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Intestinal cestodes

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Purpose of review
This review summarises the biology, clinical aspects, diagnosis, treatment and epidemiology for the common and rarer (zoonotic) intestinal cestodes of humans.
Recent findings
Mass drug application to eliminate *T.solium* carriers may have only temporary effects on cysticercosis transmission. At least two major world genotypes of *T.solium* have been identified and greater genetic heterogeneity may occur at regional level. A new human taeniid *T.asiatica* has been confirmed which occurs sympatrically with *T.saginata* and *T.solium* in SE Asia. Coproantigen and PCR tests for *Taenia* spp have greatly improved diagnostic efficacy and epidemiological studies. There appears to be an increase in human diphyllobothriasis in Europe, Japan and the Americas.
Summary
Human intestinal cestode infections are globally primarily caused by species in 3 genera- *Taenia, Hymenolepis* or *Diphyllobothrium.* Sporadic zoonotic infections caused by non-taeniids are usually food-borne or due to accidental ingestion of invertebrate hosts. Intestinal cestode infections generally result in only mild symptoms characterised chiefly by abdominal discomfort and diarrhoea. Most human intestinal cestode infections can be treated with a single oral dose of praziquantel or niclosamide.

Keywords
Cestodes, *Taenia*, *Diphyllobothrium*, *Diplogonoporus*, zoonoses

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Abbreviations
ITS inter-transcribed spacer region
PZQ praziquantel
Th2 T helper lymphocyte sub-set 2
ELISA enzyme-linked immunosorbent assay
MYBP millions of years before present
wpi weeks post-infection

Introduction

Intestinal cestodes are the gut-dwelling, segmented, ribbon-like adult stages of tapeworms (Cestoda). The adult tapeworm develops from a cyst-like juvenile or

metacestode stage that occurs in tissues or organs of vertebrate or invertebrate hosts (or humans). If metacestode stages occur in human tissues they usually have more potential than the adult tapeworm to cause pathology and morbidity [1, 2]. Nevertheless, intestinal tapeworm infection of humans has been recorded since antiquity [3], and remains a cause for concern in many endemic world regions. They may possess easily visible and even motile segments, and the sheer size of an intact length (strobila) of an expelled human tapeworm often engenders fear and embarrassment in carriers and family members. Because adult tapeworms take host nutrients through their body surface (tegument) and do not invade the mucosa of the small intestine, nor therefore remove blood, infections are usually rather benign and often asymptomatic. The presence of segments (proglottides) may be noticed in a carrier`s faeces, in a toilet bowl, around a latrine or not uncommonly felt in the under-garments, especially if they are motile. Worried patients may describe that they (or their child) are infected with `worms`, noodle-like worms, `insects`, `slugs`, `maggots` or some `alien-like` parasite. At the other extreme, in some endemic regions of for example, East Africa, tapeworm infection is common and voiding of segments from the anus is almost a mark of puberty and even status in young males.

The direct effects or pathology of gut dwelling cestodes is usually only minor. One or several of the following symptoms have been reported by tapeworm infected persons: abdominal discomfort and pain, cramp, colic, flatulence, diarrhoea, constipation, nausea, dizziness, vomiting, restlessness, vertigo, headache, tiredness, malabsorption, anorexia, muscular pain, vitamin deficiency, megaloblastic anaemia, weight loss (or gain), intestinal blockage, jejunal perforation, appendicitis, pancreatitis, pseudo-incontinence, pruritis ani, rectal-flutters, spontaneous voiding of segments from the anus, depression and psychosis. More seriously, a history of taeniasis (also referred to as taeniosis) may increase the risk of neurocysticercosis a life-threatening larval cestodiasis, through self-infection with eggs of the pork tapeworm *Taenia solium* [2*].

There are 4 species of tapeworm that are distributed world-wide and are responsible for the vast majority of all human intestinal cestode infections: *Taenia saginata* (the beef tapeworm), *Taenia solium* (the pork tapeworm), *Hymenolepis nana* (the dwarf tapeworm) and *Diphyllobothrium latum* (the broad or fish tapeworm) (Table). In

addition a number of other tapeworm species, obligatorily infect humans, or do so as a result of accidental sporadic zoonotic exposure. These include a relatively recently described third species of human *Taenia* ie. *T. asiatica* (Asian *Taenia*), other zoonotic fish species of *Diphyllobothrium* eg. *D.pacificum* (from the Americas) and *D.nihonkaiense* (from Japan), and also potentially the largest tapeworm species *Diplogonoporus grandis* (the whale tapeworm-infections mainly in Japan). Humans may also occasionally acquire zoonotic infection with the following tapeworm species/genera that are common in mammals: from dogs or other canids- *Dipylidium caninum* (the common dog-flea tapeworm) and *Mesocestoides* spp.; from rodents- *Hymenolepis diminuta, Raillietina* spp. and *Inermicapsifer* spp,; and from primates- *Bertiella* spp. (Table). The life-cycles are still not fully known for *Mesocestoides*, *Bertiella* or *Inermicapsifer* species.

When intact tapeworms or their segments are recovered post-treatment or by the carrier themselves, they are often in poor condition and therefore difficult to identify parasitologically based on morphological criterion. The advent of immunodiagnostic tests for detection of tapeworm antigen in stools (coproantigen), and molecular diagnostic methods for DNA amplification and analysis has greatly improved patient diagnosis, species confirmation, and usefulness of epidemiological studies [4,5*]. In addition analysis of cestode DNA has also contributed to the re-evaluation of taxonomic relationships and evolutionary origins of tapeworm species [6*]. Development and application of coproantigen ELISA for human taeniosis increased detection of carriers at least two-fold in endemic areas of Latin America compared to traditional stool concentration with microscopy for taeniid egg detection [5] (fig.a). Species specific detection of human taeniosis is very effective using mitochondrial DNA probes to analyse voided tapeworm segments. Furthermore copro-PCR for detection of DNA in extracts of human stool samples was effective in specific diagnosis of *Taenia* spp prior to treatment [7**, 8*]. In addition a specific serologic test for human *T.solium* taeniasis has now been developed to enable testing for taeniasis and cysticercosis using a single serum sample [9]. Other non-parasitological based detection methods for human intestinal cestodiasis are not usually important though in at least one report routine ultrasound (after gastric pain) detected a *T.saginata* tapeworm in the small intestine [10].

Treatment for human intestinal tapeworm infection is usually quite effective (85-98%) with modern widely available anthelmintics such as praziquantel (5mg/kg single oral dose) or niclosamide (usually 2 gm single oral dose) [11, 12, 13]. Note broad spectrum benzimidazole anthelmintic drugs like albendazole, commonly used to treat roundworm, are not usually as effective in a single dose for treatment of human tapeworm infections [14]. Recently, the anti-microbial agent, nitazoxanide, has also been used to treat hymenolepiasis with 75-85% efficacy [15*]. Frequently, the intact tapeworm(s) is required to be recovered post-treatment for identification purposes, and in that case it is recommended that a purge (eg. castor oil or magnesium sulphate solution) be administered within 2 hours of taking a cestocidal drug. A successful purge should result in passage of a tapeworm or its fragments within 6-12h, and the patient could also be requested to collect all their faeces over 48-72h so that all detached segments might be recovered. The administration of an electrolyte-polyethyleneglycol solution as an alternative purge, *prior* to treatment with niclosamide, significantly improved recovery of scoleces (tapeworm `heads`) of *Taenia* spp in one trial in Peru [16**]. Aswell as proprietory drugs traditional treatments and remedies for intestinal cestodiasis are also commonly used in many endemic developing countries and may include the following herbs, plants or extracts: pumpkin seeds, areca nut, male fern extract, *Embelia* fruit, breadfruit, black cumin seeds, or garlic [12].

In this article we provide a comprehensive review and update of recent diagnostic, epidemiologic, taxonomic aspects and clinical developments in human intestinal cestodiases. For the more obscure intestinal tapeworm zoonoses the literature is sparse, thus for reader interest and completeness a number of older case studies/reports/reviews are also cited.

Taenia solium

In 2005, WHO published updated guidelines for the surveillance, prevention and control of taeniosis/cysticercosis [17*]. The human pork tapeworm *T.solium*, is the most important of all tapeworms that can infect humans because it is the sole source of infective eggs that cause neurocysticercosis, a life-threatening condition and the leading cause of acquired epilepsy world-wide [2]. The tapeworm life-cycle alternates between an intestinal adult cestode (fig.c (i)) in humans (~ 10 weeks to develop) and a

metacestode (cysticercus) stage in pigs. Humans can only contract taeniasis caused by *T.solium* from eating raw or under-cooked pork meat (or rarely infected dog meat). In contrast, human cysticercosis is contracted by ingestion of viable eggs (microscopic ~ 40um, see fig.a) from a *T.solium* tapeworm, either by self-contamination via poor personal hygiene, or from exposure to egg contaminated food, the environment or from direct contact with a human tapeworm carrier. Therefore in endemic areas vegetarians may also contract cysticercosis. Around 15-25% of neurocysticercosis patients present with a tapeworm or have a previous history of taeniasis [2, 17].

High endemicity of cysticercosis occurs mainly in rural under-developed regions where free-range pigs are an economic necessity. This includes large parts of Latin America, Sub-Saharan Africa, India, China, and Southeast Asia. Isolated foci (and imported cases) also occur in Western Europe (eg. Spain, Portugal), the Caribbean, Indian Oceania and USA [17, 18**, 19]. Low prevalences (<1-5%) of human *T.solium* taeniasis appear capable of maintaining transmission within a community to sustain 25-75% prevalence of porcine cysticercosis, and human cysticercosis seroprevalences of 5-25% with human epileptic rates 1-5% [2,11,17]. It was assumed that the high biotic potential of an adult tapeworm, worm longevity (>10yrs), pig coprophagia of human faeces, and resistant eggs in the environment, were key factors in transmission. Application of *Taenia* coproantigen ELISA for mass screening, with use of PCR for species confirmation and to differentiate *T.solium* infection from *T.saginata* (and/or *T.asiatica* in Asia) carriers, together with a specific immunoblot test for human/porcine cysticercosis, has been very useful in epidemiological studies [2, 4, 5, 8, 11, 20]. These and other studies indicate that, *T.solium* specimens from carriers in endemic communities, are relatively small (ave. 2-3m) compared to *T.saginata* (ave. 4-5m), the worm has a relatively short life-span of <2-5 years, tapeworm re-infection occurs readily in endemic communities, and even egg transfer from pig to pig by coprophagia may be possible [21*]. *T.solium* tapeworm carriers have also been shown to exhibit high rates of seropositivity to oncosphere antigens, which suggests exposure to eggs and thus risk of neurocysticercosis, but also possibly for some individuals development of anti-cysticercosis immunity [22]. Furthermore, several community based studies showed that human *Taenia* carriers tend to be clustered with porcine cysticercosis, seropositive persons and epileptic cases in

households, which were also are more likely to lack a proper latrine and to own free-roaming pigs [2, 23*]. A recent report from an endemic area of Peru showed that swine seroprevalence and sero-incidence significantly increased with closer proximity to households of *T.solium* tapeworm carriers [24**].

Analysis of mitochondrial DNA of *T.solium* isolates from across the world indicates 2 main genotypes/strains ie. an Asian type and an African/Latin America type [25*]. It is still not clear if these two broad genotypes also correlate with cyst pathology/site location, for example the frequent occurence of subcutaneous cysticercosis in Asia versus its relatively rare occurrence in Latin America? In general there appears to be less genetic variation in *T.solium* compared to some other related taeniids (eg. *Echinococcus* spp.). However, a recent study in Peru using single nucleotide polymorphism analysis of three mitochondrial genes, showed that a least 3 sub-genotypes of *T.solium* occurred and tended to be geographically separated [26**].

T.solium cysticercosis is a potentially eradicable disease [27] if development or interventions leads to reduction/elimination of the adult tapeworm in humans (the only definitive host) either by mass treatment of human taeniosis, improvement in sanitation and meat hygiene, separation of pigs from human excreta, changes in pig husbandry, health education and/or vaccination/treatment of pigs [2, 11, 17, 27]. Mass treatment for human taeniosis using praziquantel (PZQ) or niclosamide can be effective in reducing infection pressure in endemic areas [14], but total elimination of transmission did not occur in a recent trial involving use of one round of niclosamide in 12 endemic villages in Peru [28**]. Some concern has been voiced in relation to the potential for PZQ to cause brain inflammation in asymptomatic neurocysticercosis cases [11].

Taenia saginata

The commonest and most widely distributed human *Taenia* tapeworm is the beef tapeworm *Taenia saginata.* It is estimated that world-wide 60 million people are infected [13], and human prevalence rates as high as 22-27% may occur, for example in Bali (Indonesia) [29*], in Tibetan populations (China) [8], and in East Africa [30]. Prevalence rates in Western Europe ranged from <0.01-2% [31]. Though closely related to *T.solium,* molecular and morphometric phylogenetic analyses indicates that

T.saginata probably evolved separately in early hominids and originated from an ancestral tapeworm of felids and bovids. In contrast *T.solium* likely adapted separately to early humans from a tapeworm ancestor of hyaenids [6].

T.saginata is a large robust tapeworm up to 6-8 m long with >2000 proglottides (fig.b), but average size is more like 2-5m, and average worm length decreases with increasing worm burden. In 26 Ethiopian carriers, 30% harboured a single tapeworm while the others had from 2-8 worms [30]. The scolex is seldom recovered, but is characterised by 4 suckers, no rostellum and no hooks, in contrast to *T.solium* whose scolex possesses both suckers and 2 rows of hooks (fig.c (i)). Humans become infected by ingestion of one or more viable cysticerci in under-cooked or raw beef and individuals may remain infected for several years. Voluntary self-infection experiments with *T.saginata* showed that egg bearing proglottids actively and spontaneously voided from the anus (5-15 proglottids per day) as early as 10 weeks post-infection, by which time the worm was already approximately 3m long. Prior to segment release volunteers were mostly asymptomatic, though up to 6 months post-infection intermittent abdominal discomfort, diarrhoea and/or alternating constipation occurred, but not significant weight loss [PS Craig and A. Ito personal observations]. Rarely however, complications such as bowel obstruction have been reported [32]. *T.saginata* eggs in voided segments or in faeces from carriers may directly contaminate pasture or cattle feed-lots as a result of indisciminant defaecation, and also indirectly via application of treated urban sewage sludge/ effluent [31]. In cattle viable cysticerci (5-7mm) develop in striated muscles by 10 weeks after infection, but in older resistant animals may become calcified after 6 months. There is an effective vaccine against bovine cysticercosis which has economic potential [4].

Copro-ELISA to detect *Taenia* sp. antigens in human faecal samples has been successfully applied in community surveys for *T.saginata* [8, 29]. For identification to species level PCR based DNA tests showed excellent potential not only for *T.saginata* taeniosis but also to differentiate all 3 human *Taenia* species [7, 8, 33]. Treatment of taeniosis caused by *T.saginata* (or *T.asiatica*) is usually effective with a single dose of praziquantel or niclosamide [12].

Taenia asiatica

Taenia asiatica is a relatively newly described human helminth, which was unknown prior to the 1930s and only formally described as a new species in 1993 [34] (fig.d). The gross morphology of the adult tapeworm is very similar to *T.saginata* and difficult to differentiate, however *T.asiatica* possesses a rostellum on an unarmed scolex (fig. c (ii)), and exhibits posterior protruberances in gravid proglottids [34] (fig.f). *T.asiatica* has a 4.8% genetic divergence in *cox1* genes compared to *T.saginata* , and the estimated age for divergence of the two species is 0.78-1.71 MYBP [6]. The former is also transmitted in pigs as the intermediate host (small 2-3 mm cysticerci in liver or other viscera) but not bovids. *T.asiatica* has been identified in Taiwan, Korea, Indonesia, Malaysia, China, Philippines, Vietnam, and Thailand [8, 20, 34, 35, 36, 37]. This tapeworm characteristically occurs in culturally/ethnic minority communities eg. Bataks of Sumatra, central Taiwan Aborigines, or Kham Tibetans in southwest China. Village prevalence rates of *T.asiatica* ranged from 2-20% in Indonesia [35*]. Carriers usually reported a history of eating raw pig liver or other pig viscera, and most experienced spontaneous discharge of proglottids. Following a human self-infection with *T.asiatica* active segments migrated from the anus at 17 weeks post-infection, with a daily discharge of 1-5 proglottids; a peak in blood eosinophils occurred at 12wpi [38].

Taenia solium, T. asiatica and *T. saginata* may occur sympatrically (co-endemic in same niche/hosts) in Southeast Asia, furthermore an interesting recent finding was a dual infection with *T. solium* and *T. asiatica* in Thailand (fig. c) [37*]. *Taenia saginata*-like tapeworms found in Asia and the Pacific region should be re-evaluated as to whether specimens are really *T. saginata* or *T. asiatica.* Human cysticercosis cases due to taeniid species are expected to be due to *T. solium* metacestodes, however, histopathological examination, serology or neuroimaging may not always give conclusive information. We therefore recommend that specific PCR for DNA amplification be applied to suspected cysticercosis biopsy material or histopathological specimens especially from the Asia/Pacific region [7].

Hymenolepis nana

H.nana (the dwarf tapeworm, 1-5cm, armed scolex, oval egg) (fig.g) is probably the commonest tapeworm infection of humans with a worldwide distribution and

estimates of 50-75 million carriers with prevalences of 5-25% in children [39]. *H.nana* is also described as *Vampirolepis nana* or *Rodentolepis nana* (without molecular evaluation), however, in this text the species name *H. nana* is used. *H.nana* is unique amongst human intestinal cestodes in having a direct life-cycle not requiring an intermediate host. All other mammalian animal hosts of other *Hymenolepis* species utilise insect intermediate hosts for the tailed-cysticercoid stage. In human *H.nana* infection the larval cysticercoid (tailess cyst) develops directly in intestinal villi. Human infections with *H.nana* can therefore build up rapidly through direct egg ingestion, and autoinfection within the gut may also occur though is not proven. Some authorities also believe that *H.nana* or its sub-species (*H.nana var fraterna*?) can also infect rodents and be transmitted via beetles or fleas, and thus be considered a zoonosis [40]. Patency in humans (ie. time to an egg producing adult tapeworm) occurs in 3-4 weeks after direct egg/oncosphere infection via cysticercoids that grow in intestinal villi within 96h then break out into the gut lumen to develop to an adult tapeworm. In children large burdens of *H.nana* tapeworms can occur (>300) and cause abdominal discomfort, irritability, diarrhoea and possibly malabsorbtion. Egg counts in stool of >10,000 eggs per gm are considered a heavy infection, though such infestations are not always associated with symtomatology [15]. Hymenolepiasis may also ameliorate colitis [41**]. Praziquantel and niclosamide (>90% efficacy) aswell as nitazoxanide (75-93% efficacy) appear to be effective anthelmintics for human hymenolepiasis and it is recommended that a carrier`s family/household members are also treated [12, 13].

Diphyllobothriasis and *Diplogonoporus*

Human diphyllobothriasis is usually caused by the pseudophyllidean tapeworm *Diphyllobothrium latum* (the broad fish tapeworm) with its characteristic scolex (has bothridial grooves, but no hooks or suckers), very long strobila (3-10m), and a complex 3-host life-cycle (crustacean, fish, human). Oval operculated eggs (60um) require freshwater to hatch and release a free-swimming ciliated oncosphere (coracidium) that is ingested by a crustacean (copepod) first intermediate host in which it encysts (procercoid). A plerocercoid second larval stage (1-2cm) develops from the procercoid in the tissues of fresh-water fish the second intermediate host when they predate on copepods. Humans (or fish eating mammals) therefore contract infection from eating raw or under-cooked fish. *D.latum* was formerly more prevalent

in Scandanavian countries where a proportion of older carriers developed megoblastic anaemia as a result of cestode-uptake of vitamin B12, but improvement in sewage treatment out-flows to lakes has reduced transmission. Never the less transmission still occurs in parts of Europe, the Americas and Russia, with a recent cluster of human cases in Swiss and Italian lakes (>100 cases since 1990), as well as in Chilean and Argentina freshwater lakes [42*, 43, 44*]. About 9 million cases occur worldwide [42]. The traditional cuisines of Japan and parts of South America include raw marine fish dishes and this increases the risk of acquiring *D.pacificum* a closely related tapeworm whose normal final host are seals. Adult *D.pacificum* is morphologically very similar to *D.latum*, however it eggs are smaller (40-60um vs 60-75um) and recent ITS gene sequencing of human derived tapeworms from South American and Japanese patients demonstrated that it is a valid species [45*]. In Japan a third species, *D.nihonkiaense*, has been confirmed in humans infected from eating raw Pacific salmon [46*], and this species has now been reported in France from imported Canadian Pacific salmon [47] and apparent locally acquired infections occurred in Switzerland [48]. Voluntary self-infections with *D.latum* were asymptomatic and 2 of 3 volunteers spontaneously dewormed at 7 and 54 months post-infection, however abdominal pain, diarrhoea and cramp was reported by Swiss diphyllobothriasis cases [42, 49*]. A single 2 gm dose of PZQ is an effective treatment for human diphyllobothriasis.

In contrast, eating raw/under-cooked marine fish such as anchovies, sardines or herring from Pacific waters, especially in coastal Japan and Korea, may result in potential infection with the whale diphyllobothriid tapeworm, *Diplogonoporus grandis* (syn. *D.balaenopterae*) probably the largest tapeworm known (6-20m in the natural host *Balaenoptera* spp of wales) [49]. In an out-break of diplogonoporosis in 1996 in Shizuoku Prefecture (Japan), 46 cases were reported mainly in elderly males who probably ate raw anchovy within a month of onset of the major symptoms ie. diarrhoea, fever and spontaneous evacuation of lengths of tapeworm strobila [50*]. Eggs were present in faeces of several cases (fig.j). Treatment with praziquantel, paromomycin sulphate or gastrograffin was successful and uneventful, however the latter drug resulted in expulsion of mostly immature tapeworms (size range 15-665 cm) (fig.h). In many human diplogonoporiasis cases from Japan, tapeworms were often expelled spontaneously and patients did not need treatment. Cooking fish

properly (56 ^{o}C for 5-10 minutes), deep freezing (< -35 ^{o}C for 15 h) or household freezing (-20^{o}C for 7 days) will kill plerocercoid larvae in fish tissues [43]. The genus *Diplogonoporus* is morphologically very close to *Diphyllobothrium*, but each segment has a double uterus (fig. i). As yet there is no molecular information on the phylogenetic relationship between *Diphyllobothrium* and *Diplogonoporus* species [46].

Sporadic infection with zoonotic tapeworms

Most human intestinal infections involve the above cestode species, especially, *Taenia* spp, *Hymenolepis nana* or *Diphyllobothrium* spp. However, sporadic exposure and infection may occur with a number of animal tapeworm species, especially those that have dogs (canids), rodents or non-human primates as their final hosts. A common epidemiologic feature for these relatively rare zoonotic infections is the involvement of invertebrate intermediate hosts (usually insects or mites) that are accidentally ingested.

The commonest cestode of domestic dogs, *Dipylidium caninum* is a small to medium sized (10-50 cm) pinkish coloured tapeworm with double-pored barrel-shaped segments. A single intermediate host is required to complete the parasite life-cycle. It is transmitted to dogs (or cats) during grooming via ingested fleas (*Ctenocephalides* spp.) or body lice (*Trichodectes* spp.) that are infected with the larval cysticercoid stage of the tapeworm. More than 20-30 tapeworms of different lengths may reside in the dog small intestine. Humans, usually young children (0.5-5yrs) probably acquire infection after accidental ingestion of fleas or lice from contact with pets, for example when a dog licks a child`s face after it has crushed a flea/louse in its mouth. One 6 month old child harboured 13 *Dipylidium* tapeworms. Infection is invariably asymptomatic and detection usually follows the discovery of small white motile rice-like or maggot-like segments in diapers or underwear, sometimes over an extended period of months. Some patients may however have loss of appetite, abdominal pain or diarrhoea [51]. Diagnosis can be confirmed microscopically by the presence of characteristic egg packets/sacs containing numerous hooked oncospheres in the voided segments. Praziquantel and niclosamide are effective anthelmintic treatments for human dipylidiasis [12, 51]. Regular treatment of pet dogs or cats with anthelmintics and anti-flea collars is preventative.

Canid tapeworms in the genus *Mesocestoides* (adult length 40-80 cm) probably utilise mites or coprophageous insects as a first intermediate host with amphibians, reptiles, birds or mammals (rodents) as potential second intermediate hosts. Dogs and foxes are good final hosts for the tapeworm. Human infections in Japan, Korea and China (*M.lineatus*) occur mainly in adult males probably through taking/eating uncooked snake or turtle `tonics` containing encysted tetrathyridia tapeworm larvae, and to date around 30 cases have been reported [49, 52]. In contrast *M.variabilis* infection is usually reported in very young children in the USA some of whom may contract infection from under-cooked wildlife/game preparations [52]. Patients or parents often notice segments in faeces and may report diarrhoea and abdominal pain. Parasitological diagnosis is based on segment morphology, but requires differential diagnosis from *Dipylidium, Raillietina* and *Inermicapsifer*. The tapeworm responds to praziquantel or niclosamide treatment [49].

About 60-70 cases of human intestinal infection with the anoplocephalid tapeworm of monkeys *Bertiella* spp. have been described, mostly from children in tropical or sub-tropical regions, including Africa, the Middle East, India, Sri Lanka, Indonesia, Philippines, Japan, China, Thailand, Mauritius and Brazil [12, 13, 53, 54]. Two species, *B.studeri* and *B.mucronata* appear to be responsible. The latter species occurs in New World primates, though some authors consider that *B.studeri* is species-complex [55]. Free-living oribatid mites are the only intermediate host of the cysticercoid larvae. Ingestion of infected mites by foraging monkeys, or by children with a pica habit or through playing out-doors in areas frequented by monkeys, may result in growth of 2-30 cm tapeworms that release small chains of fleshy proglottides (3-30 in number, 0.5x 1cm wide) (fig.l). A 3.5 year old in China may have contracted *Bertiella studeri* from a pet monkey [54]. Infections are usually asymptomatic, or occasionally associated with intermittent epigastric pain, vomiting, diarrhoea and weight loss [12, 54].

Rats and other rodents are host to several intestinal cestodes including some potential zoonotic species, that utilise arthropod intermediate hosts. Three genera are most important ie. *Hymenolepis, Raillietina,* and *Inermicapsifer*. Commonly referred to as the rat tapeworm, *H.diminuta* is larger (20-90cm, no hooks, round egg) than *H.nana* (see above and Table). It is a rare tapeworm zoonosis transmitted to humans after

accidental ingestion of cysticercoid infected beetles, fleas or other insects. The prepatent period of *H.diminuta* in humans is about 3 weeks and infection is normally mild though diarrhoea, nausea, anorexia have been attributed to infestation. In an experimental self-infection a pronounced eosinophilia occurred [13]. Treatment with praziquantel or niclosamide is effective. *H.diminuta* has a cosmopolitan distribution with prevalences up to 1% in parts of India, and children are most likely to contract infection after contact/play with stored grain or cereals [12]. The rat is a permissive host for *H.diminuta*, but experimentally the mouse is non-permissive and the mechanism of resistance in mice strongly suggests that expulsion of *H. diminuta* is mediated by a Th2 type immune enhanced goblet cell hyperplasia, increased mucin production and secretion [41]. The latter mechanism may also occur in human *H.nana* infections.

Another common gut tapeworm of rats in Asia, Polynesia and Australasia belongs to the genus *Raillietina.* The species *R. celebensis* (adult length 15-50 cm) has a characteristic necklace or bead-like posterior strobila, with barrel-shaped gravid proglottids filled with 150- 400 `egg-balls` each containing 2-3 eggs. The life-cycle is not properly known, but ants appear to be an important intermediate host. Humans probably get infected through ingestion of ants, and children 2-5years of age have been reported infected [12, 49]. *Inermicapsifer madagascariensis* is a small to medium size tapeworm (5-50cm, without hooks) of rodents and hyraxes in Africa, Madagascar and Mauritius, and has also been reported in Cuba. The identity of the arthropod intermediate host(s) is unknown, but as above children are more likely to contract infection from playing in soil or in association with pica. The only symptom may be presence of individual rice-like motile white segments (fig.k) or chains of proglottides in a child`s diaper, under-wear or faeces [12, 13, 49].

Concluding remarks

Intestinal cestodes have a cosmopolitan distribution with highest prevalences in under-developed regions. *Taenia saginata*, *T.solium*, *Hymenolepis nana* and *Diphyllobothrium latum* infect a total of approximately 170-200 million people. Prevalences for all these species are increasing in several regions. Incidence of neurocysticercosis which is caused by *T.solium* carriers, is expected to increase in poor rural communities with trends for greater reliance on free-range pigs. A third

species of human *Taenia* is now confirmed as *T.asiatica*, which is also transmitted in pigs. DNA analysis is recommended to confirm *Taenia* spp. tapeworms in SE Asia. Intestinal tapeworm infections may cause diarrhoea and abdominal discomfort but are usually treatable with a single dose of an anthelmintic. Modern diagnostic tests have improved detection, control program surveillance and epidemiological studies.

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Table : Main intestinal cestodes of humans and zoonotic infections

Species or Genus	**Size * (cm)**	**PPP** (days)**	**Intermed. host*** ** (cyst type)	**Final host**	**Primary distribution**	**Egg size (um) morphology**
Taenia solium	300	70	pig (cs)	human	Global	40, round
T.saginata	400	70	bovid (cs)	human	Global	40, round
T.asiatica	500	70	pig (cs)	human	SE Asia	40, round
Hymenolepis nana	3	15-20	none (cd) or insects	human	Global	50,oval, polar filaments
Diphyllobothrium latum	600	25	fish (pl)	human	Global	60, oval,+opc. immature
D.pacificum	600	25	fish (pl)	seals	Pacific Rim	60, oval,+opc.
***Diplogonoporus* sp**	700	25?	fish (pl)	whales	Japan,Pacific	60, oval,+opc. immature
Dipylidium caninum	20	20	flea (cd)	dog, cat	Global	40, round, 6 - 20 in egg sac
***Mesocestoides* sp.**	50	15	insects(td)	dog, canids	Eurasia	40, oval
***Bertiella* sp.**	5-30	?	mites (cd)	monkey	Africa, Asia	40-50, oval, pyriform
Hymenolepis diminuta	40	20	beetles, fleas (cd)	rat	Global	70, round no filaments
***Raillietina* sp.**	30	?	ants (cd)	rat	Asia-Pacific	90 , oval, 2-3 in egg sac
***Inermicapsifer* sp.**	30	?	insects? mite? (cd)	rodents	Africa	40-60, oval, no pyriform

* average length in final host ; ** PPP= earliest pre-patent period in final host ; ***infective to humans; cs = cysticercus, cd = cysticercoid, pl = plerocercoid, td = tetrathyridium, +opc = egg with operculum

Figure legends

a. Eggs of *T.saginata* which are morphologically the same for all *Taenia* sp.

b. *T.saginata* tapeworm (6m) after PZQ and traditional areca/pumpkin seed purge, Gansu, China.

c. Scoleces of (i) *T.solium* and (ii) *T.asiatica*, from a dual infection of an adult female (Kanchanaburi Province,Thailand)

d. Typical appearance of a purge collected post-treatment after PZQ for taeniasis (*T.asiatica*, Samosir Island, Sumatra).

e. Motile gravid proglottids of *T.asiatica* from a 45 yr male, Sumatra.

f. Strobila of *T.asiatica* post treatment/purge, Sumatra.

g. Typical egg (50um) of *H.nana*, with visible hooklets and polar filaments.

h. *Diplogonoporus grandis* adult tapeworm (4 m) from a Japanese patient.

i. Mature proglottids of *D.grandis* showing double uterus.

j. Egg of *D.grandis* (60um); very similar to that of *D.latum*.

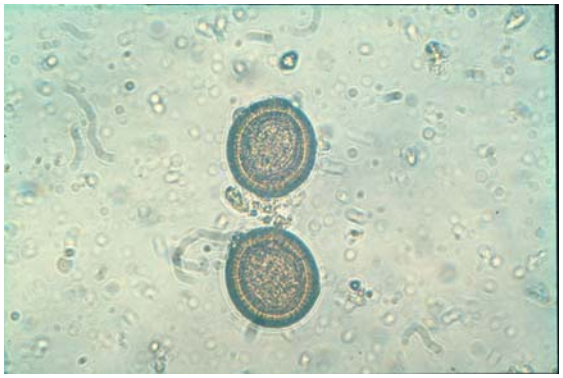
k. Proglottids of *Inermicapsifer* sp. in the faeces from an 18 month old child (Zimbabwe).

l. Single proglottid of *Cittotaenia* spp- a rabbit anoplocephalid tapeworm similar to *Bertiella* sp.

Craig and Ito « Intestinal Cestodes »

Figures

a. *Taenia* spp eggs

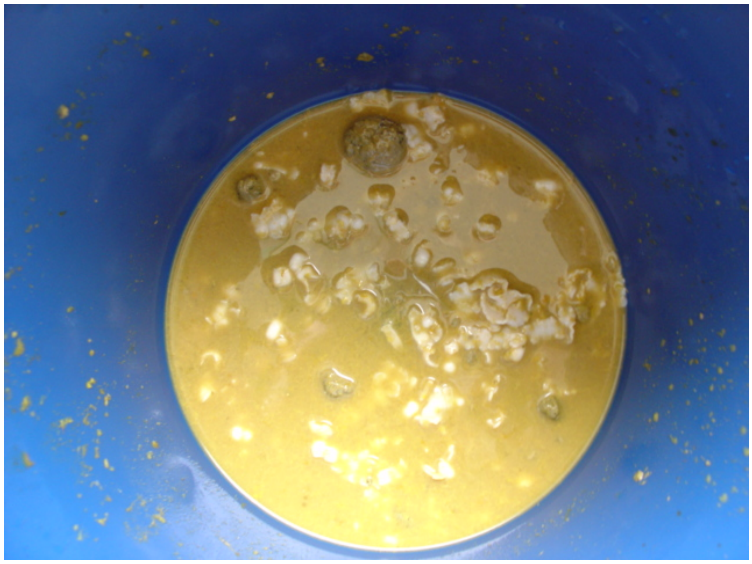


b. *T.saginata* from 19 yr female (China)

c. Scolex of (i) *T.solium* and (ii).*T.asiatica* from a double infection in an adult female (Thailand). Stained with carmine (courtesy Dr. Anantaphruti) .

(i) (ii)

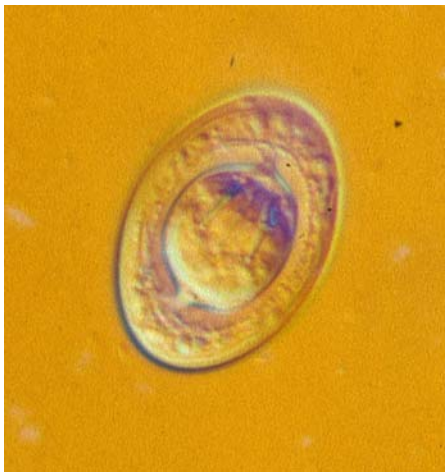
d. *T.asiatica* fragments in a human purge (Sumatra)



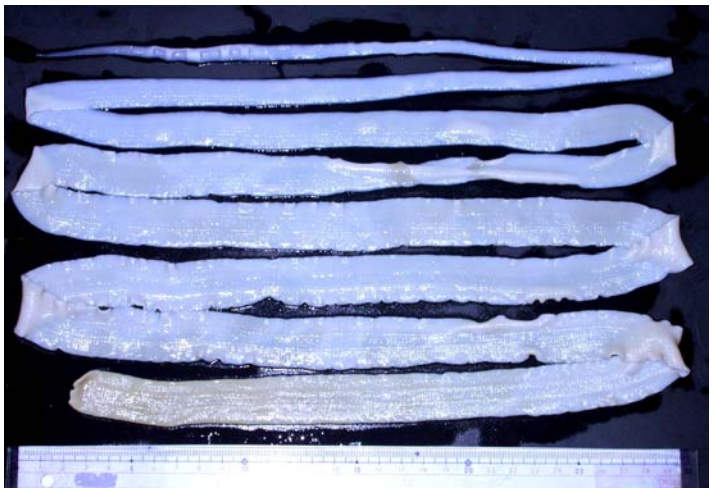
e. *T.asiatica* gravid proglottids

f. *T.asiatica* stobila from a purge (Sumatra)

g. Egg of *Hymenolepis nana*

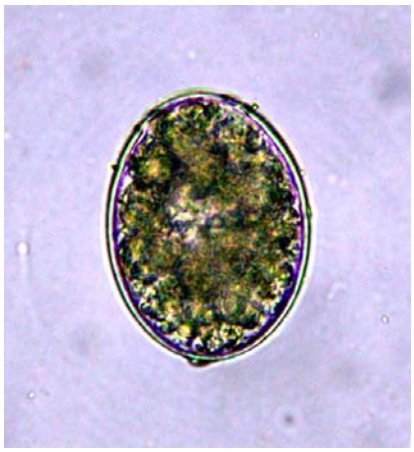


h. *Diplogonoporus grandis* adult tapeworm from human (Japan, courtesy Dr. Kino)

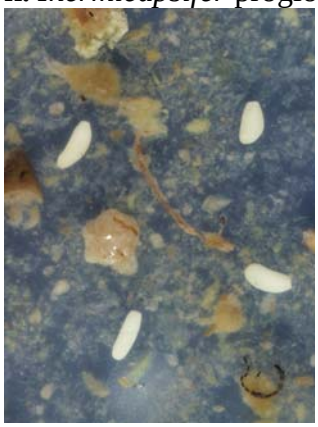


i. Mature proglottid (stained) of *D.grandis* (Japan, courtesy Dr. Kino)

j. Egg of *D.grandis* from human faeces (courtesy Dr. Kino)



k. *Inermicapsifer* proglottids in stool from 18 month child (Zimbabwe)



l. Anoplocephalid proglottis on rabbit faecal pellet (similar to *Bertiella* spp.)