion of the duodenum and upper jejunum by large numbers of immature fluke. Counts of up to 30,000 immature paramphistomes may be associated with diarrhoea after 8 weeks grazing in tracer calves (Rolfe and Boray 1993). Juvenile fluke are attached to the intestinal mucosa and, being small, are easy to overlook at necropsy. Catarrhal to necrotic and haemorrhagic duodenitis with little thickening may be seen in the early stages, progressing to thickening (mucosal oedema, submucosal hypertrophy), haemorrhages and ulceration. Anaemia, hypoproteinemia (manifested as submandibular oedema) and emaciation of the host ensue. After juvenile fluke migrate to the rumen, the intestine repairs, leaving a thickened duodenum and jejunum as a result of diffuse mucosal and submucosal hypertrophy and fibrosis.

Oxyclozanide, present with levamisole in Nilzan®, is the most effective anthelmintic for the treatment of acute and subacute paramphistomosis with two treatments given two days apart (Rolfe and Boray 198, 1988) and combined with fencing to restrict access to wet snail habitats. However, there are currently no anthelmintics, including Nilzan, registered for specific use against stomach fluke in Australia.

8. Parasites of the abomasum

8.1. *Haemonchus* ('barbers pole worm')

Haemonchus spp are among the most pathogenic helminth species of ruminants in Australia. *Haemonchus contortus* is mainly a parasite of sheep and goats (sometimes cattle) and *H. placei* is mainly a parasite of cattle (sometimes sheep and goats). *Haemonchus* are most dominant in summer rainfall areas.

Female worms are 18-30 mm long and are easily recognised by the 'barbers pole' appearance of the white ovaries and uteri twisting for the length of the worm around a red blood-filled intestine. Males are 10-20 mm long and uniformly reddish-brown.

Both the developing 4th larval stages (L4s) and adults cause punctiform haemorrhages at sites of feeding on the abomasal mucosa which may be oedematous. The ingesta may be reddish brown and fluid. Worms may be attached to the mucosa and free in the lumen.

Clinical signs include anaemia and hypoproteinemia (manifested as submandibular oedema). In South Africa, the Famacha© system of standard colour charts is used for assessing/scoring the level of anaemia by comparison of the colour of the inner lower eyelid and is used for tactical treatment of heavily infected sheep. In heavy and rapid infections, even animals in fat condition may die relatively quickly. Scouring is not a feature in sheep and goats unless the parasite infection is mixed and includes 'scour worms' (notably *Ostertagia* and *Trichostrongylus* spp).

8.2. *Ostertagia* ('small brown stomach worm')

Ostertagia spp in small ruminants and cattle tend to be more important in winter and non-seasonal rainfall areas. Heavy infections (particularly if accompanied by *Trichostrongylus* spp in sheep & goats) can cause profuse scouring, ill thrift and possibly deaths. *O. ostertagi* is considered to be the most pathogenic cattle nematode in southern Australia and other temperate cattle raising regions in the world. The free living stages of *Ostertagia* spp can develop at lower temperatures than most other trichostrongylid species.

Ostertagia are small, brown hair-like worms. Adult females are 8-12mm long and males are 7-9mm long.

Type 1 *O. ostertagi* infections are composed almost entirely of adult worms resulting from the majority of ingested larvae developing normally to adults in 18-20 days. White, raised, umbilicated nodules (containing developing L4 worms) occur mainly in the fundic mucosa. As the larvae develop and emerge from gastric glands, hyperplasia of gastric epithelium may cause enlargement and coalescing of nodules, the mucosa classically referred to as having a 'Morocco leather' appearance. Mucosal congestion and oedema is also evident, with thickening of abomasal folds. In Australia, type 1 infections occur mainly in dairy calves 3-10 months of age and weaned beef calves 6-12 months of age during late winter and early spring. Clinical signs include inappetence, profuse watery diarrhoea (scours) and rapid weight loss.

Pre-type II infections consist of large numbers of inhibited (hypobiotic) early L4s in the gastric glands with minimal tissue reaction and clinical signs apart possibly from ill thrift. This form occurs mainly in beef cattle during spring and summer, with inhibited larvae resuming development 4-6 months later in late summer / early autumn.

Type II infections consist of adult worms arising from simultaneous maturation of many inhibited early L4s, with glandular hyperplasia, loss of gastric structure, abomasitis, impairment of protein digestion, and leakage of plasma proteins especially albumin into the gut lumen. The mucosa appears thickened and oedematous. Outbreaks of type II ostertagiosis with diarrhoea and rapid weight loss may be seen in 18 month old beef cattle in autumn and in heifers and cows soon after calving. However, the incidence of type II and other forms of clinical ostertagiosis has tended to decrease with the introduction of anthelmintics with greater efficacy against inhibited and other stages of parasitic worms. These drenches include the third generation benzimidazole carbamates (fenbendazole, oxfendazole, albendazole etc.), but more particularly the macrocyclic lactones (ivermectin, abamectin, moxidectin, doramectin, eprinomectin), which tend to have consistently high efficacy, especially with respect to against inhibited stages, as well as persistent activity against incoming ingested L3s.

8.3. *Trichostrongylus axei* ('stomach hair worm')

Trichostrongylus axei occurs commonly in ruminants, often in association with *Ostertagia*, and also in other host species, such as horses, but appears to be relatively non-pathogenic.

Adult *T. axei* are very small, (smaller than *Ostertagia*), slender, hair-like and reddish-brown. Females are 5-8 mm and males 4-7 mm long.

In heavy infections, aggregations of worms occur mainly in the fundus, with localised hyperaemia progressing to catarrhal inflammation with white raised circular plaques. Heavy burdens (40-70,000 or more worms) may exacerbate *Ostertagia* - associated gastritis and accompanying clinical signs. The seasonal pattern of larval availability is similar to that for *O. ostertagi*.

9. Parasites of the intestines

Small intestine

9.1. (Intestinal) *Trichostrongylus* spp ('black scour worms')

Trichostrongylus colubriformis and *T. vitrinus* occur commonly in sheep in Australia, the former tending to be more important in summer rainfall areas and the latter in winter rainfall areas. Commonly they occur in mixed infections with *Ostertagia*, producing similar clinical signs (inappetence, weight loss and scouring). (*T. axei* may also be found in the intestines of sheep and cattle). Sub-optimal nutrition exacerbates pathogenicity. Intake of *Trichostrongylus* larvae is believed to be the primary agent responsible for 'hypersensitivity scouring' in sheep in the winter dominant rainfall areas of Victoria/South Australia and south-western Western Australia

Intestinal *Trichostrongylus* spp are small, hair-like reddish brown worms (females 6-8mm and males 6-7mm long), not readily seen at necropsy.

Trichostrongylus colubriformis and *T. longispicularis* are recorded in Australian cattle (the latter more so in Western Australia). Small numbers are relatively harmless to young cattle and are usually mixed with larger numbers of *Cooperia* spp.

9.2. *Cooperia* spp

Cooperia spp are widespread but relatively uncommon and non-pathogenic parasites in sheep.

Adult *Cooperia* are small (females 6-10mm and males 5-9mm long), reddish hair-like worms.

Cooperia punctata, *C. pectinata* and *C. oncophora* occur commonly in the proximal half of the small intestine of cattle in Australia, with the first two being more pathogenic and occurring together as a complex particularly in subtropical and tropical areas. *Cooperia oncophora* occurs mainly in cooler southern regions of Australia and appears to be relatively non-pathogenic.

From 6 months of age, most cattle become increasingly resistant to reinfection with *Cooperia* larvae.

Gross pathology and clinical signs are those of parasitic gastroenteritis (PGE), and include inappetence, intermittent, watery diarrhoea and weight loss. Mucosal inflammation and thickening, epithelial erosions (with leakage of plasma proteins into the gut lumen) and a profuse mucous exudate may be found at necropsy.

Large worm burdens in cattle often in excess of 500,000 may be acquired over a short period, with inhibited early L4s comprising up to 50% of the population, but even such large numbers are not usually particularly pathogenic on their own.

9.3. *Nematodirus* spp ('thin-necked intestinal worm')

Nematodirus spathiger is a very common parasite of young Australian sheep, and usually relatively non-pathogenic unlike the situation in New Zealand where this parasite inexplicably became more important from the 1960s. Heavy infections, scouring and ill thrift with mortalities can be seen in young sheep under or soon after drought conditions in Australia (south western NSW, for example)

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presumably become *Nematodirus* eggs are relatively desiccation-tolerant. Clinical nematodirosis is also not uncommon in young lambs in irrigation areas such as the Riverina area of southern New South Wales.

Nematodirus is whitish, relatively long (females 18-12mm, males 10-17mm long) compared to other trichostrongyle nematodes, with the anterior portion thinner than the posterior end (hence 'thin-necked intestinal worm').

Nematodirus helvetianus occurs commonly but in small numbers in dairy calves, usually mixed with much larger numbers of *Cooperia*. Alone they appear to be of little significance although in the United States they have been regarded as an important parasite.

9.4. Bunostomum spp ('hookworm')

Bunostomum trigonocephalum is a potentially pathogenic parasite of sheep recorded from all states, but is relatively uncommon and burdens tend to be light and of little consequence. Ill thrift and anaemia has been attributed to this parasite in New Zealand.

These reddish worms are one of the larger intestinal parasites of cattle (females 24-28mm and males 10-18mm long).

Bunostomum phlebotomum, the hookworm of cattle, occurs principally in the proximal small intestine. It mainly occurs in mixed infections in dairy calves in southern Queensland and NSW. Worms attach to the mucosa by a large buccal capsule, causing mucosal inflammation, thickening and punctiform haemorrhages. Clinical signs include anaemia, inappetence, ill thrift, a dark scour, and submandibular oedema. Infection in calves maintained in wet/muddy conditions can be associated with skin penetration by the infective larvae.

9.5. Strongyloides spp ('threadworms')

Strongyloides papillosus eggs are often seen in faecal counts in sheep, but this parasite is of doubtful significance. Its importance if any is overshadowed by parasites such as *Ostertagia* and *Trichostrongylus*.

Female adults are very small (3-6mm long) and parasitise the proximal small intestine, deep in the mucosal crypts, and so are usually overlooked on necropsy except by the most diligent pathologist.

Strongyloides papillosus can infect animals by ingestion, skin penetration (in wet conditions) and through the milk of lactating ewes. (Only female worms occur as parasites in the small intestine and these are parthenogenetic).

Clinical signs reported in experimental infections include anorexia, weight loss, variable anaemia, lassitude, dyspnoea (due to larvae migrating through the lungs) and lameness.

Losses in lambs with heavy natural infections during a wet period following a drought have been reported from Kenya.

Strongyloides papillosus is commonly found in young dairy calves. Clinical parasitism is seen rarely and usually when animals are confined or under wet, muddy conditions. Clinical signs include dull demeanour, inappetence, harsh cost and diarrhoea.

Trematodes

9.6. Paramphistomes ('stomach fluke')

Migrating immature paramphistomes can cause duodenitis (See 'Parasites of forestomachs').

Cestodes

9.7. *Moniezia* spp ('tapeworms')

Moniezia and less commonly *Thysaniezia giardi* infect sheep. These tapeworms are generally regarded as relatively harmless. However, anthelmintic combinations containing praziquantel, which is highly effective in removing tapeworms, are actively promoted.

Moniezia benedini and *M. expansa* are similar in appearance and may reach a length of 600cm.

Whereas *M. expansa* occurs mainly in sheep, *M. benedini* is found chiefly in young cattle, and is believed to be of little significance.

Protozoa

9.8. *Eimeria* spp (small and large intestine)

Coccidiosis is a parasitic enteritis of small and large intestines of cattle, sheep and goats caused by *Eimeria* species. Oocyst counts may not correlate with severity of infection. Infection may be exacerbated by various stressors and other pathogens – viruses, bacteria and worms. The stress of weaning, even (for example) in calves grazing in extensive conditions under dry tropical conditions, has been known to precipitate clinical disease. Coccidiosis usually occurs in younger animals –or in adults introduced to higher rainfall areas from the drier pastoral zones - and with high stocking rates or overcrowding under wet and cool conditions.

Lesions in acute and subacute coccidiosis include a catarrhal enteritis (mucosa appears velvety), multiple well-defined whitish lesions ranging in size from less than 1mm to patches 7mm in diameter, and whitish, polyp-like lesions or cone-shaped spots depending on the species of *Eimeria* and the stage of parasite (schizonts (meronts) or gamonts) contained within the lesion. Infections with a mixture of species are common but clinical disease is normally associated with only a small number of species, for example *Eimeria zuernii* and *E. bovis* in cattle. In clinical disease, characteristic bloody diarrhoea is often seen.

9.9. *Cryptosporidium* (small and large intestine)

Once considered a benign coccidium, *Cryptosporidium* is now regarded as a cause of disease in birds, reptiles and various mammals including man.

Cases in farm animals in Australia have mainly involved calves, with isolated diagnoses in lambs, birds and other species.

Calves are clinically affected mainly in the first 3 weeks of life with the enteritis being self limiting due to rapid development of host immunity. A diagnosis of cryptosporidiosis is suggested by

demonstration of moderate to large numbers of the very small (~5µm diameter) oocysts in faeces of affected animals, or identification of *Cryptosporidium* in ileal mucosa post-mortem. These oocysts are easily confused with yeasts and usually appropriate stains or interference microscopy to confirm the diagnosis. Clinical signs include profuse non-haemorrhagic diarrhoea of variable colour (often creamy-yellow). Other causes of neonatal diarrhoea need to be considered.

9.10. *Giardia*

These characteristic flagellates may rarely be associated with acute episodes of diarrhoea in young calves or weaner cattle.

10. Parasites of the large intestine

10.1. *Oesophagostomum* spp ('nodule and large bowel worms')

Oesophagostomum columbianum (nodule worm) and *O. venulosum* (large bowel worm) occur in sheep and goats. Until the introduction of improved pastures (better nutrition) and more efficacious anthelmintics (eg thiabendazole, 1961 in Australia), *O. columbianum* was second in importance only to *H. contortus* in summer rainfall areas. *Oesophagostomum columbianum* has virtually disappeared from higher rainfall areas (eg northern NSW tablelands and slopes), which have relatively cold winters and relatively frequent anthelmintic treatments (drenching). However, the parasite still occurs in pastoral zones (western plains) of northern NSW and southern Qld, and processors sourcing sheep from those areas can suffer significant economic losses due to condemnation of intestines ('runners') affected by *Oesophagostomum*-associated 'pimply gut'

Histiotrophic phases of larval stages (L3/L4) of *O. columbianum* cause caseous nodules 0.5 – 1cm diameter (histologically eosinophilic granulomata) in small intestines and colon, although small intestinal nodules may be more 'gritty' than 'cheesy'. Nodules can also be found in the lung, liver, mesentery and mesenteric lymph node. Clinical signs in heavy infections include variable diarrhoea, emaciation, a humped appearance and stiff gait. Intussusception has also been reported.

Oesophagostomum venulosum is a mildly or non-pathogenic species, prevalent in winter rainfall areas. It also seems to have partly filled the niche vacated by *O. columbianum* in summer rainfall areas. *Oesophagostomum venulosum*-associated nodules occur infrequently, are small, and occur mainly in the caecum and colon.

Oesophagostomum radiatum ('nodular worm') and *O. venulosum* occur in cattle, the former being the significant parasite and the most frequently encountered large bowel parasite of cattle. *Oesophagostomum radiatum* particularly favours subtropical and tropical zones. Adults (14-22mm long) are whitish and found in thick mucus in the caecum and proximal colon. Numerous nodular lesions, 3-6mm diameter and resulting from the histiotrophic phase, appear scattered on the serosa of the small intestine and to a lesser extent the caecum and colon. In heavy infections, the caecal and proximal colonic mucosa is congested, oedematous and thickened with excessive amounts of turbid mucus being produced. Such infections may cause severe clinical disease in young animals with signs including inappetence, ill thrift, intermittent diarrhoea, anaemia, emaciation and death. Infections are usually mixed including *H. placei* and *Cooperia* spp.

As with *O. venulosum* (large bowel worm) in small ruminants, this parasite in cattle is relatively harmless and prefers cooler, winter rainfall climates. Adults are 10-25 mm long and are found in the caecum and proximal colon. There is a histiotrophic phase but little nodule formation.

10.2. *Chabertia ovina* ('large-mouthed bowel worm')

This parasite widely occurs in sheep, cattle and goats, usually in low numbers, and with a preference for winter rainfall zones. It has little pathogenic significance in cattle and occasionally causes clinical disease in small ruminants.

Adult females are 17-20 mm and males 12-14 mm long.

Like *Oesophagostomum*, there is a histiotrophic phase, with L3s entering the wall of the small intestine, re-emerging and then maturing in the caecum and proximal spiral colon. Adults take a plug of mucosa into the buccal cavity, causing haemorrhage, protein loss and oedema. Faeces of affected sheep are soft, mucoid and perhaps blood-flecked. Ill thrift may occur.

10.3. *Trichuris* spp ('whipworms')

This parasite occurs commonly in Australia and throughout the world. The most common species in Australian cattle, sheep and goats are *T.ovis* and *T.globulosa*.

Adults are 50-80 mm long, creamy-white, with the anterior three-quarters of the body being very slender.

Larvated ova are resistant to environmental effects and are ingested with soil. L3 larvae are released from ingested eggs, enter the small intestinal mucosa, and then re-emerge to undergo maturation in the caecum. They attach by their filamentous anterior ends to the mucosa. The eggs are lemon shaped with bipolar plugs. *Trichuris* spp are considered harmless except in very heavy infections (eg large soil intake by grazing animals in drought) in which case there may be a sub-acute typhlocolitis, diarrhoea and ill thrift.

11. Parasites of the liver

Trematodes

11.1. *Fasciola hepatica* (liver fluke)

The distribution of *F. hepatica* is determined by that of its lymnaeid snail intermediate host. The parasite is generally limited to high rainfall and irrigation areas of NSW, Victoria and Tasmania, with pockets also in South Australia and Qld. *Fasciola* is absent from Western Australia and importation of livestock requires pre- and post-import faecal sedimentation examinations plus border treatment with triclabendazole. This fluke was inadvertently introduced to WA (since eradicated) in horses infected with drug-resistant *F.hepatica* from the Goulburn valley of northern Victoria in the early 1990s

Where endemic, *F.hepatica* is an important parasite of cattle, but more particularly sheep and goats. Patent infections can develop in other wild and domestic animals and in humans. (Take care when eating water cress).

These flukes are leaf shaped and ~25 mm long in sheep and slightly larger in cattle.

Adult flukes are found in the main bile ducts of the liver, but occasionally small adults are found encapsulated in caseous nodular lesions in the lungs. Juvenile fluke (8-12mm long) can be squeezed from cut surfaces of the liver. Being hermaphroditic, only one fluke is required to establish a patent infection. Egg production at up to 20,000 per adult per day rivals or exceeds that of *Haemonchus*, that other fecund blood-sucker. Individual fluke may live several years or more.

Migrating juvenile fluke cause haemorrhagic tracts in liver parenchyma, with associated peritonitis. Some juveniles become encysted in the parenchyma. Healing proceeds and the tracts are replaced by scar tissue. Heavy infestations by immature flukes may cause death in the stage of acute hepatitis (acute fasciolosis). Black disease (*Clostridium novyi* intoxication) may result during the acute stage also. Acute fasciolosis is not common but occurs in sheep.

Mature flukes in bile ducts cause cholangiohepatitis, with changes most severe in the left lobe. From the visceral surface affected ducts may stand out as whitish, firm, branching cords due to distension by flukes and bile. Connective tissue proliferates, particularly in cattle, resulting in fibrosis. Mineralisation of old lesions is also common in affected cattle livers.

Acute and sub-acute forms of fasciolosis develop 2-3 weeks after massive infections and signs include anorexia, abdominal pain, yellowish and pale conjunctivae, weight loss and sudden death. Clinical signs develop more slowly in the chronic form and include ill thrift, anaemia, and sub-mandibular oedema ('bottle jaw'). Production losses can be economically significant even in relatively light fluke infections. Clinical signs are less well-defined in cattle, particularly adult cattle, which are more resistant to fasciolosis than sheep.

12. Parasites – respiratory tract

Nematodes

Lungworms in cattle, sheep and goats are generally not economically important although they occasionally cause significant disease in Australia, usually in host animals debilitated by other parasitic diseases and sub optimal nutrition.

12.1. *Dictyocaulus* spp ('large lungworm')

Dictyocaulus filaria, the large lungworm of sheep and goats, is a slender, whitish worm 3-10cm long. Adults live mainly in the small bronchi. Verminous pneumonia is mainly a disease of cool, moist climates as further development of L1 passed in faeces to the infective L3 stage requires such conditions.

Dictyocaulus viviparus occurs in cattle. This is an extremely important parasite in Britain and increasingly so in continental Europe. *Dictyocaulus viviparus* causes parasitic bronchitis, known in Britain as 'husk'. It occasionally causes disease in Australia in young cattle, mainly dairy cattle.

In the pre-patent phase, *Dictyocaulus* spp may cause patchy interstitial pneumonia in heavy infections. As worms mature, emphasis shifts to the bronchial lesion. Dorsocaudal and ventrocaudal (diaphragmatic) lobes are most affected. Worms are usually bathed in mucinous, foamy bronchial exudate. There may be patchy to large wedge-shaped areas of dark red or grey consolidation in the caudal lobes in heavy infections. Clinical signs in heavy infections include coughing, polypnea, nasal discharge, inappetence and ill thrift.

12.2. *Protostrongylus* ('small lungworm') and *Muellerius* spp ('small or nodular lungworm')

Species from these genera occur in Australia but are of little importance. *Protostrongylus rufescens* is parasitic in sheep, goats and deer. Adults are reddish, mainly inhabit bronchioles and are 16-35mm long, smaller than *D. filaria*. Lesions are broadly similar to those produced by *D. filaria* and *M. capillaris*.

Muellerius capillaris parasitizes sheep and goats. Adults live in the alveolar parenchyma, rarely the bronchioles, and usually provoke an enveloping granulomatous response, hence a common name, 'nodular lungworm'. There is rarely clinical evidence of disease in affected sheep.

13. Other internal parasites

Although largely beyond the scope of this paper, we mention other parasites below.

13.1. Larval cestodes

Information on larval tapeworms of sheep and cattle is summarised in Table 3.

Hydatid cysts (metacestodes of *Echinococcus granulosus*) are fluid filled cysts, some up to the size of oranges or grapefruits, found in the lungs and livers, and rarely free in the peritoneal cavity of cattle and sheep. High prevalence rates of up to 20-30% have been reported historically in defined regions of Australia. Recent studies suggest a decreasing occurrence, probably associated with increased awareness of the dangers of feeding uncooked sheep offal to dogs and public health awareness campaigns in Tasmania, NSW and ACT. Recently Tasmania has applied for declaration of freedom from hydatids following a lengthy eradication campaign.

Hydatid cysts have a typical multilaminar wall which is characteristic even if the cyst is degenerating, necrotic or caseous. In cattle cysts are mostly sterile (devoid of the protoscolices, "hydatid sand"), and are probably derived from accidental ingestion of *E. granulosus* eggs from the sylvatic cycle involving dingos and macropods.

In sheep hydatid cysts are usually smaller, are fertile and contain protoscolices.

13.2. Tick fevers – *Babesia*, *Theileria* and *Anaplasma* spp

There are four tick fever parasites affecting cattle in Australia. Three are blood protozoan parasites called piroplasms: *Babesia bovis*, *B. bigemina* and *Theileria buffeli*. The fourth is a blood rickettsia: *Anaplasma marginale*. The primary effect of these parasites is haemolytic anaemia. The economically important tick fevers are caused by *B. bovis* and *A. marginale*, which are transmitted by the cattle tick *Boophilus microplus*. These occur throughout northern Australia, eastern coastal areas of Queensland, and sporadically in New South Wales. For more information, see Smeal (1995). A finding of any *Babesia* sp in NSW is regarded as significant.

13.3. *Eperythrozoon ovis*

Eperythrozoon ovis is a rickettsia that parasitises erythrocytes in sheep and goats, causing haemolytic anaemia and icterus. Disease is often subclinical, but severe clinical signs, particularly in stressed animals, may be encountered.

13.4. *Oestrus ovis* ('nasal bot')

The sheep nasal botfly *Oestrus ovis* is a cosmopolitan parasite, the larvae of which inhabit the nasal passages and paranasal sinuses of sheep and goats. The larval period can vary from one to 10 months. Sneezing and a mucopurulent nasal discharge results. The main effects for the host are persistent annoyance and associated debility. Vary rarely secondary bacterial infection spreads from the olfactory mucosa to the meninges. In Australia, ivermectin, abamectin, moxidectin and closantel are registered for use against nasal bot.

13.5. *Onchocerca* spp ('beef nodules')

These are filariid worms. Three species occur in cattle in Australia, mainly northern Australia, but also coastal districts of New South Wales.

Major infections are due to *O. gibsoni*, which forms 10-20 mm diameter nodules in the connective tissue of brisket, stifle and hip regions. The nodules are often caseous or partly calcified. The adult female worms are up to 20 cm long and lie intimately coiled in the honeycomb-like fibrous nodules. Adult male worms are slender and only about 2 cm long.

The other two species do not form nodules. *Onchocerca gutturosa* is found in the ligamentum nuchae and *O. lienalis* in the gastrosplenic ligament and are difficult to see *in situ*. Microfilariae of *Onchocerca* are ingested by intermediate hosts, which include biting flies of the Family *Ceratopogonidae* including biting midges (*Culicoides* spp.). Simuliids (in Australia, 'black fly', 'buffalo gnat') are vectors for human onchocerciasis (River Blindness) in West Africa and South America but not for onchocerciasis in cattle.

13.6. *Stephanofilaria* spp

Stephanofilaria spp are filariid parasites of cattle, which cause localised dermatitis. The distribution (mainly Queensland) follows that of the intermediate host which is probably the buffalo fly (*Haematobia irritans exigua*). They are small parasites 2.5.-4.5 mm long and found in small cysts (up to 4 parasites per cyst) just beneath skin surface in *Bos indicus* cattle. Lesions are raised, circumscribed hairless areas on head, especially around the eyes, neck, dewlap and sternum. Cattle rub and scratch lesions. The disease can cause severe damage to hides.

13.7. *Thelazia* spp. ('eye worms')

Species belonging to this nematode genus occur in the eyes of cattle, sheep, horses, dogs, other domesticated animals and man. *T. gulosa* and *T. skrjabini* have been found in Australia. These white nematodes (5-20 mm) occur in the conjunctival sac, lacrimal ducts, and nasolacrimal canals of cattle. They have been associated with conjunctivitis and keratitis severe keratitis that can lead to corneal opacity and even blindness. However, they are also found in normal eyes.

The worms are found behind the third eyelid and in lacrimal ducts, and can be difficult to detect clinically. Worms can be recovered from saline eye washings. Muscid flies are the intermediate host.

Thelazia spp once were endemic on the north coast of NSW but may have disappeared because of anthelmintic usage (benzimidazoles and more recently macrocyclic lactones). They have been reported from Queensland, northern Victoria and south western Western Australia

13.8. *Setaria labiato-papillosa*

Setaria labiato-papillosa is a long thin filarial nematode occurring in the peritoneal cavity cattle in north Queensland. It has no apparent pathogenic effects, although in the Middle East and Russia related worm species cause cerebrospinal nematodiasis and lumbar paralysis in sheep and goats. Adults are 35-100 mm long (females up to 130 mm) and occur in the peritoneal cavity. Microfilariae are found in the blood. Intermediate hosts in Australia probably are mosquitoes and possibly the stable fly, *Stomoxys calcitrans*.

13.9. *Ascaris suum*, *Toxocara* and *Gongylonema* spp

See Tables 4 and 5.

Main references/bibliography

In producing this paper we have relied particularly on the following:

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Table 2. Some laboratory tests for worms – Example from NSW Agriculture Veterinary Laboratories

Test	Purpose	Sample required	Cost of test incl GST	Comments
WormTest “Gold” (Faecal egg count +/- larval culture)	Monitor worm egg counts. Can be used after drenching to check drench effectiveness.	Faecal samples from 10 animals.	Worm egg count \$42.50. Worm egg count plus larval differentiation \$57.30. Liver fluke egg count (2 counts of pooled faeces) \$37.40 (5 counts of pooled faeces) \$61.95	10 individual egg counts + average count +range. Worm type (larval diff.) also if requested. Use a WormTest kit, available from Rural Lands Protection Boards, stock and station agents and NSW Agriculture.
WormTest “Basic” (Faecal egg count +/- larval culture)	Monitor worm egg counts. Can be used after drenching to check drench effectiveness. Check with your adviser.	Faecal samples from 10 animals.	Worm egg count \$26.65 Worm egg count plus larval differentiation \$39.50 Liver fluke egg count (2 counts of pooled faeces) \$37.40 (5 counts of pooled faeces) \$61.95	Egg counts are done on two pools each consisting of five samples i.e. two egg counts + average. Worm type also if requested. Use a WormTest kit, available from Rural Lands Protection Boards, stock and station agents and NSW Agriculture.
Liver Fluke ELISA1	Test for liver fluke infection.	Blood samples (serum).	Single sample \$16.25 More than one sample \$10.75 ea	Can detect infected animals before they shed fluke eggs. Best as herd/flock test (12-15 samples preferred).
DrenchRite™ (<i>In vitro</i> larval development assay)	Test for drench resistance.	Bulk faecal sample from 20 animals.	\$262.10	Sheep should not have been drenched in the last 8 weeks. Can test BZ, LEV, BZ+LEV, and in some cases, ML drenches. Little on-farm effort required.
DrenchTest (Faecal egg count reduction tests)	Test for drench resistance.	Faecal samples from untreated and treated animals.	\$220.45 for a test with 3 treatment groups and the control group. (\$57.50 per extra group)	Can be customised to test any drench. More on-farm effort required, however, DrenchTest is more flexible and yields more information than DrenchRite™
Closantel Resistance Test (<i>In vitro</i> larval migration assay)	Test for closantel resistance in barber’s pole worm.	Bulk faecal sample from 20 animals.	\$248.50 Also requires single egg count (\$11.40) + larval diff. (\$24.05) = Total \$283.95”	Sheep should not have been drenched with a closantel drench in the last 8 weeks. Little on-farm effort required.
Note: [1] Similar parasitology tests are available from other accredited government and private laboratories around Australia. [2] The tests outlined above are mostly relevant to sheep and goats, but the ‘WormTests’ and liver fluke ELISA are applicable to cattle also. [3] Prices current at time of writing (Dec 2002) and are included to indicate relative costs of different tests. [4] Other parasitology services – including total worm counts, and parasite identification – are not listed. Contact your laboratory for further information.				

Table 3. Larval cestodes of sheep and cattle (adapted from Cole (1986))

Definitive host		Intermediate host/larval stage				
Tapeworm, length, location	Definitive host	Larval stage	Intermediate hosts	Location	Size	Appearance
<i>Echinococcus granulosus</i> , 4-6mm (4-6 segments), small intestine	dog, dingo	<i>E. granulosus</i> (hydatid cyst)	Sheep, cattle, goat, pig, wallaby, kangaroo, man	Liver, lung, kidneys, spleen, heart, brain, bone	4-5 mm at 3 months, 20 mm at 6 months	Viable cysts enclosed within fibrous capsule and embedded in substance of affected organ. If fertile, contain many scolices ('hydatid sand'). Degenerated cysts contain caseous material that 'shells out'.
<i>Taenia ovis</i> , 2m, small intestine	dog	<i>Cysticercus ovis</i> (sheep measles)	Sheep, goat	Heart, diaphragm, masseter muscles, oesophagus, all striated muscle	3-6 mm at 7 weeks. Oval shape, up to 10 mm long.	Viable cysts contain fluid and a single protoscolex. Dead cysts become calcified.
<i>Taenia saginata</i> , 4-10m, small intestine	man	<i>Cys. bovis</i> (beef measles)	Cattle, buffalo, deer, giraffe	Heart, tongue, masseter muscles, diaphragm, all striated muscle	Variable in size: 2-20 mm, average 5 mm Fully developed in 16 weeks.	Viable cysts contain fluid and a single protoscolex. Degenerated cysts become caseous and calcified.
<i>Taenia hydatigena</i> , 3m, small intestine	dog, dingo	<i>Cys. tenuicollis</i> (bladder worms)	Sheep, cattle, goat, pig	Liver and abdominal cavity	Average 50mm; range 1-60 mm.	Cysts loosely attached to surface of viscera. Contain clear, jelly-like fluid and a single large scolex.

Note: *Taenia pisiformis*, *T. serialis* and *Dipylidium caninum* are common tapeworms of dogs, foxes and dingoes that need to be differentiated from *T. ovis* and *T. hydatigena*. The intermediate hosts of *T. pisiformis* and *T. serialis* are the rabbit and hare. The flea and possibly the biting louse are the intermediate hosts for *D. caninum*.

Table 4. Sheep parasites - summary (adapted from Cole 1986)

Parasite, length, location	Gross pathology	Clinical signs	Significant faecal egg counts (FECs) and worm counts (WC); other
<i>Haemonchus contortus</i> -'barbers pole worm'. 10-30mm. Abomasum.	Abomasum oedematous in heavy and chronic infections. Pinpoint haemorrhages. Red and white 'barbers pole' appearance of females. Abomasal contents brown from leakage of blood.	<i>Heavy infections</i> Mainly in young sheep but all ages can be affected. Exercise intolerance. Anaemia, submandibular oedema, constipation, rapid death. <i>Light infections</i> Ill thrift, mild anaemia.	<i>FECs</i> 2 000+ may be clinically significant. Around 30 000 in heavy infections. Eggs typically strongyle. <i>WCs</i> Heavy infections: 2 000-10 000 worms Light infections 500-1000 worms. <i>Egg output</i> 5-10 000 per female per day. Blood loss from host ~ 0.05 ml per worm per day.
<i>Ostertagia</i> spp - 'small brown stomach worm'. 6-10mm. Abomasum.	<i>Heavy infections</i> Weight loss; worms visible on mucosa in clumps, whitish nodules from worms in gastric glands; folds oedematous, congested.	Weight loss, scouring and even deaths depending on severity of infection.	<i>FECs</i> 500+ may be clinically significant, however significant disease can occur with lower FECs. Eggs typically strongyle. <i>WCs</i> Heavy infections: 5 000-10 000+ worms Light infections 1000-2000 worms. <i>Egg output</i> 100-200 per female per day
<i>Trichostrongylus axei</i> -'stomach hair worm' 3-4mm. Abomasum.	Infections usually light. Much smaller than <i>Ostertagia</i> and difficult to see. Worms mainly in pyloric region. Gastritis in heavy infections.	May contribute to scouring-ill thrift syndrome in mixed/heavy infections.	<i>FECs</i> Counts usually low. Moderate infections may contribute 500-1000 epg to mixed infections. Eggs typically strongyle. <i>WCs</i> Range 2 000-7 000 worms in mixed infections.
<i>Trichostrongylus</i> spp -'black scour worm'. 4-7mm. Small intestine.	<i>Heavy infections</i> Carcase emaciated; mucous exudate, flattening of mucosa (villous atrophy). Worms in first 3 m of SI but hard to see. Mesenteric lymphadenomegaly and oedema.	Especially affects young sheep. <i>Heavy infections</i> Rapid weight loss, scouring, death. <i>Note</i> Pathogenic effects of <i>Trichostrongylus</i> and <i>Ostertagia</i> appear to be more than additive.	<i>FECs</i> 500 -2000 may be significant; over 2000 in heavy infections. Eggs typically strongyle. <i>WCs</i> Heavy infections: 5 000-10 000+ worms Light infections 1000-2000 worms. <i>Egg output</i> 200 per female per day

<i>Nematodirus</i> spp - 'thin-necked intestinal worm'. 10-23 mm. Small intestine.	<i>Heavy infections</i> Worms visible as tangled red mass, concentrated in middle of SI. No specific gross lesions.	Usually non-pathogenic. <i>Heavy infections</i> May be seen in young sheep under dry conditions. Profuse diarrhoea, deaths.	<i>FECs</i> Heavy infections: 500-2000, but sometimes quite low. Light infections: 50-300. Eggs large and easily distinguishable from strongyle. <i>WCs</i> Heavy infections: 5 000-15 000+ worms Light infections 1000-2000 worms. <i>Egg output</i> 25-30 per female per day
<i>Cooperia</i> spp. 5-8 mm. Small intestine.	No evidence of specific effects. Relatively uncommon in sheep.	No characteristic signs. Usually in mixed infections.	
<i>Bunostomum trigonocephalum</i> - 'hookworm'. 12-26 mm. Small intestine.	Uncommon. Worms clearly visible. Infections usually light. Focal haemorrhages in intestinal mucosa and lungs. Variable anaemia.		<i>FECs</i> Low and of little diagnostic value. Eggs typically strongyle. <i>WCs</i> Range 300-1000 may cause ill thrift, anaemia.
<i>Strongyloides papillosus</i> . 4-6 mm. Small intestine.	Heavy natural infections seldom seen. Experimentally: ascites, catarrhal enteritis, mucosal oedema.	Experimentally: dyspnoea (migrating larvae in lungs) and diarrhoea. <i>Heavy infections</i> Most likely in young sheep under wet conditions.	<i>FECs</i> Heavy experimental infections: 2000-10 000. Eggs smaller than common strongyles and embryonated. <i>WCs</i> Experimental: 100 000-300 000.
<i>Trichuris</i> spp - 'whipworm'. 40-80 mm. Caecum.	Common in tip of caecum, but mostly unimportant. May be important in some conditions eg drought. <i>Heavy infections</i> Thickening and haemorrhage of mucosa; accumulation of mucus.	Usually non-pathogenic. <i>Heavy infections</i> May be seen in young sheep under dry conditions. Ill thrift, mucoid diarrhoea, deaths.	<i>FECs</i> Generally low but useful to diagnose presence of <i>Trichuris</i> . Eggs characteristic (brown with transparent polar plugs). <i>WCs</i> Several hundred in heavy infections but hard to count as worms clump together.

<i>Oesophagostomum columbianum</i> - 'nodule worm'. 12-21 mm. Colon.	Stout white worm with hooked head. Larvae develop in nodules of SI (small gritty lesions) and LI (caseous lesions). Nodules elsewhere in viscera also. <i>Heavy infections</i> Colon thickened, oedematous. Adhesions between loops of bowel. Once a major summer -rainfall parasite, second only to <i>Haemonchus</i> . Still causes losses at some abattoirs (condemnation of nodule-affected small intestines).	Rarely seen now. Weight loss, stiff gait, weakness, intermittent scour.	<i>FECs</i> Heavy infections: 500-1000. <i>WCs</i> 100 worms pathogenic in weaners; 200-300 in adults. <i>Egg output</i> 5-12,000 per female per day.
<i>Oesophagostomum venulosum</i> - 'large bowel worm'. 11-24 mm. Caecum.	Similar to <i>O. columbianum</i> but head not hooked. Relatively non-pathogenic. Results in few if any nodules. <i>Heavy infections</i> Patchy mucosal congestion.	Relatively non-pathogenic. Experimental: scouring, ill thrift. May have partly filled niche vacated by <i>O. columbianum</i> eg in NSW Northern Tablelands.	<i>FECs</i> Uncertain significance. Eggs typically strongyle. <i>WCs</i> Heavy infections; 200-300. <i>Egg output</i> probably similar to <i>O. columbianum</i> (5-12,000 per female per day).
<i>Chabertia ovina</i> - 'large mouthed bowel worm'. 14-20 mm. Colon.	Stout greyish-white worm. Attached to mucosa by buccal capsule (visible as a knob), resulting in petechiae. <i>Heavy infections</i> Mucosa thickened, oedematous, longitudinally ridged.	Widely distributed in winter rainfall areas. Heavy infections uncommon. Light infections: passage of soft faeces with brown mucus and flecks of blood.	<i>FECs</i> Not a specific guide however 1000-2000 may be significant. Eggs typically strongyle. <i>WCs</i> Heavy experimental infections; 500-700 worms Light infections: less than 100 worms. <i>Egg output</i> 5,000 per female per day.
<i>Dictyocaulus filaria</i> - 'large lungworm'. 30-100 mm. Lungs.	<i>Heavy infections</i> (uncommon) Adults in bronchi and bronchioles cause dark red-grey consolidation of caudal lobes and chronic catarrhal bronchitis.	Usually in small numbers, and mostly in young sheep. May cause coughing. <i>Heavy experimental infections</i> Dyspnoea, secondary pneumonia, deaths.	<i>FECs</i> First stage larvae (with distinctive knob on head) passed in faeces. <i>WCs</i> White thread-like worms clearly visible in bronchi. Heavy infections: intertwined worms extend to bifurcation of trachea. Light infections: less than 50 worms.
<i>Muellerius capillaris</i> - 'small lungworm'. 12-22 mm. Lungs.	Adults in (lead) shot-like nodules in lung, immediately under pleura.	Ill thrift in artificially infected sheep.	<i>FECs</i> First stage larvae (no knob on head, but dorsal spine on tail) passed in faeces. <i>WCs</i> Adults live in nodules under lung surface.

<i>Protostrongylus rufescens</i> - small lungworm. 16-35 mm. Lungs.	Rare in Australia. Slender worms which may cause bronchiolitis and focal pneumonia.		<i>FECs</i> First stage larvae (no knob on head, or dorsal spine, but tail is pointed) passed in faeces. <i>WCs</i> No guidelines. Worms reddish and slender.
<i>Ascaris suum</i> . Liver <i>Note: Rare, academic interest only?</i>	Rare infections in sheep, infected from pigs. No specific lesions reported in sheep.	No specific signs reported (II thrift in pigs)	<i>FECs</i> Characteristic eggs: brown, thick with pitted outer walls. <i>WCs</i> Worms large and clearly visible in small intestine and bile ducts.
<i>Gongylonema</i> spp. Oesophagus, rumen <i>Note: Rare, academic interest only?</i>	Rare parasite in Australia. Found tightly coiled or as a zigzag in mucosa of oesophagus and forestomachs. No known pathogenic effects. Adults are large nematodes: 60-150 mm long.		Worms long, threadlike, red.
<i>Fasciola hepatica</i> - liver fluke. 20-30 mm. Liver.	<i>Acute fasciolosis</i> (massive infection) Severe anaemia, bloody peritoneal fluid, peri-hepatic fibrinous peritonitis, haemorrhagic tracts in liver. <i>Subacute form</i> Some adults in bile ducts, anaemia, haemorrhagic tracts. <i>Chronic form</i> Bile ducts fibrosed thickened and may contain adult fluke.	Variable, ranging from abdominal pain, severe anaemia and deaths to milder anaemia, submandibular oedema and production loss.	<i>FECs</i> 100+ may be associated with disease (acute and subacute: 150-2500; chronic: 2000-4000), however low counts may be associated with significant production loss. Eggs large yellowish brown, with operculum. <i>Total fluke counts</i> Acute: 1000+ Subacute: 500-1000 Chronic: 100-400 <i>Egg output</i> 10-20,000 per female per day, possibly for life (5-10 years or more)
Paramphistomes. 5-12 mm. Rumen, reticulum, small intestine.	Most damage done by immature parasites embedded in or attached to SI mucosa causing erosions, haemorrhage and oedema. Necrosis of ruminal papillae also may occur.	Rarely causes clinical disease in sheep. Anorexia, watery diarrhoea, submandibular oedema.	<i>FECs</i> Low in acute disease. Eggs large, transparent with operculum. <i>Total fluke counts</i> Acute: 10 000 (up to 100 000) immature fluke in SI.
<i>Moniezia</i> spp., <i>Thysaniezia</i> sp. 1-6 m. Small intestine.	Little or no pathology.	Questionable importance.	<i>FECs</i> Variable numbers. Eggs medium size, triangular, dark grey. <i>WCs</i> Worms may fill the SI of young lambs. No specific lesions.

Important note: This is an overview only. Egg and worm counts are merely indicative. Opinions vary on levels on the significance of different counts for various worms. Additionally, egg and worm counts need to be interpreted in light of the nutritional and physiological status as well as age of the host.

Table 5. Cattle parasites -summary (adapted from Cole 1986)

Parasite, length, location	Gross pathology	Clinical signs	Significant faecal egg counts (FECs) and worm counts (WC); other
<i>Haemonchus placei</i> . 10-30mm. Abomasum.	Blood clots and mild abomasitis in heavy infections. Red and white 'barbers pole' appearance of females; worms clearly visible. Light infections: no gross lesions.	<i>Heavy infections</i> Mainly in young cattle in summer rainfall areas. Usually with <i>Oes. radiatum</i> and <i>Cooperia spp.</i> Exercise intolerance. Anaemia, submandibular oedema. <i>Light infections</i> Ill thrift, mild anaemia.	<i>FECs</i> 700-1500+ may be clinically significant. Eggs typically strongyle. <i>WCs</i> Heavy infections: 5 000-10 000+ worms. Mainly in calves. Generally less important than <i>Haemonchus</i> in sheep.
<i>Ostertagia</i> spp - 'small brown stomach worm'. 6-10mm. Abomasum.	An important pathogenic parasite of young and adult cattle. Larvae entering gastric glands produce small white crater-like nodules which coalesce to give mucosa 'morocco leather' look. Inflammatory response with oedema and congestion when larvae emerge from glands. Type I and II lesions similar. Gross distension of folds seen in type II.	Type I affects young dairy calves and beef weaners in post-weaning period. Type II affects yearlings, pregnant heifers and old cows. Typical acute symptoms: anorexia, severe weight loss, scouring, submandibular oedema and deaths depending on severity of infection. Lighter infections: ill thrift, moderate scour.	<i>FECs</i> 300+ may be clinically significant; however significant disease can occur with lower FECs. Counts generally low, up to 1500+. Eggs typically strongyle. <i>WCs</i> Up to 100 000 - 600 000+. Up to 80% may be arrested in type II disease.
<i>Trichostrongylus axei</i> -'stomach hair worm'. 3-4mm. Abomasum.	Infections usually light. Much smaller than <i>Ostertagia</i> and difficult to see. Worms mainly in pyloric region. Gastritis in heavy infections with congestion and ringworm-like lesions.	May contribute to scouring-ill thrift syndrome in mixed/heavy infections.	<i>FECs</i> Counts usually low. Moderate infections may contribute 500-1000 epg to mixed infections. Eggs typically strongyle. <i>WCs</i> Heavy infections: 100 000 - 5000 000 worms.
<i>Trichostrongylus</i> spp. 4-7mm. Small intestine.	Rarely produces lesions or clinical disease in cattle and is an uncommon parasite.		<i>FECs</i> No diagnostic value. Eggs typically strongyle. <i>WCs</i> No information.

<i>Nematodirus</i> spp. - 'thin-necked intestinal worm'. 10-20 mm. Small intestine.	No specific gross lesions. A rare parasite of beef cattle; seen occasionally in dairy calves in mixed infections.	Usually non-pathogenic.	<i>FECs</i> . Eggs large and easily distinguishable from strongyle. Useful for diagnosis. <i>WCs</i> Heavy infections: rare but may be seen in dairy calves (10 000 worms)
<i>Cooperia</i> spp. 5-9 mm. Small intestine.	The most common small intestinal worm. Usually in mixed infections with <i>Ostertagia</i> (or <i>Haemonchus</i> in (sub) tropical areas. Heavy infections are pathogenic for young calves. Catarrhal enteritis, patchy necrosis, haemorrhages. Emaciation.	Mainly in calves: Intermittent diarrhoea, ill thrift. Listlessness, death. Usually in mixed infections.	<i>FECs</i> Counts in young calves up to 1000 - 5000. In acute disease, from 10 000 - 30 000. Eggs typically strongyle. <i>WCs</i> Heavy infections (eg dairy calves): 50 000 - 200 000 worms.
<i>Bunostomum phlebotomum</i> - 'hookworm'. 10-28 mm. Small intestine.	Infection can be percutaneous. Focal haemorrhages in intestinal mucosa, and lungs, though which larvae migrate en route to the gut. Variable anaemia. Parasite's large buccal capsule strips off villi, producing inflammation and exudation. Mainly affects dairy calves in (sub) tropical coastal areas.	Dull demeanour, anaemia, submandibular oedema, dark foetid scour.	<i>FECs</i> 500 - 800 in heavy infections. Eggs typically strongyle. <i>WCs</i> 100-500+ may cause ill thrift, anaemia in young dairy calves.
<i>Strongyloides papillosus</i> . 4-6 mm. Small intestine.	Common in dairy calves in Queensland, especially if cross grazed with lambs. Percutaneous infection occurs. Calves can be become heavily infected, but infections rapidly eliminated naturally.	Heavy infection said to produce 'white scour' syndrome.	<i>FECs</i> Eggs smaller than common strongyles and embryonated. <i>WCs</i> Infections of 5000 worms have been found in calves.
<i>Trichuris</i> spp - 'whipworm'. 40-80 mm. Caecum.	Not a serious parasite of cattle. Pathogenic importance unknown.	Usually non-pathogenic.	<i>FECs</i> Generally low but useful to diagnose presence of <i>Trichuris</i> . Eggs characteristic (brown with transparent polar plugs). <i>WCs</i> Several hundred in heavy infections but hard to count as worms clump together.

<i>Oesophagostomum radiatum</i> - 'nodular worm'. 14-22 mm. Colon.	Very pathogenic parasite. Common in young cattle 4-12 months old in tropical and sub-tropical areas. Third stage larvae form nodules, mainly in ileum but also caecum and colon. Colon thickened, oedematous. Excess mucus.	Heavy infections: weight loss, scour, anaemia, submandibular oedema, and death. Histiotropic phase may also cause ill-effects.	<i>FECs</i> Low counts usual: 300-500. A count of 500 may be significant. Eggs typically strongyle. <i>WCs</i> Heavy infections: 1500 - 4000 worms. Light to medium: 500 - 800.
<i>Oesophagostomum venulosum</i> - 'large bowel worm'. 11-24 mm. Caecum.	Not an important parasite of cattle. Usually present in small numbers.	Relatively non-pathogenic.	<i>FECs</i> Uncertain significance. Eggs typically strongyle. No value for diagnosis.
<i>Chabertia ovina</i> - 'large mouthed bowel worm'. 14-20 mm. Colon.	Rare parasite of cattle. Occurs in sheep areas, e.g. tablelands of NSW. Pathological lesions have not been reported.	No specific clinical signs reported.	<i>FECs</i> As for <i>Oes. columbianum</i> .
<i>Dictyocaulus viviparus</i> - 'large lungworm'. 40-80 mm. Lungs.	A serious parasite of calves in Europe but relatively unimportant in Australia, although heavy infections are seen in dairy calves. Heavy infections (uncommon): Adults in bronchi and bronchioles cause dark red-grey consolidation of caudal lobes and chronic catarrhal bronchitis.	May cause coughing, weight loss. Often seen in conjunction with gastrointestinal helminthosis.	<i>FECs</i> First stage larvae (with distinctive knob on head) passed in faeces. <i>WCs</i> Blockage of bronchi and bronchioles with white thread-like worms indicative of pathogenic effects.
<i>Onchocerca</i> spp. Brisket, ligamentum nuchae, gastrosplenic ligament.	<i>O. gibsoni</i> forms nodules 10-20 mm in connective tissue of brisket, stifle and hip regions, <i>O. gutturosa</i> mainly in the lig. nuchae, and <i>O. lienalis</i> in the gastrosplenic ligament.	No clinical signs. Lesions may be palpable. Microfilariae in skin snips. Lesions normally detected at meat inspection.	Insect borne (midges).
<i>Thelazia</i> spp. Eye.	White nematode in conjunctival sac, lachrymal ducts, and nasolacrimal canal. Associated with conjunctivitis and keratitis but also found in normal eyes.	Worms behind third eyelid and in lachrymal ducts, so worms are difficult to detect clinically. Larvae recoverable from saline eye washings.	Insect borne (flies).

<i>Toxocara vitulorum</i> Adult worms large: ~20-25 cm. Small intestine.	Rare parasite in Australia. No specific lesions/signs. Adult worms large: ~ 20-25 cm.		<i>FECs</i> Eggs characteristic: spherical with thick pitted outer shell and granular contents.
<i>Ascaris suum</i> Lungs.	Pneumonia. Presence of <i>A suum</i> .	Case reported from South Australia where infected yearling cattle developed respiratory distress. Also Atherton Tablelands (northern Queensland).	
<i>Stephanofilaria</i> spp. Small parasite 2.5. - 4.5 mm long Skin	Found in small cysts (up to 4 parasites per cyst) just beneath skin surface in <i>Bos indicus</i> cattle. Lesions raised circumscribed hairless areas on head, neck, dewlap and sternum.	Cattle rub and scratch lesions.	Insect borne (buffalo fly).
<i>Setaria labiato-papillosa</i> . Adult s 35-100 mm long. Peritoneal cavity	Found in north Queensland. No pathogenic effects. Adult sin peritoneal cavity 35-100 mm long.	Microfilariae found in blood.	Insect borne. Found in north Queensland.
<i>Gongylonema</i> spp. Adults are large nematodes: 60-150 mm long Oesophagus, rumen.	Found in oesophageal and ruminal submucosa or mucosa. No known pathogenic effects. Adults are large nematodes: 60-150 mm long.		
<i>Fasciola hepatica</i> - liver fluke. 20-30 mm. Liver.	<i>Acute fasciolosis</i> (massive infection) Severe anaemia, ascites, haemorrhagic tracts in liver. <i>Chronic form</i> (most common in cattle) Bile ducts fibrosed, thicken	Variable, but usually mild/non-specific in cattle but sometimes with significant production losses. Anaemia and deaths may occur rarely. An important cause of liver condemnations at abattoirs.	<i>FECs</i> Little correlation between <i>FECs</i> and worm burdens. Low counts can be associated with significant production loss. Eggs large yellowish brown, with operculum. <i>Total fluke counts</i> Light infestation up to 50; medium 50-100; heavy >100.

Paramphistomes. 5-12 mm. Rumen, reticulum, small intestine.	Most damage done by immature parasites embedded in or attached to SI mucosa causing erosions, haemorrhage and oedema. Necrosis of ruminal papillae also may occur. Adults provoke little reaction.	Young cattle: Anorexia, watery diarrhoea, submandibular oedema (due to immature paramphistomes). Adult cattle: production loss and mild clinical signs (rough coat, mild anaemia) has been reported (adult parasites).	<i>FECs</i> Low in acute disease. Eggs large, transparent with operculum. <i>Total fluke counts</i> Acute: 10 000 (up to 100 000) immature fluke in SI.
Moniezia spp., Thysaniezia sp. 1-6 m. Small intestine.	Little or no pathology.	Questionable importance. Common, particularly in calves grazed with sheep.	<i>FECs</i> Variable numbers. Eggs medium size, triangular, dark grey. <i>WCs</i> Tapeworms are large but few are present.
Important note: This is an overview only. Egg and worm counts are merely indicative. Opinions vary on levels on the significance of different counts for various worms. Additionally, egg and worm counts need to be interpreted in light of the nutritional and physiological states as well as age of host.			