

8.10.1 Cestodes (tapeworms) 1520

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ESSENTIALS Adult tapeworms maintain anchorage to the small-gut mucosa of their vertebrate definitive host, and their eggs enter the faecal stream. Their life cycle then includes larval stages in two or more intermediate hosts. Serious disease can result when larval stages occur accidentally in humans, whereas infections by the adult stages often cause little harm. Two groups of cestode infect humans: the Cyclophyllidea and the Pseudophyllidea. The former have a terrestrial life cycle and cystic larvae; the latter have an aquatic cycle and worm-like larvae.

Cyclophyllidean tapeworms *Taenia saginata* The beef tapeworm is common in Africa, the Middle East, Asia, and South America. Transmission occurs where cattle have access to human faeces and where humans eat undercooked beef containing cysts. Symptoms include nausea, abdominal pain, and pruritis ani, but many people who are infected are asymptomatic. Diagnosis is by finding typical eggs in perianal swabs. Treatment is with niclosamide or praziquantel. Prevention is by health education concerning production and cooking of meat, also by proper sewage treatment and disposal. Mass treatment of selected or whole adult populations is the most effective short-term measure when endemicity is high.

Taenia solium The pork tapeworm is common in Africa, parts of Asia, and Central and South America. Infections occur when cysts in undercooked pig meat are eaten. Symptoms, diagnosis, and treatment are similar to those of *T. saginata*.

Cysticercosis (chapter 8.10.3) occurs when eggs from the faeces of persons harbouring adult worms are ingested, producing cysts in striated muscle, subcutaneous tissue, nervous system, and the eye.

Other tapeworms These include (1) *Echinococcus granulosus*—the dog tapeworm, cause of hydatid disease (chapter 8.10.2); (2) *Echinococcus multilocularis*—the fox tapeworm, cause of alveolar hydatid disease; (3) genus *Multiceps*—common tapeworms of dogs and foxes, cause of coenurosis; (4) other gut tapeworms including *Taenia asiatica* and *Hymenolepis nana*.

Pseudophyllidean tapeworms *Diphyllobothriasis* ('fish or broad tapeworm infections') Infection is now most common east of the Urals and follows ingestion of infected undercooked fish. Infections are often asymptomatic, apart from passage of

worm segments in stools, but there can be bowel upset or urticaria. Heavy or prolonged infections can lead to vitamin B12 deficiency and sometimes pernicious anaemia. Diagnosis is by finding eggs or proglottids in faeces. Treatment is with praziquantel or niclosamide and, if necessary, with vitamin B12. Sparganosis *Spirometra* tapeworms are parasites of canids and felids. Human infections are most common in East Asia. The plerocercoid larva grows as it migrates slowly in the tissues as a form of 'larva migrans', most frequently subcutaneously but also in brain, orbit, and elsewhere. Treatment is primarily surgical: anthelmintics give poor results and may aggravate neurological lesions. Introduction Adult tapeworms maintain anchorage to the host small-gut mucosa by means of the scolex, a holdfast structure. The rest of the body forms the strobila and consists of a chain of flattened proglottids, which proliferate just behind the scolex. The worms

8.10.1 Cestodes (tapeworms) 1521 change their site of attachment regularly, and are surprisingly motile. Gravid proglottids are lost from the end of the worm and are replaced by others that have grown and matured as they pass down the strobila. Each proglottid possesses a complete set of hermaphroditic sex organs and genital openings. Eggs accumulate in the uterus of gravid proglottids and only enter the faecal stream if the proglottids are disrupted. In many species the eggs enter the environment within intact proglottids. The life cycle of tapeworms includes two or more host species; the adult worm being in the definitive host and the larval stages being in the intermediate hosts. When larval stages occur in humans, serious disease can result. Two groups of cestode infect man: the Cyclophyllidea and the Pseudophyllidea. Cyclophyllidean tapeworms These include the beef and pork tapeworms, echinococcosis (hydatid) and several other species. The larval stages occur in vertebrates, adult worms have a scolex bearing a circlet of four suckers and usually a central evertible rostellum with one or more circlets of minute hooks (Figs. 8.10.1.1a, b, c). In many species the eggs enter the environment within intact proglottids. In either case the eggs are embryonated and contain a six-hooked hexacanth embryo. The egg shells have two membranes, but in *Taenia* the outer is lost early and the inner forms the thick embryophore. After ingestion by the intermediate host, eggs hatch and the released hexacanth embryo bores its way into the mucosa. The larval stages of the parasite ('metacestode') are generally cystic with an invaginated embryonic scolex—the protoscolex. The cycle is completed when the larval stage, within the intermediate host or its tissues, is eaten by the definitive host; the protoscolex evaginates and attaches to the gut mucosa. Humans can be infected by adult parasites in the gut. More serious disease occurs when larval stages in the tissues: 1. Cysticercosis caused by *Taenia solium* (see next and Chapter 8.10.3). 2. Hydatid disease caused by the dog tapeworm *Echinococcus granulosus* (see Chapter 8.10.2). 3. Alveolar hydatid disease caused by the fox tapeworm *Echinococcus alveolaris*. 4. Coenurosis caused by tapeworms of the genus *Multiceps* in canids and rabbits. Cyclophyllidean gut tapeworms In four gut species, humans are an obligatory part of the life cycle (Table 8.10.1.1), in the rest they are an accidental host (Table 8.10.1.2). The three *Taenia* species are anthroponoses because the cycle is maintained by an obligatory alternation between human and nonhuman hosts. Phylogenetic studies suggest that *Taenia* tapeworms were acquired, before humans domesticated cattle and pigs, by hominid hunters intruding into predator-prey cycles involving perhaps lions and hyenas. Patients with *Taenia* infections pass proglottids in their faeces or experience their active migration per annum. The clinical importance of the pork tapeworm relates mainly to cysticercosis, the occurrence of larval forms in human tissue (see Chapter 8.10.3). The dwarf tapeworm *Hymenolepis nana* infects an estimated 9 million people; there is normally no intermediate host. With any gut cestode, symptoms also result from local hypersensitivity reactions to the worm and its scolex, altered gut

motility, and poorly defined systemic symptoms with an immunological basis. A blood eosinophilia up to 10% can occur. (a) (b) (c) Fig. 8.10.1.1 (a) *Taenia saginata* showing scolex with four suckers and no hooks. (b) *Taenia solium* showing scolex with four suckers and a double row of hooks. (c) *Taenia solium* detail of hooks. Courtesy of Professor Viqar Zaman.

section 8 Infectious diseases 1522 *Taenia* tapeworms *Taenia saginata* Geographical distribution The beef tapeworm *T. saginata* is prevalent where cattle have access to human faeces and where humans eat undercooked beef. The highest prevalence is in Africa, particularly in eastern and north-eastern parts; it is also common in many countries in the Middle East, South America, and Southeast Asia. Prevalence is now very low in the United States of America, Canada, and Australia. It persists endemically in Europe; but prevalence increases progressively eastwards and into the former Soviet Union. Table 8.10.1.1 Major gut cestodes that infect humans *Taenia saginata* Beef tapeworm *Taenia asiatica* Asian tapeworm *Taenia solium* Pork tapeworm *Hymenolepis nana* Dwarf tapeworm Larval tapeworm Intermediate hosts Cattle, water buffalo, other bovids, reindeer Pig, wild boar Pig, wild boar; also in humans (cysticercosis) None but human and murine subspecies perhaps cross-infect Type and size *Cysticercus* 7–10 × 4–6 mm *Cysticercus* 2 × 2 mm *Cysticercus* 5–8 × 3–6 mm Minute tailless cysticercoid 50 µm Location Muscle, viscera, brain (reindeer only) Viscera, mainly liver Muscle, brain, subcutaneous, eye, tongue Villi of small intestine Adult tapeworm Length 4–12 m 4–12 m 3–5 m 25–40 mm Number of proglottids 2000 (mean) 2000 (mean) 700–1000 200 (mean) Gravid proglottid Longer than wide; 20–30 × 5–7 mm Longer than wide; 20–30 × 5–7 mm Longer than wide; 18–25 × 5–7 mm Wider than long; 0.8 × 0.2 mm Scolex No rostellum, no hooks Rostellum; no hooks Rostellum with double circlet of hooks Rostellum with single circlet of minute hooks Gravid uterus 15–20 lateral branches 15–20 lateral branches 7–12 lateral branches Bilobed Egg (contains hexacanth embryo) Embryophore shell is radially striated and 31–40 µm in diameter Embryophore shell is radially striated and 31–40 µm in diameter Embryophore shell is radially striated and 31–40 µm in diameter Oval, 30–47 µm long; two shell membranes; 4–8 filaments arise from each pole of inner membrane Table 8.10.1.2 Uncommon gut cestodes that infect humans Species Geographic distribution Definitive hosts Intermediate hosts Length and width of tapeworm Shape of gravid proglottid Other features *Bertiella mucronata* South America, Cuba Primates Oribatid mites 15–45 cm × 5–10 mm Wider than long Inner eggshell bears bicornuate knob *B. studeri* South and Southeast Asia, Africa, Cuba Primates Oribatid mites 27–30 cm × 6–10 mm Much wider than long As above *Dipylidium caninum* Worldwide Dog, cat Fleas and dog louse 10–70 cm × 2.5–3 mm Elongate, wider in middle Double set of sex organs. Egg capsules with 8–15 eggs *Hymenolepis diminuta* (rat tapeworm) Worldwide Rat Fleas, beetles, cockroaches 20–60 cm × 3–4 mm Much wider than long Egg like *H. nana* but yellow outer membrane and no filaments; 60–85 µm *Inermicapsifer madagascariensis* Madagascar, Africa, Central America, Cuba Rats Arthropod 26–42 cm × 2.6 mm Slightly elongate, white, and opaque Egg capsules with 6–11 eggs *Mathevotaenia symmetrica* Thailand Rodents Beetles 13 cm × 1–2 mm Elongate, wider in middle Capsule surrounds individual eggs *Mesocestoides lineatus* China, Japan, Korea Carnivores Mites (1st host); amphibia, reptiles, birds, rodents (2nd hosts) 40 cm × 1.5–2 mm Longer than broad Single medioventral genital opening *Mesocestoides variabilis* Greenland, USA Carnivores Mites (1st host); amphibia, reptiles, birds, rodents (2nd hosts) 40 cm × 1.5–2 mm Longer than broad Single medioventral genital opening *Raillietina celebensis* East Asia, Polynesia, Australia Rats Ant 16–60 cm × 3 mm As above Egg capsules with 1–4 eggs *R. demerariensis* Guyana, Cuba, Ecuador Rats Cockroach 16–60 cm × 2–3 mm As above Egg capsule with 8–10 eggs

8.10.1 Cestodes (tapeworms) 1523 Epidemiology Most worms are solitary. Multiple worms are smaller and typically occur in high-transmission areas, probably by simultaneous infection. Viable eggs from human faeces persist on pasture for many months and can survive most forms of sewage treatment. Cattle have access to human faeces on farms, at camp sites and recreation areas, and on railway lines. Infected herdsmen can initiate epizootics. Eggs may be dispersed by flies and dung beetles, and seabirds can ingest proglottids in refuse or estuarine waters and deposit them in their faeces on inland pastures. In cattle the whitish, ovoid cysticerci become infective within 12 weeks and remain viable in the living host for 2 years; they are viable in stored, chilled meat for several weeks but are killed at -20°C within 1 week. The prepatent period in man is 3 months and worms may live 30 years. Cattle develop protective immunity to new infection.

Clinical features The whitish mature proglottids, approximately 2–3 cm long, are actively motile, elongating and contracting (Fig. 8.10.1.2). Most patients experience active exit of single proglottids through the anus, others pass proglottids at defecation, often in short chains; free eggs also occur in faeces. Many have no other symptoms, but others complain of nausea and upper abdominal pains, often relieved by food. In children, impaired appetite can have nutritional consequences. Some patients have symptoms suggestive of hypoglycaemia, namely dizziness and sweating. Pruritus ani is common. The worm can sometimes be visible on small-bowel barium studies. Proglottids have been found in a variety of surgical specimens, including resected appendices, but a pathogenic role is usually difficult to establish. They occasionally obstruct the small intestine, pancreatic duct, or bile duct. Proglottids are recorded in the gallbladder, and eggs have been found in gallstones.

Diagnosis The typical eggs (Fig. 8.10.1.3) can be found in faeces, but this is an insensitive method; perianal swabs are more useful. Eggs are indistinguishable from those of *T. solium* and *T. asiatica*; patients should be asked to bring worm specimens. Unless the proglottid is fully gravid the number of uterine branches is an unreliable diagnostic character. A better morphological distinction is the presence of a vaginal sphincter; this is absent in *T. solium*. In human surveys in endemic areas a 24-h faecal collection after an anthelmintic will give the most reliable prevalence.

Treatment Niclosamide, 2 g, is given to adults and older children as a single morning dose on an empty stomach; the tablets should be chewed. Children aged 2 to 6 years should receive 1 g, and those below 2 years 500 mg. The alternative is praziquantel, 5–10 mg/kg as a single dose after a light breakfast. After either drug the proximal part of the worm disintegrates in the gut and the scolex cannot be found. Failure of proglottids to reappear within 3 to 4 months indicates cure.

Control This includes health education concerning raw beef, meat inspection, sanitation and hygiene on cattle farms, and proper sewage treatment and disposal. Mass treatments of herd contacts, or whole adult populations, are the most effective short-term measures when endemicity is high. *T. saginata* causes great economic loss to the beef industry in some developing countries. Vaccines may soon become available for use in cattle.

Taenia asiatica This was first described in 1973 as a subspecies *T. saginata* from rural Taiwan, where raw pig or wild boar liver, but no beef, was eaten. It is now recognized as a separate species and known also to occur in Korea, China, northern Sumatra, Indonesia, Philippines, Thailand, India and Nepal. The cysticerci in pig viscera are very small. In immunodeficient mice *T. asiatica* eggs, but not those of *T. saginata*, produce cysticerci with hooked protoscolices. Eating uncooked pork with viscera from home-killed pigs is a recognized risk factor. Symptoms and treatment are the same as for *T. saginata*.

Fig. 8.10.1.2 Actively mobile, contracting proglottid of *Taenia saginata* found by a patient in the stool. Copyright D. A. Warrell. Fig. 8.10.1.3 Egg of *Taenia*. Courtesy of Professor Viqar Zaman.

section 8 Infectious diseases 1524 It appears not to cause cysticercosis in humans; possibly the species can hybridize with *T. saginata*. *Taenia solium* (see also Chapter 8.10.3) Generally less common than the beef tapeworm, the pork tapeworm *T. solium* is now very rare in North America and Western Europe, but it remains common in much of sub-Saharan Africa, and in China, India, and other parts of Asia. It is highly prevalent in Mexico and other Latin American countries. Two genotypes are now recognized: the European type that has been introduced into the Americas and Africa since the 1500s, and the Asian type. Both types can produce neurocysticercosis, but only the latter causes subcutaneous cysticercosis. Epidemiology In pigs, muscle cysticerci produce 'measly pork' (Fig. 8.10.1.4). The cysts are most numerous in the tongue, masseter, heart, and diaphragm, but also occur in the brain. When eaten by humans in undercooked pork, the worms mature in 5 to 12 weeks. The eggs have the same resistant qualities as those of *T. saginata*. Human cysticercosis arises when eggs from the faeces of people infected with adult worms are ingested and hatch in the upper gut; humans thus become an accidental intermediate host. Conditions favouring cysticercosis include poor personal hygiene, which facilitates external autoinfection, and contaminated fingers among food handlers. Faecal pollution of the peridomestic environment, irrigation water, or cultivated vegetables is also important. In parts of Africa, tapeworm proglottids are used in traditional medicine. In the absence of these factors, cases of cysticercosis may be very sporadic even when *T. solium* is common. Cysticercosis is a major health problem in Mexico, some South American countries, and to a lesser extent in Africa and Asia. In 1969, *T. solium* was introduced from Bali into the highlands of Indonesian New Guinea, where the disease is now of great importance. Pathology of human cysticercosis Cysts occur especially in striated muscle, subcutaneous tissue (Asian genotype), the nervous system, and the eye. Many remain clinically silent until the parasite dies after 3 to 5 years, when vigorous inflammatory and hypersensitivity reactions can occur; later, lesions may calcify. In the brain, particularly in the subarachnoid and the ventricular system, atypical racemose cysts may occur. They appear as irregular or grape-like clusters of cysts that have no protoscolex; they can be mistaken pathologically for nonparasitic cysts. Clinical features Symptoms, if any, due to the adult worms are similar to those of *T. saginata* but are often milder and not associated with pruritus ani. The proglottids do not migrate actively per annum. Diagnosis Adult worm infection is detected as for *T. saginata*. Methods for detecting faecal antigen are available and have great potential use in epidemiological studies. Proglottid fragments can be identified using DNA probes. Treatment and control Adult worms are treated as for *T. saginata*. Because of the potential risk of internal autoinfection vomiting must be avoided and an antiemetic is often recommended before treatment, together with a laxative 2 h after the medication. It should be remembered that the faeces will be potentially highly infective for several days, for both the patient and the attendants. Control measures include meat inspection, health education, and population-based chemotherapy. Local risk factors for human cysticercosis must receive special attention. Pigs can be treated with a single dose of oxfendazole and perhaps in the future given recombinant hexacanth vaccines. *Hymenolepis nana* The dwarf tapeworm, sometimes now placed in the genus *Rodentolepis*, is the most common cestode in humans; it is also the smallest. When worm loads are high, it causes more gut pathology than any other species. It is common in most developing and tropical countries. The life cycle normally involves only humans. Fully embryonated infective eggs are passed in the faeces; gravid proglottids normally disintegrate completely in the gut. Infection is commonly direct, but also by the other faeco-oral routes. Eggs hatch in the jejunum and the hexacanth embryo bores into a villus where it transforms into a cysticercoid larva. After 4 to 6 days it re-enters the gut, everts the scolex, and attaches to the mucosa; eggs appear in the faeces within 12 days. The lifespan is 3

months. The eggs are delicate and survive less than 10 days in the environment. Prevalence is usually much higher in children than adults; outbreaks can occur in families and institutions. External autoinfection is common in high-risk groups and enables high worm loads to build up. In addition, internal autoinfection occurs when there is gut stasis or retroperistalsis. Because of the importance of direct transmission, this infection may be common even in arid environments such as Western Australia. A similar parasite, recognized as a subspecies *H. nana* *fraterna*, occurs in the mouse but this normally has the flour beetle *Tribolium* as intermediate host, although direct mouse-to-mouse transmission can occur. Both human and murine subspecies will infect these

Fig. 8.10.1.4 'Measly pork' showing numerous cysts in the pig's muscle. Copyright Sornchai Looareesuwan.

8.10.1 Cestodes (tapeworms) 1525 beetles. The zoonotic potential of the murine subspecies is uncertain, as at least Australian human strains will not infect mice. Clinical features Heavily infected people, especially children, may harbour up to 1000 or more worms. Mucosal damage caused by both larval and adult worms leads to protein loss and sometimes malabsorption. Abdominal pains and anorexia are common. Immunosuppressant or steroid therapy, particularly in lymphoma patients, can lead to the development of bizarre cystic larval forms in the gut wall, mesenteric nodes, liver, and lungs. A similar condition can be produced in immunosuppressed mice. Diagnosis and treatment Eggs can be detected in faeces using concentration methods. Proglottids are rarely found in faeces, except after treatment. Praziquantel in a single dose of 25 mg/kg is the most effective drug. If niclosamide is used, a 7-day course is needed to ensure that larval stages are killed when they re-enter the gut lumen. The dose on the first day is as for *T. saginata*; on the remaining days one-half of this dose is given. Relapses often result from persistence of eggs in the patient's environment. Uncommon gut cestodes Several species have been recorded in humans (Table 8.10.1.2). All have arthropods as intermediate hosts, the larval cysticercoid stage being in the haemocoel; the full life cycles of some species are still uncertain. The normal definitive host becomes infected by eating the arthropod, intentionally or accidentally. The means by which humans become infected is sometimes not clear, but fleas, small beetles, and mites are easily overlooked in food. *Dipylidium caninum* infection occurs in children who have groomed their pets. Infections with *Bertiella* are mostly in owners of pet monkeys, but oribatid mites are common in fallen fruit, especially mangoes. Children may eat insects deliberately, and this appears to be the mode of infection by *Raillietina* in Bangkok. Beetles are used for medicinal purposes in parts of Thailand and Malaysia, and this is the most likely route by which *Mathevotaenia* is acquired. In many of these species the eggs are in capsules that are released when the proglottid disintegrates in the gut, or more commonly, in the faecal mass. *Mesocestoides* is unique among these parasites in that two intermediate hosts are required, and the genital opening is medioventral. Human *Mesocestoides* infections follow ingestion of raw viscera or blood from game, including birds, or from chickens. Many patients will present because they have passed proglottids. *D. caninum* actively migrates out of the anus, like *T. saginata*. Faecal examinations of people with abdominal complaints may reveal unusual eggs or egg capsules. Poorly defined systemic and allergic complaints are common. Treatment is as for *T. saginata*. Recognition of these parasites is of epidemiological interest and may indicate potential transmission of other zoonotic pathogens. It is certain that all these parasites are underreported. Unusual proglottids or eggs should be preserved in formol saline and sent to a parasitologist. Tissue cyclophyllidean tapeworms (For cysticercosis caused by *Taenia solium*, see earlier and Chapter 8.10.3. For hydatid disease caused by the dog tapeworm *Echinococcus granulosus*, see

Chapter 8.10.2.) Alveolar hydatid disease caused by the fox tapeworm *Echinococcus multilocularis*

Epidemiology Because of its high mortality and difficult clinical management this parasitic disease is important. Adult *E. multilocularis* tapeworms, which are smaller than those of *E. granulosus*, are widespread gut parasites of foxes and arctic foxes in the Northern hemisphere, faecal eggs are ingested by rodents, especially voles and lemmings, which develop hepatic multilocular cysts; these intermediate hosts are in turn eaten by foxes to complete the cycle. Humans become accidental intermediate hosts when eggs contaminate food or water. Dogs and more rarely cats can also be infected by the adult parasite. The global annual incidence rate is now estimated to be 18 000, with 91% in China, and 1600 elsewhere, particularly Russia, Turkey, and Europe (Fig. 8.10.1.5). Prevalence of the parasite in European foxes is quite widespread, but human disease quite rare with about 60 cases annually in Germany and Switzerland and smaller numbers in France, Poland, and the Baltic states and elsewhere. The principal rodent host in Europe is the common vole, but also muskrats, nutria, and the beaver. There is concern that European beavers brought to the United Kingdom in reintroduction schemes might harbour this parasite. The raccoon dog (*Nyctereutes*) has been introduced to Europe and is now a potentially dangerous new host for the adult worm. Human cases are predominantly rural and focal, and can usually be attributed to ingestion of apples, berries, and salad vegetables or water sources contaminated by fox faeces; fur trappers may be infected during skinning of wild canids. Increases in populations of both rural and urban European foxes raise concerns, and in France where 407 human cases were diagnosed between 1982 and 2007, infected foxes are reported from Paris and on the Channel coast, but infected dogs are rare in France.

Pathology Primary lesions are in the liver and consist of an amorphous mass of minute irregular spaces, containing little fluid, in an avascular adventitia but no surrounding fibrous capsule; unlike the lesions in the vole brood capsules and protoscolices are scarce. The lesion enlarges progressively with exogenous budding over a period of years, and may extend from the liver through the diaphragm or abdominal wall, sometimes metastasizing to the brain or elsewhere. Untreated, most cases are fatal but some resolve and may calcify.

Clinical features and management Five or more years after presumed infection patients present with hepatomegaly, cholestatic jaundice, or less suggestive symptoms. Later there might be signs of liver failure or spread outside the liver. Liver ultrasound shows an irregular tumour with juxtaposed hypo- and hyperechoic areas, scattered calcification, and central necrosis. MRI can show the multivesicular nature of the lesion. Biopsy material

section 8 Infectious diseases 1526 can be stained with Periodic acid-Schiff to show the germinal layer and parasite antigen detected by PCR. Immunodiagnosis gives good sensitivity and specificity. Treatment must aim at complete surgical excision with a 2 cm tissue margin whenever this is possible and be followed by albendazole for two years if resection is complete, and lifelong otherwise. The usual dose is 10–20 mg/kg daily in two divided doses. This drug does not kill the parasite directly but is parasitostatic. Patients are monitored by regular ultrasound, liver function tests, drug levels, blood counts, and perhaps serology. When complete removal is not possible then palliative care should be multidisciplinary, preferably in centres experienced in this condition. Liver transplantation has been successful, but the necessary immunosuppression facilitates parasite growth and albendazole cover must be given. Praziquantel is not used in humans with this infection but is used in baits for foxes as an effective control measure.

Coenurosis caused by canid tapeworms of the genus *Multiceps*

Epidemiology *Multiceps multiceps* is a common tapeworm in dogs, foxes, coyotes, and other canids worldwide, *M. serialis* occurs mainly in North American dogs and foxes, while *M. brauni* and *M. glomerata* infect African canids. The worms measure a metre or

more in length. Gravid proglottids and eggs, passed in faeces are ingested by sheep and less commonly cattle, horses, goats, rabbits, or rodents and in these intermediate hosts the cystic larval stage or coenurus develop in the brain and other tissues. These cysts show characteristic multiple invaginated scoleces. Sheep can develop a fatal ataxia known as 'gid'. Human infections, while uncommon, occur especially in Africa but also in sheep-raising areas worldwide. They follow accidental ingestion of eggs from canid faeces and are commoner in children. Clinical features and management Coenurus cysts are usually unilocular and can measure 3 cm or more in diameter; they occur most commonly in the brain, spinal cord, eye, muscle, and subcutaneous tissue. The cysts of *M. serialis* are most frequent in subcutaneous tissue, and *M. brauni* in the eye. The clinical features are of a mass or space occupying lesion with the associated secondary effects. The cystic lesions must be differentiated from cysticerci and hydatid, but diagnosis will usually only be confirmed after surgical removal when parasitological methods including recent molecular techniques are used. Besides excision the role of praziquantel appears promising. *Taenia crassipes* cysticercosis This is a common tapeworm of dogs, foxes, and felids; the intermediate hosts are rabbits and rodents in which the small cysticerci are in muscle and subcutaneous tissue, but sheep may also be infected and develop a fatal neurological disease. An important characteristic of this species is exogenous budding producing many daughter cysts. So far 10 human cases are reported; of whom 5 had Fig. 8.10.1.5 Global distribution of alveolar echinococcosis. Reprinted from Torgerson PR, et al. (2010). The Global Burden of Alveolar Echinococcosis. PLoS Negl Trop Dis 4(6): e722, © 2010 Torgerson et al.

8.10.1 Cestodes (tapeworms) 1527 AIDS and one lymphoma with cysts in muscle and subcutaneous tissue. In immunocompetent patients, cysts were found in the eye, but cysts in the human nervous system have not been reported so far. Treatment is by excision, but this is difficult because of the budding. Cestocidal drugs may be ineffective. Pseudophyllidean tapeworms These include the fish tapeworms (*Diphyllobothrium* spp.) and the *Spirometra* species that cause sparganosis. When eggs of these parasites reach fresh water, they hatch into a coracidium, a spherical ciliated larva which when engulfed by small crustacean copepods becomes an elongated proceroid larva. If infected copepods are ingested by a fish, they become a motile plerocercoid or sparganum; fish-eating mammals complete the life cycle when plerocercoids attach to the small-gut musosa and become adult worms. The life cycle may also include nonfish vertebrates that ingest infected copepods. In addition, amphibia and snakes that ingest infected fish, become paratenic hosts in which the worm remains a plerocercoid; this is also the situation in humans who develop sparganosis. Adult pseudophyllidean worms have two sucking grooves or bothria on opposite sides of the scolex, the proglottids are usually much wider than broad, and the separate genital and uterine openings are on the mid-ventral surface. *Diphyllobothriasis* ('fish or broad tapeworm infections') Epidemiology In 1970 there were five million cases of *D. latum* infection in central and eastern Europe, Finland, and the Baltic states maintained by ingestion of undercooked fish, particularly pike, perch, and burbot containing the plerocercoid larvae. Prevalence has since greatly declined but a recrudescence is now occurring in Switzerland, northern Italy, and eastern France as undercooked fish delicacies become popular; up to 5% of perch in some Alpine lakes are now infected. The larvae measure up to 20 mm and appear glistening opaque white and unsegmented; they occur throughout the fish tissues but migrate to muscle in dead fish. The adult worm, 2-15 m in length and 5-10 mm wide, is folded repeatedly within the small intestine. The scolex attaches to the ileum and the worm can grow 22 mm/day and live 20 years. Prevalence has also declined in North American great lakes where the main fish host

is pike, perch or walleye; the parasite was originally introduced by Scandinavian migrants. In Asia it is prevalent in all river basins east of the Urals. It has been introduced to Brazil and other South American countries where there have been recent outbreaks. Humans are infected by 13 species of *Diphyllobothrium* in addition to *D. latum*. The three most important, with their intermediate and nonhuman final hosts are: (1). *D. nihonaiense* in the North Pacific especially Japan, Pacific salmon, brown bears; (2). *D. dendriticum* is circumpolar, salmonelid, and coregonid fish, piscivorous birds especially gulls and bears: this species is now regarded as an emerging infection. (3). *D. pacificum* on Pacific Coast South America and Japan, marine fish, sea-lions, and seals: human coprolites containing eggs of this species dating from 2000 BC have been found in Chile. In Japan 200 cases of infection by another diphyllid worm, *Diplogonoporus grandis*, normally a parasite of whales, is reported following ingestion of raw anchovy or sardine. Clinical features, treatment, and prevention Many patients are unaware of their infection apart from noticing proglottids or long parts of the worm passed per annum, 20% complain of abdominal pain or discomfort, diarrhoea, or allergic symptoms such as urticaria. Rarely infections cause obstruction of the gut or bile duct. The worms cause dissociation of the vitamin B12-intrinsic factor complex and 80% of the oral intake of the vitamin is taken up by the worm. Up to 40% of patients have a low serum B12 and a few with heavy or prolonged infections develop pernicious anaemia. Diagnosis is by parasitological examination of proglottids or faecal eggs (Fig. 8.10.1.6). Treatment is usually straightforward using a single dose of praziquantel 25 mg/kg or niclosamide 2 g for adults and 1 g for children over 6 years; vitamin B12 may be necessary. Fish to be eaten raw or semi raw should be kept at -20°C for 7 days or -35°C for 15 hours to kill larvae; cooking to 55°C for 5 minutes will also kill them. Smoking fish will not kill larvae but brine storage will. The worldwide nature of fish trade, fish transport on ice, global warming, and El Nino may all facilitate outbreaks and introduction of these parasites to new areas. Sparganosis Epidemiology *Spirometra* tapeworms are parasites of canids and felids, *S. erina ceieuropaei* (syns. *mansoni*, *erinacei*) occurs throughout Asia and western Pacific, and *S. mansonioides* in the Americas. The second intermediate hosts are fish, snakes, and frogs or tadpoles; when these are eaten, or when snake tissue or frogs are applied to wounds, the eye, or vagina for ritualistic or medicinal reasons, the parasite may be transferred. Humans are also at risk by swallowing water containing infected copepods. By all these routes humans become infected with the plerocercoid stage of the parasite which continues to grow and may reach 10 cm in length and 2 mm in width (Fig. 8.10.1.7); more than 1000 cases have been reported from China alone and is under reported elsewhere. Fig. 8.10.1.6 Egg of *Diphyllobothrium latum*. Courtesy of A. R. Butcher.

section 8 Infectious diseases 1528 Clinical features and management The worm migrates slowly in the tissues as a form of 'larva migrans'; most frequently subcutaneously but also in viscera, the orbit, and the brain. More than 160 cases of central nervous system involvement have been reported and are being increasingly recognized as neuroimaging becomes widespread. Incubation periods may be long and subcutaneous migration may continue for years. Eye lesions may present as pain, proptosis, and blindness; brain lesions as seizures, headache, parasthesiae, or weakness. A rare form of sparganosis, in which the plerocercoid multiplies within the host, is now thought to be due to a separate species *S. proliferum*; prognosis is poor. In endemic areas the diagnosis may be suspected by clinical features, serological tests are not yet very specific. Rarely serial neuroimaging may demonstrate a tunnel through which the worm migrates (Fig. 8.10.1.8). More often diagnosis will be made on histology from an excision specimen or biopsy; unlike the cysts of cyclophyllidean tapeworms the worm is solid with no suckers or rostellar hooks, and no 'bladder wall'. Treatment is primarily surgical, prognosis after excision of brain lesions can be good

but the location of the lesion is critical. Praziquantel and albendazole or mebendazole generally give poor results and can aggravate neurological lesions. FURTHER READING Cyclophyllidean tapeworms Anita A, et al. (2014). Epidemiology and genetic diversity of *Taenia asiatica*: a systematic review. *Parasit Vectors*, 7, 45. Bagrade G, et al. (2016). *Echinococcus multilocularis* in foxes and raccoon dogs: an increasing concern for Baltic countries. *Parasit Vectors*, 9, 615. Brunetti E, Kern P, Vuitton AV (2010). Expert consensus for the diagnosis and treatment of cystic and alveolar echinococcosis in humans. *Acta Tropica*, 114, 1–16. Campbell-Palmer R, et al. (2015). *Echinococcus multilocularis*: detection in live eurasian beavers (*Castor fiber*) using a combination of laparoscopy and abdominal ultrasound under field conditions. *PLoS One*, 10, e0130842. Conraths FJ, et al. (2017). Potential risk factors associated with human alveolar echinococcosis: systematic review and meta-analysis. *PloS Negl Trop Dis*, 11, e0005801. Galán-Puchades MT, Fuentes MV (2013). Lights and shadows of the *Taenia asiatica* life cycle and pathogenicity. *Trop Parasitol*, 3, 114–9. Gawor J (2016). Alveolar echinococcosis in Europe and Poland. Threats to humans. *Przegł Epidemiol*, 70, 281–8. Hemphill A, et al. (2014). Treatment of echinococcosis: albendazole and mebendazole—what else? *Parasite*, 21, 70. Hoberg EP (2006). Phylogeny of *Taenia*: species definitions and origins of human parasites. *Parasitol Int*, 55 Suppl, 23–30. Hoberg EP, et al. (2001). Out of Africa: origins of the *Taenia* tapeworms in humans. *Proc Roy Soc London B*, 268, 781–7. Muehlenbachs A, et al. (2015). Malignant transformation of *Hymenolepis nana* in a human host. *N Engl J Med*, 373, 1845–52. Pawlowski Z, Schultz MG (1972). Taeniasis and cysticercosis (*Taenia saginata*). *Adv Parasitol*, 10, 269–343. Subianto DB, Tumada LR, Morgono SS (1978). Burns and epileptic fits associated with cysticercosis in mountain people of Irian Jaya. *Trop Geogr Med*, 30, 275–8. Torgerson PR, et al. (2010). The global burden of alveolar echinococcosis. *PLoS Negl Trop Dis*, 4, e722. Umhang G, et al. (2013). Nutrias and muskrats as bioindicators for the presence of *Echinococcus multilocularis* in new endemic areas. *Vet Parasitol*, 197, 283–7. Pseudophyllidean tapeworms Anantaphruti MT, et al. (2011). Human sparganosis in Thailand: an overview. *Acta Trop*, 118, 171–6. Bennett HM, et al. (2014). The genome of the sparganosis tapeworm *Spirometra erinaceieuropaei* isolated from the biopsy of a migrating brain lesion. *Genome Biolog*, 15, 1–17. Kuchta R, et al. (2013). Tapeworm *Diphyllobothrium dendriticum* (Cestoda)—neglected or emerging human parasite? *PLoS Negl Trop Dis*, 7, e2535. Liu Q, et al. (2015). Human sparganosis, a neglected food borne zoonosis. *Lancet Inf Dis*, 15, 1226–35. Scholz T, et al. (2009). Update on the human broad tapeworm (genus *Diphyllobothrium*), including clinical relevance. *Clin Microbiol Rev*, 22, 146–60. Both groups of tapeworms Lescano AG, Zunt J. (2013). Other cestodes: sparganosis, coenurosis and *Taenia crassiceps* cysticercosis. *Handb Clin Neurol*, 114, 335–45. Fig. 8.10.1.7 A sparganum surgically removed from a subcutaneous mass. Fig. 8.10.1.8 MRI scan of cerebral sparganosis. Coronal contrast-enhanced T1-weighted image shows a tortuous curvilinear enhancing lesion (arrows) with surrounding low density of oedema and degeneration in the right frontal lobe.

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