Taeniid tapeworms incl T.ovis ('sheep 'measles') – some notes  SL, DPI Armidale May 2016

Following is my interpretive summary of various, especially Jenkins et al, 2014 (J1). These are somewhat disorganised notes, not a polished treatise! Information mostly from J1 unless stated otherwise.

J1: “Data collected through the Australian National Sheep Health Monitoring Program (NSHMP) (AHA, 2011) reported metacestodes of T. ovis to be widespread and common in sheep slaughtered in mainland Australia\(^1\), but less common in Tasmania. Sheep infected with metacestodes of T. hydatigena are also found commonly in slaughtered sheep from all sheep rearing areas of mainland Australia but less commonly in Tasmania (Animal Health Australia, unpublished data)”

~~~~~~~~~~~~~~

[SL:] Prevalence of sheep measles and of adult T ovis in AU. In 2014-2015, ~ 15000 lines of sheep (incl. lambs) which amounted to ~ 3 million sheep incl. lambs were inspected as part of NSHMP. This was in 18 abattoirs, across various states. Approx two thirds of the lines were direct lines (direct consignments to the abattoir). However, two of the biggest mutton processors in NSW (Dubbo, Goulburn) are not part of NSHMP. In 2015, approx. 31 million sheep were slaughtered in AU (~ 8.5M sheep, 22.2 M lambs). Total AU sheep pop is ~ 70M (Source: MLA). So, the sheep inspected under NSHMP is about 10% of all those slaughtered and two major mutton processors are not involved. Question then: how representative are the NSHMP results of the AU sheep population? Indicative only?

J1, citing NSHMP data, say sheep measles (metacestodes of T ovis) are widespread and common in sheep slaughtered in AU, especially in mainland AU. While lines of sheep may be commonly affected, the proportion of individual sheep sheep affected is somewhat lower, generally a few to several percent. But then we don’t have data from two bigmutton processors. Also note in individual cases, prevalence within a line can be quite high, e.g. one case: 400 lambs went to a NSW abattoir (Oberon), 100 carcases were condemned or severely trimmed due to T ovis (B McLeod, pers comm). (Is this something like the T ovis 'storms' that NZers talk about? (Naïve young sheep exposed to heavily infected pasture?))

~~~~~~~~~~~~~~

\(^1\) But, is it the case that, at the abattoir, flock/mob prevalence of sheep measles) is high, but individual animal prevalence is somewhat lower? - SL
Prevalence of *T. ovis* in canid hosts in AU?: J1 examined approx. **500 foxes** (*T. ovis* found in two foxes (1/97 (Jugiong NSW) and 1/102 (Katanning WA)), **52 wild dogs** (with no *T. ovis* found. More dogs are currently being sampled?), and **245 rural domestic dogs** (one dog (from TAS)) found with *T. ovis*).

In Australia, only *Taenia ovis* and *T. hydatigena* of the genus *Taenia* have sheep as their intermediate host (IH). Other *Taenia* spp infecting canids (wild and domestic) – ie *T. pisiformis* and *T. serialis* – uses rabbits as their IH.

*T. ovis* metacestodes (the cysts (4-6mm) are also known as ‘sheep measles’, *Cysticercus ovis*) and are reportedly common and widespread in sheep (heart, diaphragm, sometimes also skeletal muscle) monitored at abattoirs as part of the National Sheep Health Monitoring Program\(^2\) (2011 report), with the prevalence being lower in Tasmania.\(^3\) The situation is similar with *T. hydatigena* (‘bladder worm’ aka ‘false hydatids’, *C. tenuicollis*. Cysts mostly in liver). Common to see sheep measles and bladder worm together in sheep [K].

Bladder worm rarely causes disease on farm but can occasionally cause death by triggering black disease (Clostrid. novyi) [K], as may also happen with migrating liver fluke.

**Adult *T. ovis*** and *T. hydatigena* live in small intestines of canids, commonly domestic dogs. Eggs pass onto pasture in faeces.

**Prepatent period** (PP) for *T. ovis*: **35 days** (K, NZ), 5-8 weeks [UP]; PPP for *T. hydatigena*: 10-12 weeks (K). **J2:** “Each (cyst contains a single tapeworm head and once eaten by a dog, (T ovis) tapeworms take approximately **42 days** to become mature and begin producing eggs.”

(Current) **control strategies**: **J2:** ‘Control strategies rely on regular (ideally monthly) de-worming with a product containing praziquantel and only feeding commercially prepared dog food. However, if sheep meat and/or hearts are to be fed to dogs they should be either thoroughly cooked or frozen for 10 days prior to feeding. Currently there is no commercial treatment to kill infection in sheep or to protect sheep from becoming infected. However, an experimental vaccine for sheep against sheep measles has been developed (Johnson et al 1989)’.

**T. ovis** (eggs) could be **viable on pasture** for at least 300 days. **Spread** by wind, rain and coprophagous flies etc. Sheep infected while grazing.

---


\(^3\) Where there are no foxes
T. ovis never recorded in Australian native herbivores. (c.f. [NZ]: “Sheep ingest tapeworm eggs from the pasture, these eggs can survive on pasture for up to six months but most eggs are no longer viable at four months, length of egg survival is highly dependent on the environment”).

“NZ” on sheep measles lifecycle: http://www.sheepmeasles.co.nz/on-the-farm/sheep-measles-lifecycle/ (Emphases mine-SL)

“Sheep ingest tapeworm eggs from the pasture, these eggs can survive on pasture for up to six months but most eggs are no longer viable at four months, length of egg survival is highly dependent on the environment.

“The eggs if swallowed by a sheep, hatch in the intestine and the larvae migrate through the intestinal wall into the blood stream where they eventually lodge in muscle tissue (e.g. diaphragm, heart and skeletal muscle of sheep) where they develop.

“Cysts become mature in around 35 days and remain alive for up to 90 days in muscle tissue. Some cysts have been found to survive up to 18 months. Once cysts die they become hard gritty and more easily detected at processing.

“The viable cysts are highly infective and one viable cyst consumed by a dog is likely to result in infection. Therefore if dogs are fed or get access to untreated meat containing viable cysts a tapeworm will develop in the dog’s gut and mature in approximately 35 days (PPP=~35 days). The tape worm is extremely fecund and can shed up to three segments a day, each segment containing around 60,000-80,000 eggs. The eggs are expelled when the dog defecates.”

From “NZ”: Sheep measles (‘ovis’ as they call it) storms:

Sheep Measles Storms http://www.sheepmeasles.co.nz/on-the-farm/bringing-in-store-lambs-or-sheep/

“Ovis storms are the result of lambs with low or no immunity being introduced onto infected pastures. Lambs not exposed to Sheep Measles eggs on pastures develop no natural immunity. As a result these lambs are highly susceptible to infection. Should these lambs graze heavily contaminated pastures, the absence of an immune reaction allows many eggs to develop into cysts. The result is an ovis storm with large numbers of lambs heavily infected.”

“These lines have high condemnation and downgrading rates during processing meaning severe financial loss to the farmer. Where more than
five cysts are detected in a carcass at meat inspection, the carcass is condemned.”

T. ovis and T. hydatigena infections not known to cause ill health in sheep or humans (unlike the taeniid cestode, E. granulosus (hydatids, which is a human health hazard). But, T. ovis, and to a lesser extent T. hydatigena, are of economic importance due to downgrading of affected tissues and condemnations at abattoirs and trade implications. [Carcases are trimmed if less than five cysts are found in the muscle. If more than five cysts are found, the carcase is condemned. Trimming and condemnations cost both producers and processors money. (J Coad, LNB)]

J2: ‘Controlling sheep measles would conservatively save the Australian sheep meat industry several million dollars per year’.

T. ovis cysts: 4-6 mm, with single cestode scolex. Cysts infective to dogs after ~ 2 months of development post-infection and remain infective for ~ 1 month (J2: 2-3 months). Host immunity kills cysts which fill with pus and mineralise.

First report of T ovis infected sheep in an Australian abattoir was 1930 (Homebush, NSW). Commercial significance apparent in 1969: 82 000 cartons of boned Australian mutton rejected by USA due to sheep measles.

Domestic dog considered to be main definitive (final) host of T ovis and T hydatigena, but, a survey (Jenkins) of >1400 rural domestic dogs found zero T ovis, hence (their) attention turned to sylvatic cycles (red foxes, dingoes and dingo-domestic dog crosses).

J2: “The study showed domestic and wild dogs appear not to have a major role in transmission but identified the, hitherto unrealised, role of foxes in transmission”

Foxes as (significant) definitive host for T ovis and T hydatigena remains controversial. Two major surveys, with intestines from >2000 foxes examined (NSW and Vic, ~ 1970s): various taeniids were found but zero T ovis or T hydatigena. There was an old report of T ovis in foxes (Pullar, 1946. Method of ID not stated), and a report of T hydatigena in two foxes (1974, NSW central tablelands), but it was concluded in 1974 that foxes were not hosts for these two taeniids. T ovis in foxes in ACT and nearby areas was reported in 1986 (Howkins; using rostellar hook measurement (unreliable)), T hydatigena was reported in a fox from WA in 2013. But, in all cases I.D was based on morphology, viz, rostellar hook arrangement, but this is unreliable due to overlap in hook length between taeniid species.
Status of wild dogs as host for *T. ovis* also unclear. Past studies on wild and rural domestic dogs have commonly focussed on *E. granulosus*, and none have reported *T. ovis*, but some have periodically reported *T. hydatigena* (again based on morphology and/or rostellar hooks).

**Feral cats.** "**Feral cats:** *Taenia ovis* has never been reported in feral cats in Australia (Arundel 1970) or in New Zealand (Sweatman and Williams 1962), however Arundel (1970) reported natural infection in a cat which was passing segments that contained no fully formed eggs. In an experimental infection study with *T. ovis* in 24 cats (Sweatman and Williams 1962) tapeworms in only 7 animals produced eggs. Although this study demonstrated *T. ovis* can establish and develop to patency in some cats, in most cats the parasite does not establish or fails to reach patency. These experimental data and the lack of natural infection data from feral cats suggest cats are not sylvatic definitive hosts for *T. ovis*.

**A PCR assay** was developed ~ 2007 to identify (using eggs or worm tissue) a variety of cestodes. Molecular methods were used in the Jenkins 2014 study.

In the Jenkins 2014 study, **499 foxes** (ACT 13; NSW 231; WA 255) and **52 wild dogs** were examined, with 3 to 102 foxes and 1 to 20 wild dogs collected from each site. Only 5-6% of the **foxes** had *Taenia* spp tapeworms except in the Brindabella/Wee Jasper area\(^4\) (26%). One fox had both *T. hydatigena* and *T. pisiformis*.

About 50% of **wild dogs** (n=52) (NSW, ACT) had *Taenia* spp tapeworms, with 3 dogs having both *T. pisiformis* and *T. serialis*. The cestodes *Spirometra\(^5\)* erinacei and *Dipylidium caninum* were commonly found in foxes and wild dogs, often with *Taenia* spp. **J2:** ‘Although no sheep measles tapeworms were recovered, 7 (13.5%) wild dogs were found infected with *T. hydatigena*. The absence of sheep measles tapeworms and the presence of *T. hydatigena* strongly suggests the sheep being predated or scavenged were the older age groups of sheep those less likely to contain viable sheep measles cysts’. "Curiously infection with *T. ovis* in wild dogs was absent despite 7 being infected with *T. hydatigena*. This absence of *T. ovis* and presence of *T. hydatigena* in wild dogs may be largely influenced by the biology of the parasites, namely the short time cysts in sheep remain infective for definitive hosts and wild dogs more commonly predating on older age groups of sheep, those less likely to

---

\(^4\) Near, just west of, Canberra ACT

\(^5\) *Spirometra* = 'spiral uterus' (G)
contain viable sheep measles cysts. *T. ovis* cysts are only infective to definitive hosts for a few weeks whilst those of *T. hydatigena* remain infective for several years. “

**Rural domestic dogs:** 245 faecal samples/faecal flotations (NSW 125; Tas 101; WA 19). Overall one third had intestinal helminths (range: 38% in NSW, 16% in WA). Just one dog had a taeniid tapeworm, this was *T. ovis* (1/245=0.4% of dogs examined), and the dog lived in Tas., and [J2], was the member of a wallaby hunting pack. Hookworm (sp not identified) was the most common helminths found in all states. Eggs of other tapeworms found: *S. erinacei* and *D. caninum*, and only in NSW.

*T. ovis* was identified (PCR) in just two foxes (one from Jugiong NSW (1 ex 80), the other from Katanning WA) (1 ex 102). So, two out of ~500 (therefore, 0.4% of foxes overall), and no wild dogs (but n=52. Possibly more will be examined).

The Jenkins 2014 study also looked at sequence diversity of *T. ovis* metacestodes in cysts in abattoir material from NSW, Tas and WA. Two genotypes/sequences were observed, both seen in each state, with one of the sequences being the same as a New Zealand sequence. [J1].

*T. hydatigena* was found in one fox and 4 wild dogs, with 3 genotypes being observed. *T. pisiformis* was found in 2 foxes and 15 wild dogs; only 2 genotypes observed. *T. serialis*, the most prevalent species, was found in 21 foxes and 4 wild dogs – one genotype.

**Dietary items** (36 foxes from Jugiong, NSW examined): most common non plant items: insects, followed by sheep remains (22%). Other items included fox remains.

**From J1 discussion:**

This study unequivocally confirms a sylvatic transmission pathway in Australia for *T. ovis*, with fox as definitive host, and for *T. hydatigena* with both foxes and wild dogs as def. hosts. Also, first study to use molecular methods to identify *T. ovis* and *T. hydatigena* from foxes and wild dogs in Australia.

**Role of domestic dogs** in transmission of *T. ovis* and *T. hydatigena* has declined. Possible factors include use of commercial dog food and wide availability of the efficient cestocide, praziquantel. In addition to this study, a study (Jenkins, unpub) of 1425 rural domestic dogs (1119

---

6 NSW southern tablelands, between Yass and Gundagai
from mainland eastern AU and 306 from Tas) found only 11 dogs with Taenia spp, 4 of which had T hydatigena and zero with T ovis. A 2013 study (Palmer et al) in WA dismissed the role of foxes in transmission of T ovis and nominated domestic dogs as having the primary role. Faecal flotation of faeces from 245 dogs in the WA study, and 1425 in Jenkins’, found eggs of Taenia spp were uncommon and T ovis was rare. Jenkins et al disagree with Palmer’s view that foxes are unimportant (in WA at least) and that rural domestic dogs are primary. Jenkins (J1) further cites survey data indicating that, although raw sheep meat/offal is sometimes fed to farm dogs, surveyed farmers (perhaps a biased sample?) de-worm their dogs several times / year (usually every 2-4 months) with an all-wormer containing praziquantel.

Jenkins 2014 (J1) found just 2 foxes with T ovis; 1/80 at Jugiong (NSW) and 1 ex 102 at Katanning (WA). “In each jurisdiction, the T. ovis- infected fox was found in the location where the largest sample was collected, giving a prevalence in each location of approximately one percent.” (Emphases mine-SL).

**Infectivity:** T ovis metacestodes in adult sheep are less likely to be infective (host immune response) than lambs( older than ~ 2 months...it takes ~ 2 months for the cysts to be infective) but T hydatigena metacestodes are likely to be still infective.

Genetic diversity of Taenia spp appears to be low in AU.

**Fox density** in AU is highly variable..e.g from ~ 0.6 / km² to ~ 7 / km². J1 argues that a T ovis prevalence of only ~ 1% still represents a lot of foxes, and also refers to the range of foxes (4-16 km /night), and the longevity of T ovis eggs on pasture (viable for >300 days) and dispersal by wind, rain and mechanical vectors (flies). (And according to “NZ”: one T ovis tapeworm can produce 250 000 eggs/day and some dogs can carry 3-4 T ovis tapeworms (NZ)) (SL: Clearly this needs to be modelled. E.g. what is the likely prevalence of viable T ovis eggs on pasture?).

**T ovis’ final host in Tas?:** J1 says: “Despite the presence of a few, widely dispersed, foxes in Tasmania, from a T. ovis transmission perspective, they are, for the time being, irrelevant. In the absence of wild dogs, rural domestic dogs remain the only widely available, potential definitive host for T. ovis in Tasmania in contrast to mainland Australia.” (SL: Talking to a NSW-based vertebrate pest researcher today (20/5/16): **there are no longer foxes in Tasmania**; however, in the more or less recent past, fox scats and blood have been found (DNA evidence) in TAS.
It is said that sometime during 1998-2001, there was a successful illegal release of foxes into TAS (J1). More info/discussion –see footnote.7

**J1**: “In the absence of wild dogs, rural domestic dogs remain the only widely available, potential definitive host for T. ovis in Tasmania in contrast to mainland Australia” (SL: By ‘wild dog’ I assume Jenkins means a free ranging dog not dependant on humans apart from their livestock).

Control of taeniid worms is theoretically possible through use of praziquantel-mediated baits (a German study is cited), but this is impractical in AU.

**J1**: “In view of our findings in respect of T. ovis in foxes, the most practical parasite control strategy, would be maintaining conventional control for domestic dogs, but in addition, to also provide protection for sheep through vaccination.”

Following is the entire last para from J1. (Doubtless opinions on this will vary).

“In 1989 data were published on a recombinant vaccine for sheep against T. ovis (Johnson et al., 19898). This highly efficient vaccine was registered for use in New Zealand but never in Australia. The vaccine is no longer available in New Zealand, not because of a lack of efficacy but because of a marketing oversight in that the vaccine was manufactured as a “stand alone” vaccine. Since most of the financial loss due to sheep measles in New Zealand was borne by the processors and not the farmers, farmers were not motivated to buy the vaccine. Had the vaccine against T. ovis been included with a vaccine producers were obliged to use to maintain the wellbeing of their sheep, the vaccine would have been used widely and solved the infection issues with T. ovis in New Zealand sheep. Since there are no potential wildlife definitive hosts in New Zealand to perpetuate transmission, over time, there is a realistic possibility T. ovis could have been eradicated. In the Australian environment, there is little doubt if the strategy of vaccinating sheep was adopted by producers and particularly if abattoirs also paid a premium for sheep vaccinated against T. ovis, infection, levels of infection in Australian sheep would fall rapidly. Despite the presence of sylvatic definitive hosts perpetuating

---

7 http://theconversation.com/tasmanias-fox-hunt-was-worth-it-even-if-there-were-no-foxes-34045
transmission, with wide uptake of the vaccine it is realistic to anticipate, in time, T. ovis could also be eradicated in Australia.”

**Farmer survey [J2].** 241 farmers in 3 states (NSW (90), TAS (87), WA (64)) were surveyed. Overall response rate ~ 40%. Many questions asked. One question: Frequency of deworming (Mean, SD) in months 5.6 (3.4) “No other identifiable on-farm risk factors for T.ovis transmission could be identified, except in NSW, where there was a weak correlation between farmers who bought in hay compared to those who did not. However, this correlation was not evident in either WA or Tasmania.”

**Cost to processors.** J2: ‘The financial losses borne by abattoirs (5 abattoirs, 3 states (NSW, TAS, WA) vary between states and the type of enterprise. Processors losing the most are those killing and processing older age groups of sheep, whilst for those processing predominately lambs the losses are lower. Mutton processors in WA appear to be the worst affected, losing an average of $2,138/day, however, daily spikes may be in excess of $4,000/day whilst in NSW losses are lower, averaging around $1,100/day. For lamb processors the impact of sheep measles is lowest at less than $100/day. Our study indicates the impact of sheep measles on the Australian sheep meat industry conservatively amounts to several million dollars per year’. “The best data set was obtained from Fletcher International in WA.”

J2: ‘The establishments concentrating mainly on lambs (TQM and GMP) suffer the least financial impact, those processing mainly mutton the most. Within the mutton processing establishments, it was evident that the impact in WA was about double that experienced in NSW’.


Abstract:
Great variation in the fecundity of *Taenia ovis* and *T. hydatigena* has been reported between dogs. For *T.ovis*, prepatent periods from 44 to more than 126 days, and longevity as short as 110 days, have been reported. One dog in that study was reported to be still passing *T.ovis* proglottides 5 years after infection. This communication records further details of that infection...

**Population dynamics...**

Parasitology / Volume 94 / Issue 01 / February 1987, pp 161-180

Research Article
Population dynamics in echinococcosis and cysticercosis: evaluation of the biological parameters of Taenia hydatigena and T. ovis and comparison with those of Echinococcus granulosus

M. A. Gemmell\textsuperscript{a1}, J. R. Lawson\textsuperscript{a1} and M. G. Roberts\textsuperscript{a2}

\textsuperscript{a1} Hydatid Research Unit, Research Division, Ministry of Agriculture and Fisheries, University of Otago Medical School, Dunedin, NZ

\textsuperscript{a2} Wallaceville Animal Research Centre, Research Division, Ministry of Agriculture and Fisheries, Private Bag, Upper Hutt, NZ

Abstract

An evaluation has been made of the biological and epidemiological parameters that determine the basic reproductive rates of Taenia hydatigena and T. ovis. These host-parasite systems are characterized by (i) no overcrowding in either host; (ii) no parasite-induced mortality of either host; (iii) no density-dependent constraint in the definitive host, but a strong, rapidly mobilized, short-acting immunity in the intermediate host and (iv) egg production which, in the natural environment, is high enough to prevent superinfection. It is considered that tapeworms with these characteristics are more stable to fluctuations in environmental conditions and to control measures such as dog dosing, than species which have a low egg production and infectivity such as Echinococcus granulosus. Reciprocal immunity exists between T. hydatigena and T. ovis in sheep. Exposure to T. hydatigena suppresses infection by T. ovis, but not by E. granulosus. This has important epidemiological consequences where these parasites co-exist.

\textbf{Sources/references:}

\textbf{Coad J.} \url{http://www.lbn.org.au/2015/09/30/sheep-measles-could-be-costing-you/}

\textbf{J1:} 2014. D.J. Jenkins et al. / International Journal for Parasitology: Parasites and Wildlife 3 (2014) 75–80 Red foxes (Vulpes vulpes) and wild dogs (dingoes (Canis lupus dingo) and dingo/domestic dog hybrids), as sylvatic hosts for Australian Taenia hydatigena and Taenia ovis

David J. Jenkins a,\textsuperscript{a, f}, Nigel A.R. Urwin a, Thomas M. Williams a, Kate L. Mitchell a, Jan J. Lievaart a, Maria Teresa Armua-Fernandez


G: Georgi’s Parasitology for Veterinarians. ISBN 0-7216-9283-4


MVM: http://www.merckvetmanual.com

NZ: http://www.sheepmeasles.co.nz/ (Many thanks to Dr Ginny Dodunski.) Topics at this site: Sheep Measles, The Issue; Sheep Measles Lifecycle; Dog Treatments/Dosing; Safe Feeding Of Meat; Home Killing; Disposal Of Dead Stock; On-Farm Dog Control; Foreign Dogs; Bringing In Store Lambs Or Sheep; Hydatids; New Dogs


UP: http://cal.vet.upenn.edu/projects/parasit06/website/index.htm

Glossary and other tidbits

Cyclophyllidean (c.f. pseudophyllidean) Tapeworms of the order Cyclophyllidea (the cyclophyllid cestodes) are the most important cestode parasites of humans and domesticated animals. All have multiple
proglottid "segments", and all have four suckers on their scolices (heads), though some may have other structures, as well. Proglottids of this order have genital openings on one side (except in the Dilepididae, which have genital openings on both sides), and a compact yolk gland or vitellarium posterior to the ovary.

Families include:

Dipylidiidae (formerly Dilepididae), the most important member of which is Dipylidium caninum, also called the "cucumber tapeworm" or the "double-pore tapeworm"

Hymenolepididae, with the most important genus being Hymenolepis

Taeniidae, which consists of livestock parasites in the genus Taenia and parasites that encyst in humans of the genus Echinococcus

Anoplocephalidae, which include several tapeworms of horses and a genus of tapeworms of ruminants, the Moniezia

Davaineidae that comprise 14 genera, most of which are parasites of birds

Cysticercus

Originally described as a genus of bladderworms, now known to be the encysted larvae of various taenioid tapeworms; the generic name is, however, retained as a convenience in referring to the larval encysted forms. // The larval form of certain Taenia species, typically found in muscles of mammalian intermediate hosts that serve as a prey of various predators; it consists of a fluid-filled bladder in which the invaginated cestode scolex develops.[G. kystis, bladder, + kerkos, tail] [TFD]

Cysticercoid: A single, evaginated scolex that is embedded in a small solid cyst that are typically found in small intermediate hosts such as arthropods (Cyclophyllidian tapeworms). Cysticercus: Larval stage in the cestode life cycle which is a fluid filled cyst containing an attached single invaginated scolex typically found in mammal intermediate hosts (cyclophyllidian tapeworms). [UP]

hex·a·canth (hek'sā-kanth),

The motile six-hooked first-stage larva of cyclophyllidean cestodes; it emerges from the egg and actively claws its way through the intermediate host's intestine before development into the next larval stage; for example, the hexacanth of Taenia saginata, which penetrates the
intestine of a cow that ingested the egg, then forms a cysticercus in the muscles of the intermediate host. Synonym(s): oncosphere [hexa- + G. akantha, hook or thorn] [TFD]

**Metacestode:** Mature tapeworm larva (UP (=U Penn))
http://cal.vet.upenn.edu/projects/parasit06/website/glossary.htm

**Met·a·ces·tode** (metˈä-sesˈtōd),

The larval stages of a tapeworm, including the metamorphosis of the oncosphere to the first evidence of sexuality in the adult worm, differentiation of the scolex, and beginning of proglottid formation; it includes the procercoid and plerocercoid stages of pseudophyllid cestodes, and the cysticercus, cysticercoid, coenurus, and hydatid stages of cyclophyllidean cestodes. [TFD]

**Oncosphere** [onˈko-sfēr] (syn: hexacanth) The larva of the tapeworm contained within the external embryonic envelope and armed with six hooks. [TFD]

**Praziquantel (PZQ). MVM:**

Praziquantel and epsiprantel are closely related analogs that have high efficacy against cestode parasites at relatively low dose rates but no effect on nematodes. Praziquantel PO is highly effective against cestodes of ruminants (eg, Moniezia spp, Stilesia), horses (Anoplocephala perfoliata), dogs, cats, and poultry. The PO (5 mg/kg), SC (5.8 mg/kg), or spot-on (cats, 12 mg/kg) administration of praziquantel in dogs and cats is 100% effective against Dipylidium caninum, Taenia spp, and Echinococcus spp (both adult and immature forms). Praziquantel at a dosage of 40 mg/kg is also effective against Schistosoma infections in cattle (and people). **Epsiprantel** at 5 mg/kg is used specifically for the treatment of the common tapeworms of dogs and cats, including adult E granulosus.
http://www.merckvetmanual.com/mvm/pharmacology/anthelmintics/praziquantel_and_epsiprantel.html

**Praziquantel, resistance to** ... there are reports of resistance of the tapeworm, Moniezia (Paul M, pers comm)

**Praziquantel, resistance to (Schistosoma) C&C:** No cheap, broad-spectrum alternative drugs and no indication that a vaccine is likely to become available soon, so PZQ is likely to remain the drug of choice for
treatment of schistosomiasis. Understanding the precise mechanism of action of the drug (which we don’t) will help in the search for new compounds that might complement PZQ either through targeting independent pathways or overcoming its lack of efficacy against juveniles. Why is PZQ resistance not more evident? Maybe PZQ has not yet been under enough pressure to allow resistance to develop. Approx 42 million people, representing less than 20% of infected individuals, were treated with PZQ in 2012. Most were school-aged children with preschool and adult populations often ignored. Even for those fortunate enough to receive treatment, it is often intermittent leaving a large refugium of drug sensitive parasites. Thus, a potential combination of the reduced fitness of drug resistant parasites and large refugium has likely combined to keep resistance at bay.

**Pisiformis** – relates to pea-shaped appearance of the proglottids [G]

**Plerocercoid** the second larval stage of a pseudophyllidean cestode which follows the procercoid. This larva infects a wide range of vertebrate hosts including fish, amphibia, reptiles, mammals, birds. They are elongated, have a solid body and carry an adult scolex. As a migrating larva of a tapeworm, this is an infectious stage of importance in predation; the definitive host becomes infected by eating the tissues of the second intermediate host. [TFD]

**Procercoid** [pro-serˈkoid]. a larval stage of fish tapeworms.

*pro·cer·coid (prō-serˈkoyd) The first stage in the aquatic life cycle of certain tapeworms, such as the pseudophyllideans (family Diphyllobothriidae), following ingestion of the newly hatched larva (coracidium) by a copepod (water flea). The procercoid develops into a tailed larva in the body cavity of the crustacean first intermediate host; when the procercoid and its host are ingested by a fish, the procercoid enters the new host's tissues and becomes a plerocercoid. [pro- + G. kerkos, tail, + eidos, resemblance] [TFD]

**Pseudophyllidean** Pertaining to tapeworms (cestodes) of the order Pseudophyllidae. Members within this order usually have a three hostaquatic life cycle. Adult tapeworms are parasitic in the intestines of fish eating mammals, birds, fish and humans. Lengths of the adults range from 10 to 100 feet. [TFD]

**Pseudophyllidean** cestodes (order pseudophyllidea) are a kind of flatworm with multiple "segments" (proglottids) and two bothria or "sucking grooves" as adults. Proglottids are identifiably pseudophyllid as
the genital pore and uterine pore are located on the mid-ventral surface, and the ovary is bilobed ("dumbbell-shaped").

Eggs have one flat end (the operculum) and a small knob on the other end. All pseudophyllid cestodes have a procercoid stage in their life cycle, and most also have a plerocercoid stage.

The most important family of pseudophyllid cestodes is Diphyllobothriidae, which infect mammals as their definitive hosts and use either copepods (a group of small crustaceans found in the sea and nearly every freshwater habitat, e.g. Spirometra) or both copepods and fish as in the broadfish tapeworm as intermediate hosts. The hermaphroditic Schistocephalus solidus parasitizes fish and fish-eating water birds, with a cyclopoid copepod as the first intermediate host.

When humans harbor plerocercoids of pseudophyllidean cestodes outside the small intestine, it can cause sparganosis.

https://en.wikipedia.org/wiki/Pseudophyllidea

Ros·tel·lum (rŏ-stĕlʼəm)

n. pl. ros·tel·la (rŏ-stĕl’ə) A small beaklike part, such as a projection on the stigma of an orchid or the hooked projection on the head of a tapeworm. [Latin, diminutive of rōstrum, beak; see rostrum [TFD]

Sco·lex, pl. sco·le·ces, scol·i·ces (skō'leks, skō'le-sēz, skō'li-sēz),

The head or anterior end of a tapeworm attached by suckers, and frequently by rostellar hooks, to the wall of the intestine; it is formed within the hydatid cyst in Echinococcus, within a cysticercus in Taenia, a cysticercoid in Hymenolepis, or by a plerocercoid, as in Diphyllobothrium latum. The form of the scolex varies greatly, the most familiar being rounded or club-shaped with four circular muscular suckers and an armed or unarmed rostellum, or a spatulate flattened scolex with a pair of slitlike suckers (bothria) and no rostellum, as in Diphyllobothrium and its allies. Other forms have complex leaflike, cup-shaped, or fimbriated shapes, or retractile, multiply spined proboscides. These varied forms characterize the orders of cestodes, which are particularly well developed as parasites of sharks and skates or rays.[G. skölēx, a worm] [TFD]

Sparganum [spahr´gah-num] (Gr.) a migrating larva of a tapeworm; see also sparganosis. (Pl: spargana)

spar·ga·num (spar'gă-nūm), Originally described as a genus, but now restricted to the plerocercoid stage of certain tapeworms.
sparganum /spar·ga·num/ (spahr´gah-num) pl. spar´gana [Gr.] the larval stage of certain tapeworms, especially of the genera Diphyllobothrium and Spirometra; see also sparganosis. Also, a genus name applied to such larvae, usually when the adult stage is unknown. [TFD]

Spirometra = ‘spiral uterus’ [G]

Tae·ni·a (tē'nē-ă)
A genus of cestodes that formerly included most of the tapeworms, but is now restricted to those species infecting carnivores with cysticerci found in tissues of various herbivores, rodents, and other animals of prey.

// taenia [te´ne-ah]

1. a flat band or strip of soft tissue; used in anatomic nomenclature to designate various structures.

2. a tapeworm of the genus Taenia. Defs. 1 and 2 called also tenia.

taenia co´li any of the three thickened bands (tae´nia li´bera, tae´nia mesoco´lica, and tae´nia omenta´lis) formed by longitudinal fibers in the tunica muscularis of the large intestine, extending from the root of the vermiform appendix to the rectum. // Taenia (tē'nē-ă),

A genus of cestodes that formerly included most tapeworms but is now restricted to those species infecting carnivores with cysticerci found in tissues of various herbivores, rodents, and other animals of prey. // tae·ni·a (tē'nē-ă),

1. A coiled bandlike anatomic structure.

2. Common name for a tapeworm, especially of the genus Taenia. Synonym(s): tenia (2)

[T., fr. G. tainia, band, tape, a tapeworm] //

Taenia

tē’nē-ə] Etymology: Gk, tainia, ribbon

a genus of large parasitic intestinal flatworms of the family Taeniidae, class Cestoda, having an armed scolex and a series of segments in a chain. Taeniae are among the most common parasites infecting humans
and include T. saginata, the beef tapeworm, and T. solium, the pork tapeworm.

**Taenia**

a genus of cyclophyllidean tapeworms of the family Taeniidae. The adult tapeworm inhabits the intestine of carnivores, the larval stage (metacestode) invades the tissues of a variety of animals, in some cases humans. They cause some economic loss due to condemnation of offal, but their greatest importance is their zoogenetic potential, and the preoccupation of humans with the danger of becoming infected.

Tapeworms and their hosts are listed below, but species whose intermediate hosts are unknown are: T. bubesi (lion), T. crocutae (spotted hyena), T. erythraea (black-backed jackal), T. gongamai and T. hlosei (lion and cheetah), T. lycaontis (hunting dog), T. regis (lion).

**Taenia brauni**

adult tapeworms in dogs and jackals and the larval stage (coenurus) in rats, mice and porcupines. It is probably a subspecies of T. serialis.

**Taenia crassiceps**

adult tapeworms in foxes and coyotes, the larval stage (cysticercus) in rodents.

**Taenia hydatigena**

tapeworms in small intestine of dogs, wolves and wild Carnivora, and the larval stage, Cysticercus tenuicollis, found in the sheep and other ruminants, and in pigs and occasionally primates.

**Taenia hyenae**

tapeworms are in hyenas and the cysticerci in antelopes.

**Taenia krabbei**

adult tapeworms are found in the dog and in wild carnivores and the larval cestode, Cysticercus tarandi, in the muscles of wild ruminants, especially deer.

**Taenia laticollis**

tapeworms found in carnivores and larval forms in rodents. Possibly a synonym for T. pisiformis.
Taenia macrocystis

adult tapeworms in lynx and coyote, and the intermediate stage in snowshoe lagomorphs.

Taenia martis

the adult tapeworms in the marten and the cysticercus in the vole.

Taenia multiceps (syn. Multiceps multiceps)

the adult tapeworms are found in the dog and wild canids, the larvae, Coenurus cerebralis, in the brain and spinal cord of sheep and goat.

Taenia mustelae

adult tapeworms in martens, weasels, otters, skunks, badgers and larval stages in voles and other rodents.

Taenia omissa

adult tapeworms in the cougar and larvae in deer.

Taenia ovis

adult tapeworms are found in dogs and wild carnivores and the larval stage, Cysticercus ovis, in the skeletal and cardiac muscles of sheep and goats.

Taenia parva

adult tapeworms in genets, larval stage in rodents.

Taenia pisiformis

adult tapeworms found in small intestine of dog, fox, some wild carnivores, and very rarely in cats. The metacestode stage (Cysticercus pisiformis) found in lagomorphs, in the liver and peritoneal cavity.

Taenia polyacantha

adults are in the intestine of foxes and the metacestodes in microtine rodents.

Taenia rileyi

adult tapeworms found in lynx, larvae in rodents.

Taenia saginata
adult tapeworms are intestinal parasites of humans, and the metacestode (Cysticercus bovis) in cattle and some wild ruminants.

**Taenia serialis**

the adult tapeworm is found in dogs and foxes and the metacestode, Coenurus serialis, in the subcutaneous and intramuscular tissues of lagomorphs.

**Taenia serrata**

see T. pisiformis (above).

**Taenia solium**

the adults are found in the small intestine of humans and some apes, the metacestode (Cysticercus cellulosae) in the skeletal and cardiac muscle of pigs and in the brain of humans.

**Taenia taeniaeformis**

the adult is found in the small intestine of cats and other related carnivores and the metacestode (Cysticercus fasciolaris) in the livers of rodents.

**Taenia twitchelli**


tenuicollis = ‘attenuated neck’

---

**Vaccines against cestodes:**


Abstract: Cysticercosis caused by larval tapeworms is a major public health problem and a cause of substantial economic losses in the farm-animal industries. Taenia ovis in sheep is a particularly important example. Immunity to reinfection with the larvae has a central role in
regulating natural transmission of the parasites, and vaccination with antigens from the early larval oncosphere stage can induce complete protection against infection. As it is impractical to obtain enough oncospheres for a commercial vaccine against these tapeworms, an alternative approach is to use recombinant DNA methods to generate a cheap and plentiful supply of antigens. We report here the expression in Escherichia coli of complementary DNA encoding T. ovis antigens as fusion proteins with the Schistosoma japonicum glutathione S-transferase. Vaccination of sheep with these fusion proteins gave significant, although not complete, immunity against challenge infection with T. ovis eggs. Commercial development of a vaccine is being pursued.

The University of Melbourne, Veterinary Clinical Centre, Vic. 3030, Werribee, Australia. marshall@unimelb.edu.au

Abstract
Highly effective recombinant vaccines have been developed against the helminth parasites Taenia ovis, Taenia saginata and Echinococcus granulosus. These vaccines indicate that it is possible to achieve a reliable, high level of protection against a complex metazoan parasite using defined recombinant antigens. However, the effectiveness of the vaccines against the taeniid cestodes stands in contrast to the more limited successes which characterise attempts to develop vaccines against other platyhelminth or nematode parasites. This review examines the features of the host-parasite relationships among the taeniid cestodes which have formed the basis for vaccine development. Particular consideration is given to the methodologies that have been used in making the cestode vaccines that might be of interest to researchers working on vaccination against other helminths. In developing the cestode vaccines, antigens from the parasites' infective larval stage contained within the egg (oncosphere) were identified as having the potential to induce high levels of protection in vaccinated hosts. A series of vaccination trials with antigen fractions, and associated immunological analyses, identified individual protective antigens or fractions. These were cloned from cDNA and the recombinant proteins expressed in Escherichia coli. This strategy was independently successful in developing vaccines
against T. ovis and E. granulosus. Identification of protective antigens for these species enabled rapid identification, cloning and expression of their homologues in related species and thereby the development of effective vaccines against T. saginata, E. multilocularis and, more recently, T. solium. The T. saginata vaccine provides an excellent example of the use of two antigen components, each of which were not protective when used individually, but when combined they induce a reliable, high level of protection. One important contributing factor to the success of vaccine development for the taeniid cestodes was the concentration on studies seeking to identify native host-protective antigens, before the adoption of recombinant methodologies. The cestode vaccines are being developed towards practical (commercial) application. The high level of efficacy of the vaccines against T. solium cysticercosis and hydatid disease suggests that they would be effective also if used directly in humans.

**Vaccination against helminth parasite infections.**

**Abstract**
Helminth parasites infect over one fourth of the human population and are highly prevalent in livestock worldwide. In model systems, parasites are strongly immunomodulatory, but the immune system can be driven to expel them by prior vaccination. However, no vaccines are currently available for human use. Recent advances in vaccination with recombinant helminth antigens have been successful against cestode infections of livestock and new vaccines are being tested against nematode parasites of animals. Numerous vaccine antigens are being defined for a wide range of helminth parasite species, but greater understanding is needed to define the mechanisms of vaccine-induced immunity, to lay a rational platform for new vaccines and their optimal design. With human trials underway for hookworm and schistosomiasis vaccines, a greater integration between veterinary and human studies will highlight the common molecular and mechanistic pathways, and accelerate progress towards reducing the global health burden of helminth infection.
Some notes on *T. ovis* /sheep measles

I cobbled together some notes on sheep measles, in the first place for my own benefit, but it may be of use to others.

Although a little repetitive, following are some points from my notes. (See the notes for references, more detail etc).

- **Prevalence of sheep measles** (*T. ovis* metacestodes / *Cysticercus ovis*). Based on National Sheep Health Monitoring Program (NSHMP) data, sheep measles is common and widespread, but varying between regions. At least it's relatively common for lines of sheep inspected under the NSHMP to have at least one sheep with 'measles'. However the proportion of individual animals affected is somewhat less, around a few to several percent. (It varies). But, there are occasional cases which perhaps reflect 'Ovis storm'-like conditions. For example, in one case I recall, 400 lambs were sent to an abattoir in NSW, 100 of the carcasses were condemned or severely trimmed because of sheep measles (B McLeod, pers comm). As to inspections under NSHMP: about 3 million sheep (incl. lambs are inspected per year, which is about 10% of the sheep (incl. lambs) slaughtered in Australia. Also, two of the bigger mutton processors in NSW (Dubbo, Goulburn) are not part of NSHMP. So, we need to be careful when interpreting results from the program. However, some mutton processors not currently involved in NSHMP were part of the study (on costs to processors) by Jenkins et al, 2014.

- **Prevalence of adult *T. ovis* tapeworms.** The definitive (final) hosts are canids: domesticated and wild dogs, and foxes. Theoretically cats could (very) rarely be infected, but it's highly unlikely these infections would be patent (i.e. shedding eggs onto pasture). *T. ovis* has never been reported in feral cats in AU or NZ.
Jenkins et al opine that **foxes** are more important now (in mainland Australia) in the spread of *T. ovis* than domestic dogs, with the role of the latter seemingly declining in importance in recent decades. Apparently not all agree, for example, Palmer, in Western Australia. Even if foxes are now more important, it seems, on current evidence, that even the prevalence of infected foxes is quite low (and probably variable), possibly (?) around the 1% mark (?).

- **Fecundity of *T. ovis***. *T. ovis* is fecund, with about 3 segments being shed per day, each segment containing about 60,000 - 80,000 eggs. According to “NZ”: one *T. ovis* tapeworm can produce 250,000 eggs/day and some dogs can carry 3-4 *T. ovis* tapeworms. Compare this to say *Haemonchus* (about 5-10,000 eggs/female/day) and *Fasciola hepatica* (about 20,000 eggs/louse/day). But, dogs with *T. ovis* have perhaps 1-4 tapeworms. (But, they are up to 2 metres long!). The numbers of adult *Haemonchus* and *Fasciola* carried (in sheep etc) can be in the hundreds to thousands. On the other hand, just a few *T. ovis* cysts in a sheep can be economically important, even without health consequences to sheep/goats or humans.

- **Spread of *T. ovis* eggs**. The eggs on pasture are infective to the intermediate hosts, sheep/goats. These can be spread far and wide by free-ranging wild canids (foxes and wild dogs), but are further spread by wind, rain and coprophagous flies. (‘No accounting for taste).

- **Viability of eggs on pasture**. Jenkins et al says eggs can be viable for 300 days or more, whereas ‘NZ’ (see notes) say they can be viable for 6 months, but more likely around 4 months (but some can last 18 months), depending on conditions. (Infective stages of *H. contortus* (L3 larvae) and *F. hepatica* (metacercariae) are viable for weeks to several months (and even more) depending on temperature in particular).

- **Infectivity and longevity of *T. ovis***. The host response to adult *T. ovis* is not that strong, and tapeworms possibly live from a few months to a few years in the intestine of canids. As to the metacestode (sheep measles, ’*Cysticercus ovis’*) stage, the cysts require about 1-2 months to become infective/mature, and then they are highly infective (one cyst consumed by a dog will likely result in infection), but then, unlike the closely related taeniid, *T. hydatigena*, the cysts are only infective for a short time: about 2-3 months. The immune response of the intermediate host (sheep/goats) is relatively strong: the cysts die, fill with
pus and mineralise. (Not attractive to consumers). But, "lambs not exposed to Sheep Measles eggs on pastures develop no natural immunity ('NZ')."

More on immunity..."Exposure to T. hydatigena suppresses infection by T. ovis, but not by E. granulosus. This has important epidemiological consequences where these parasites co-exist." (Gemmel et al Parasitology 1997. See notes).

- **Control.** Traditional control consists of preventing dogs from consuming sheep meat/offal containing viable cysts, and regular treatment with a tapewormer (praziquantel is the most effective) to remove *T. ovis* from the dog's intestines. Given the role, according to Jenkins et al, of a sylvatic pathway, with foxes in particular playing a part (in mainland Australia), traditional control measures, while necessary, are insufficient, the authors say, and vaccination of sheep against *T. ovis* is necessary.

- *T. ovis* vaccine. A Melbourne-based group (Joh or TAS?nstone et al) in 1989 reported on the development of a *T. ovis* vaccine and this was subsequently commercialised and marketed in NZ, but then went off the market. Jenkins et al, 2014, comment on possible reasons for this.

Theoretically the sylvatic cycle (apparently not an issue in NZ? or TAS??) could be interrupted to some extent by using cestocide-laced baits (trialled in Germany) but this would be impractical in countries like Australia. Jenkins et al much prefer the use of a *T. ovis* vaccine to augment traditional control measures.

More on vaccines..."Highly effective recombinant vaccines have been developed against the helminth parasites Taenia ovis, Taenia saginata and Echinococcus granulosus. " Lightowlers et al Vet Parasitol 2003 (See notes).

- **Resistance to praziquantel (PRZ)?** To control *T. ovis* with its pre-patent period of 35 days (others say the PPP is 5-8 weeks), monthly treatment of rural domestic dogs has been recommended. This is logical to optimise control, but on the other hand, it may increase selection for resistance. However, I know of no cases of taeniid tapeworm resistance to PRZ, although I am aware of reports from NZ of *Monezia* app resistance to PRZ. There is discussion about PRZ resistance of *Schistoma* (blood-flukes), but I gather it is not currently considered an issue.
More information, and modelling, needed? My impression is that there is still a lot to be learned about the ecology, epidemiology and economics of *Tovis* / sheep measles, at least in Australia. As to the role of various definitive hosts, although quite a few dogs and foxes have been examined over the years in Australia, it seems to me the numbers are inadequate to result in reliable estimates of prevalence. I wonder also if modelling may help to better understand the epidemiology of *T. ovis* in Australia. (On the one hand, *T. ovis* is fecund (but each dog/fox has few tapeworms) and the eggs are viable for several months, but then the prevalence of *T. ovis* in definitive hosts seems to be low, and also the cysts in intermediate hosts are only viable for 2-3 months. But then it doesn't take many cysts in a sheep or goat at an abattoir to make a case significant economically......) - SL.