Fasciola
(platyhelminth: trematode)

Overview

Platyhelminths have triploblastic acoelomate soft bodies which are markedly flattened in profile (hence their common name as flatworms). They undergo protostomial embryonic development but do not moult during growth. On the basis of molecular evidence, they are classified within the Lophotrochozoa despite the absence of lophophore mouthparts and trochophore larvae. Three classes are composed entirely of parasitic flatworms (Cestoda, Trematoda and Monogenea), which have prominent attachment organs (suckers or bothria), syncytial teguments, shell glands and vitellaria involved in ectolecithal egg development, and life-cycles involving a variety of larval stages. Trematodes (flukes) have soft leaf-like bodies, oral and ventral suckers, a blind gut (mouth but no anus) and both male and female reproductive organs (hermaphroditic). Digeneans have indirect life-cycles involving alternation of sexual stages in vertebrates and asexual stages in molluscs. Miracidia released from eggs infect snails (obligate intermediate hosts) where they undergo massive asexual proliferation through sac-like sporocyst and redia stages eventually releasing larval cercariae into the water. Vertebrate (definitive) hosts become infected by penetration of the skin by cercariae or by eating encysted stages (metacercariae) on herbage or in second intermediate hosts. Adult echinostomatids often have well-developed scales or spines on the anterior tegument and the ventral sucker is near the oral sucker. Fasciolids occur as large flukes in the livers of herbivores and infections by *Fasciola* spp. cause chronic debilitating hepatic diseases in domestic ruminants, and sometimes humans.

Classification:

Domain:	Eukaryota (membrane-bound nucleus)
Supergroup:	Amorphea (unikonts with single flagellum, or nonflagellated amoebae)
Kingdom:	Metazoa (multicellular eukaryotes, heterotrophs, notably animals)
Group:	Protostomia (triploblastic, spiral cleavage)
Subgroup:	Lophotrochozoa (lophophore feeding structure or trochophore larva or neither)
Phylum:	Platyhelminthes (flatworms, acoelomate, most hermaphroditic, prominent attachment organs)
Clade:	Neodermata (syncytial tegument = neodermis)
Class:	Trematoda (flukes, most with dorsoventrally-flattened bodies, sac-like gut)
Subclass:	Digenea (heteroxenous, larval miracidium, sac-like sporocyst/redia stages in mollusc, cercariae/metacercariae)
Order:	Plagiorchiida ('echinostomatids', plagiorchiids', mainly fish hosts, some tetrapods, infection by ingestion of cercariae or metacercariae)
Suborder:	Echinostomata (miracidium penetrates gastropod IH, redia formed, simple-tailed cercariae, encysts in open or in second IH, metacercariae eaten by DH)
Superfamily:	Echinostomatoidea (slender worms, adult with scales or spines)
Family:	Fasciolidae (large leaf-shaped flukes, in herbivores, conical anterior end, ventral sucker at level of shoulders)
Genus:	*Fasciola* (parasitic in liver of mammals)
Species:	*F. hepatica* (causes hepatic fibrosis in ruminants and humans)

Parasite biodiversity and host range: Most Metazoa are multicellular triploblastic animals with differentiated tissues, many being bilaterally symmetrical with a body cavity. Most invertebrate animals are protostomes as their embryonic development involves spiral determinate cleavage. Those that do not moult during their life-cycles are grouped together in the enigmatic clade Lophotrochozoa, including the platyhelminths, rotifers, lophophorates, annelids and molluscs. Platyhelminths (flatworms) have soft acoelomate flat bodies with three-dimensional arrays of muscles that generate a typical writhing motion (cf. longitudinal muscles in nematodes producing a thrashing motion). Flatworms do not have a single unifying characteristic (synapomorphy) but comprise diverse free-living (most Turbellaria) and parasitic (Neodermata) assemblages. Neodermata have non-ciliated syncytial (multinucleate) teguments and 3 classes are recognized, all with prominent attachment organs, namely, Cestoda with anterior bothridia/bothria (true/false suckers), Trematoda with oral and ventral suckers (previously called acetabula), and Monogenea with posterior haptors (opisthaptors). All have shell glands surrounding the ootype, and most exhibit ectolecithal egg development (yolk not present in egg but secreted by accessory glands called vitellaria or yolk glands). Most have indirect life-cycles involving the development of adult worms in vertebrates and larval stages in intermediate hosts (usually invertebrates).

The trematodes (flukes) and monogeneans have blind sac-like guts (lacking an anus) while the cestodes (tapeworms) lack digestive tracts. Trematodes have leaf-like bodies well adapted to living in confined spaces in tubular organs of vertebrate hosts. Two trematode subclasses are recognized: the Aspidogastrea with relatively few species (obligate external parasites of molluscs, fish and turtles, adults possessing a large ventral disc divided with numerous alveoli (suckerlets) or rows of suckers and the tegument having short protrusions (microtubercles)); and the speciose Digenea (obligate endoparasites of vertebrates, adults bearing undivided ventral suckers (when present) and life-cycles involving alternation of sexual stages in vertebrates and asexual stages in molluscs). The success of digeneans as widespread parasites has been attributed to their ability to proliferate at 2 separate parts of their life-cycles. Adults worms in vertebrate definitive hosts produce numerous eggs which are excreted and release free-swimming miracidia which seek molluscan intermediate hosts. Massive asexual proliferation occurs in molluscs involving unique sporocysts and rediae. Both stages are sac-like structures with almost no anatomical features (no suckers, no reproductive organs). The difference is that sporocysts lack a gut (they absorb their food), whereas rediae have a mouth, a muscular pharynx and a sac-like gut (they browse on molluscan tissues). Sequential development of these stages varies considerably, with mother sporocysts producing daughter sporocysts or rediae over multiple generations, culminating in the production of cercariae. The infected molluscs are typically rendered sterile ('castrated') with parasites replacing their gonads and producing dozens to thousands of infective cercariae every day. The cercariae are larval forms, almost always with tails, and they actively emerge from molluscs and swim around in water. There is enormous variation in cercarial behaviour, but the 3 most important routes of infection for definitive hosts are by penetration of the skin by cercariae (e.g. blood flukes), by ingestion of encysted stages (metacercariae) on vegetation (e.g. sheep liver flukes), or ingestion of encysted metacercariae in the tissues of a second intermediate host (e.g. human liver flukes). Some 6,700 digenean species belonging to 22 superfamilies have been described in fish and tetrapods. The subclass Digenea is divided into 2 orders: Diplostomida characterized by furcocercous cercariae that penetrate definitive hosts; and Plagiorchiida with variable life-cycles but often involving cercariae being ingested by definitive hosts.

Superfamily (+ no. families)	**No. spp.**	**DH**[a]	**Egg**[b]	**IH1**[c]	**Asexual**[d]	**Cercaria**[e]	**IH2**[f]	**Mode**[g]
Subclass: Aspidogastrea (large ventral disc with numerous alveoli (suckerlets) or rows of suckers, tegument with short protrusions (microtubercles), obligate ectoparasites on molluscs, turtles, fish)								
Aspidogastroidea (4)	65	M,F,C,T	A	G,B	-	-	-	8
Subclass: Digenea (oral and ventral sucker; syncytial tegument; obligate endoparasites of vertebrates)								
Order: Diplostomida (blood flukes, 'strigeids') ~1,480 species								
Brachylaimoidea (2)	250	T	E	G	S	S,F	M	6,7
Diplostomoidea (5)	800	T	P	G	S	F	C,M,A	6
Schistosomatoidea (5)	430	F,C,T	P	G,B,A	R,S	F	-	1,6
Order: Plagiorchiida ('echinostomatids', 'plagiorchiids') ~5,200 species								
Allocreadioidea (6)	1,118	F,T	P	G,B	R,S	S,Y	C,M,R,A	6
Apocreadioidea (1)	94	F	P	G	R	S	M,A	6
Azygioidea (1)	43	F,C	E	G	R	F	C	3,4
Bivesiculoidea (1)	28	F	P	G	R	F	C	3,4
Bucephaloidea (2)	410	F	P	B	S	F	C	4
Echinostomatoidea (10)	112	F,T	P	G	R	S	C,M,R	5,6,7
Gorgoderoidea (10)	106	F,C,T	P	G,B	R,S	S,Y	C,M,R	5,6,7
Gymnophalloidea (4)	200	F,T	P	B	S	F	C,M,R,A,E,N	3,4,6
Haplosplanchnoidea (1)	51	F	P	G	S	S	-	5
Hemiuroidea (15)	1,160	F,C,T	E	G,B,S	R,S	F	C,M,R,N	4
Heronimoidea (1)	1	T	P	G	S	S	-	7
Lepocreadioidea (8)	473	F	P	G	R	S	C,M,R,A,E,N	6
Microphalloidea (12)	414	F,T	P	G,B	S	S,Y	C,M,R,A,E	6.7
Monorchioidea (3)	270	F	E	G,B	R,S	S	C,R,A,E	6
Opisthorchioidea (3)	436	F,T	E	G	R	S	C	6
Paramphistomoidea (5)	74	F,T	P	G	R	S	-	5
Plagiorchioidea (16)	47	F,T	P	G	R,S	S,Y	C,M,R,A	6
Pronocephaloidea (6)	131	F,T	E	G	R	S	-	5
Transversotrematoidea (1)	27	F	P	G	R	F	-	2

LEGEND
[a] DH = definitive host: F = teleost fish; C = chondrichthyan fish; T = tetrapod; M = mollusc
[b] Fate of egg: A = larva hatches and attaches to IH1, E = eaten by IH1, P = hatches releasing miracidium which penetrates IH1
[c] IH1 = first intermediate host: G = gastropod, B = bivalve, A = annelid, S = scaphopod
[d] Asexual reproduction involves formation of secondary: R = redia, S = sporocyst
[e] F = fork-tailed cercaria, S = simple tailed cercaria, Y = cercaria with stylet
[f] IH2 = second intermediate host: C = chordate, M = mollusc, R = arthropod, A = annelid, E = echinoderm, N = cnidaria, ctenophore
[g] Mode of infection for DH: 1 = cercaria penetrates DH; 2 = cercaria attaches to DH; 3 = cercaria eaten by DH; 4 = cercaria eaten by IH2; 5 = cercaria emerges, encysts in open and eaten by DH; 6 = cercaria emerges, penetrates IH2, encysts and eaten by DH; 7 = cercaria remains in IH1, encysts and eaten by DH; 8 = no cercarial stage, infected IH1 eaten by DH.

Thirteen plagiorchidan suborders have been recognized containing 19 superfamilies. The suborder Echinostomata contains one superfamily Echinostomatoidea whose members have simple-tailed cercariae that encyst in the open or in second intermediate hosts and the resultant metacercariae are eaten by definitive hosts. Ten families are recognized (Calycodidae, Cyclocoelidae, Echinostomatidae (including Echinochasmidae), Eucotylidae, Fasciolidae, Himasthlidae, Philophthalmidae, Psilostomidae, Rhytidodidae, and Typhlocoelidae). By far the most clinically important family is the Fasciolidae which contains 6 genera (*Fasciola, Fasciolopsis, Fascioloides, Parafasciolopsis, Protofasciola* and *Tenuifasciola*). These are large (sometimes up to several cm long) leaf-shaped flukes that infect the liver, gall bladder and intestines of herbivores and undergo asexual development in freshwater snails from the superfamily Lymnaeoidea. Two main *Fasciola* spp. are widely distributed and abundant throughout many sheep and cattle producing areas around the world, particularly temperate regions with high rainfall or irrigated pastures where snail vectors are common. *F. hepatica* has been reported in sheep, cattle, goats, pigs, macropods, rats, rabbits and many other animals, including humans (mainly from western Europe, northern Africa and South America). More than 2 million people are thought to be infected from over 60 countries, and over 180 million people are considered to be at risk of infection. *F. gigantica* is found mostly in cattle and buffalo in tropical regions, including parts of Africa, India and South-East Asia. It has been estimated that some 250 million sheep and 350 million cattle are at risk of fascioliasis. Another species *F. jacksoni* has been described from the livers of elephants in India, Burma and Malaysia, but recent molecular studies have transferred the species to the genus *Fascioloides*. Likewise, many fasciolid infections in deer have now been attributed to the pathogenic species *Fascioloides magna* (giant liver fluke, deer fluke). Some workers have grouped the genera *Fasciola* and *Fascioloides* into the subfamily Fasciolinae on the basis of shared morphotypic characters (cephalic cone, branched intestinal caeca, dendritic testes and ovaries), tissue tropism (bile ducts or liver parenchyma of definitive hosts) and intermediate host specificity (lymnaeid snails).

Parasite species	**Definitive hosts [adults in bile ducts of liver]**	**Intermediate hosts [sporocysts/rediae in tissues]**	**Infective stages**	**Distribution**
Fasciola				
F. hepatica (syn. *Planaria latiuscula, Distoma hepaticum, F. humana, F. lanceolata*) (common liver fluke, sheep liver fluke)	Artiodactyla: bovid (sheep, goat, cattle, buffalo, bison), cervid (mule deer, black-tailed deer, white-tailed deer, sika deer, fallow deer, red deer, roe deer, moose), camelid (camel), suid (pig); Proboscidea: elephantid (elephant); Perissodactyla: equid (horse, donkey); Lagomorpha: leporid (rabbit, jackrabbit, cottontail, European hare, mountain hare, snowshoe hare); Rodentia: castorid (beaver), echimyid (coypu); occasionally Primates: hominid (human)	amphibious Gastropoda: lymnaeid (*Austropeplea* (*Lymnaea*) *tomentosa, A.* (*L.*) *viridis, A. ollula, Fossaria* (*L.*) *viatrix/viator, F.* (*L.*) *diaphana, F. cubensis, F. bulimoides, Galba* (*L.*) *truncatula, Lymnaea cousini, L. cubensis, L. diaphana, L. humilis, L. neotropica, L. occulta, L. palustris, L. stagnalis, Omphiscola glabra, Potamopygrus antipodarum, Pseudosuccinea* (*L.*) *columella, Radix auricularia, R. balthica, R. lagotis, R. natalensis, R. peregra, R. rubiginosa, Stagnicola caperata, S. fuscus, S. palustris, S. turricula, Succinea*)	metacercariae on herbage	worldwide
F. gigantica (syn. *Distomum giganteum, Fasciola gigantea*) (tropical large liver fluke)	Artiodactyla: bovid (cattle, buffalo, sheep, goat, blue wildebeest, sassaby, waterbuck, kob, puku, hartebeest), cervid (deer), suid (pig), camelid (camel), giraffid (giraffe), hippopotamid (hippopotamus); Perissodactyla: equid (horse, donkey, mule); Lagomorpha: leporid (rabbit); occasionally Primates: hominid (human)	aquatic Gastropoda: lymnaeid (*Radix auricularia, R. luteola, R.* (*Lymnaea*) *natalensis, R. peregra, R. rubiginosa, R. gedrosiana, Austropeplea* (*L.*) *tomentosa, A. ollula, A. viridis, Galba* (*L.*) *truncatula, Lymnaea acuminata, L. cailliaudi, L. rufescens, Pseudosuccinea* (*L.*) *columella*)	metacercariae on herbage	Africa, Asia, Europe, North America
F. nyanzae	Artiodactyla: hippopotamid (hippopotamus)	unknown		Africa
Fascioloides				
Fa. magna (syn. *Distomum magnum, D. texanicum, Fasciola magna, Fasciola carnosa, Fasciola americana*) (giant liver fluke, large American liver fluke, deer fluke)	Artiodactyla: cervid (black-tailed deer, white-tailed deer, mule deer, wapiti, caribou, moose, fallow deer, red deer, roe deer, sika deer, sambar), bovid (cattle, yak, buffalo, bison, sheep, bighorn sheep, goat, chamois, nilgai), camelid (llama), suid (pig), tayassuid (collared peccary); Perissodactyla: equid (horse); Lagomorpha: leporid (rabbit); Rodentia: caviid (guinea pig)	aquatic Gastropoda: lymnaeid (*Lymnaea trunculata, L. palustris*)	metacercariae on herbage	North America. Europe
Fa. jacksoni	Proboscidea: elephantid (Asiatic elephant)	unknown		India, Pakistan, Burma, Malaysia

Protofasciola				
P. robusta	Proboscidea: elephantid (African elephant)	unknown		Africa
Tenuifasciola				
T. tragelaphi	Artiodactyla: bovid (sitatunga)	unknown		Africa

Many putative *Fasciola* species have also been recorded from fish: including *F. alosae*, *F. appendiculata* and *F. halecis* from herring; *F. polymorpha* from eels; *F. bramae* and *F. transversalis* from cyprinids; *F. bramae* and *F. gibbosa* from pike; *F. aeglefini* and *F. scabra* from gadids; *F. crenata* from sticklebacks; *F. bramae, F. coryphaenae*, *F. fusca*, *F. lagena*, *F. luciopercae, F. tereticollis* and *F. blennii* from perch, bream and dolphinfish; *F. atomon* and *F. platessae* from flounder and plaice; *F. eriocis, F. farionis*, *F. truttae*, *F. umblae* and *F. varica* from salmon, char and trout; and *F. clavata* and *F. scorpii* from bonito and sculpins (most piscine species subsequently assigned to other trematode genera, incl. *Allocreadium*, *Crepidostomum*, *Dendrocoelum*, *Distoma*, *Podocotyle* and *Spaherostoma*); several species have been reported from birds: including *F. anatis* from ducks, *F. ardeae* from heron, *F. bilis* from falcons, *F. buteonis* from buzzards, *F. denticulata* from terns, *F. elegans* from finches, *F. gruis* from cranes, and *F. milvi* from kites (all avian species assigned to the genus *Distoma*); and one species has even been recorded from reptiles (*F. colubri* from colubrid snakes).

Parasite morphology: These flatworms form 7 different developmental stages: eggs, miracidia, sporocysts, rediae, cercariae, metacercariae, and adult flukes. The eggs are brown, ovoid and operculate (with a 'hatch' at one end). *F. hepatica* eggs are 130-150 µm in length by 63-90 µm in width, while those of *F. gigantica* are 156-197 µm long by 80-104 µm wide. Miracidia are pyriform motile larval stages (150-200 µm long) covered with cilia and they have apical papillae, glands and two pigmented eyespots. Sporocysts are pleomorphic sac-like bodies (0.3-1.5 mm in diameter) covered with a thin tegument and containing germinal cells which give rise to rediae (embryos). Rediae are elongate (1-2 mm long) with muscular collars and ventral processes (lappets or procruscula). Mature cercariae (~0.5 mm long) are free-swimming stages with simple elongate club-shaped tails. The body has rudimentary organs, including suckers (oral and ventral), a bifurcated digestive system, excretory bladder and genitalia (this cercarial form is known as 'gymnocephalous'). The cercariae swim to aquatic vegetation where they shed their tails and encyst to form membrane-bound metacercariae (~ 0.2 mm in diameter). Mature flukes are dorsoventrally flattened and leaf-shaped with a conical apex demarcated by wider 'shoulders'. *F. hepatica* adults are 2.0-3.5 cm long by 0.8-1.5 cm wide, while those of *F. gigantica* are 2.5-7.5 cm long by 0.5-1.2 cm wide. The tegument is covered with scaly spines, and they have two suckers (distome arrangement with the oral and ventral suckers close together). They have a bifurcate blind gut and each worm is hermaphroditic, possessing both male and female reproductive organs.

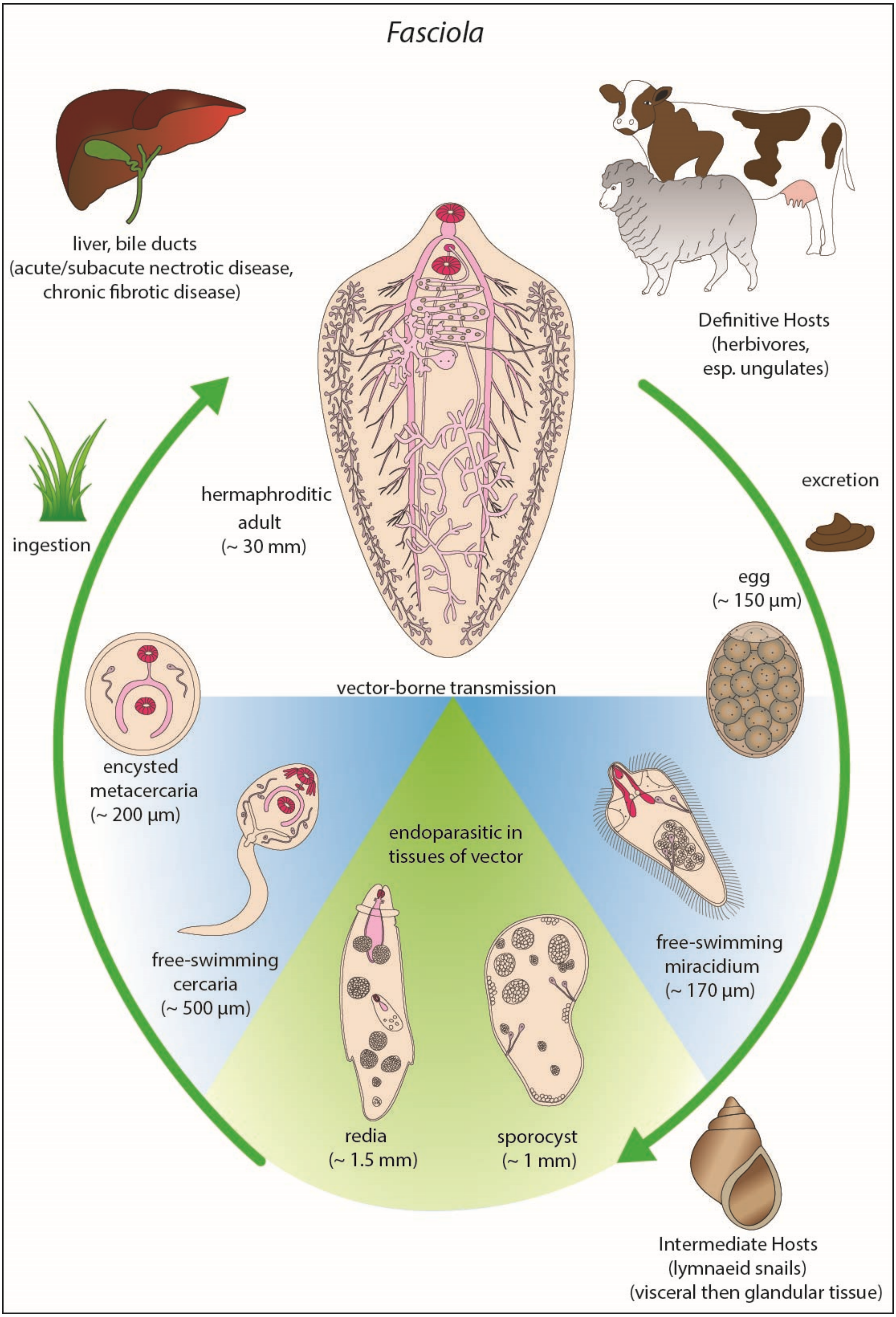
Site of infection: Immature flukes undergo transient migration through the liver parenchyma and then settle as mature flukes in the bile ducts of their mammalian definitive hosts. In some (uncommon) hosts, aberrant flukes may be found encapsulated in lungs, skin or other organs. In snail intermediate hosts, several asexual multiplicative stages are formed; sporocysts first developing in tissues near the site of penetration (foot, antenna, gill), rediae then migrating to glandular tissue (hepatopancreas and gonads) and culminating in the emergence of tailed cercariae.

Pathogenesis: Infections are associated with 2 types of liver disease in domestic animals: acute or subacute necrotic disease due to juvenile flukes (parenchymal (migratory) phase of infection); and chronic fibrotic disease due to adult flukes (biliary phase of infection). Penetration of the liver capsule by immature flukes generally does not cause much damage, but their subsequent migration through the liver parenchyma may cause significant necrosis (liver rot), bile duct degeneration and acute verminous hepatitis. Mass migration of juveniles may produce extensive traumatic tissue damage, coagulative necrosis, haemorrhage, anaemia, hepatomegaly, urticaria, eosinophilia, leucocytosis, jaundice, pallor, ascites, fever, vomiting, diarrhoea, abdominal pain and can be fatal. Acute infections in sheep can also be complicated by secondary bacterial infection causing clostridial necrotic hepatitis ('black disease'). Chronic infections by the long-lived spiny adults living and feeding in the bile ducts may result in progressive loss of condition with biliary epithelial hyperplasia, biliary colic, cholecystitis, bile duct calcification, duct obstruction, cirrhosis, cholangitis, jaundice, anaemia, hepatomegaly and eventually a fibrotic hardened liver. Interference with protein metabolism and loss of protein from the ducts leads to hypoproteinaemia. Infections have also been associated with abdominal pain, nausea, pruritus, cardiac disorders, pancreatitis and fatty food intolerance. Occasionally, ectopic infections have been reported involving the peritoneal cavity, intestinal wall, lungs, lymph nodes, subcutaneous tissues and eyes. Sheep develop hypochromic macrocytic anaemia with eosinophilia and become emaciated developing submandibular oedema (bottle-jaw) and ascites. In cattle, the bile ducts become fibrotic and sometimes calcified producing a 'clay-pipe' or 'pipe-stem' liver. Chronic fascioliasis causes significant economic losses to many animal industries through mortality, general ill-thrift, debilitation, scouring, reduced meat, milk and fibre production, condemned livers, secondary infections and expensive treatments. Infected animals develop little in the way of protective immunity but continue to accumulate flukes as long as they graze infected pasture. However, some host species and breeds appear to be more resistant or resilient to infections than others; e.g. buffalo calves are more resistant to *F. gigantica* than *Bos indicus* breeds.

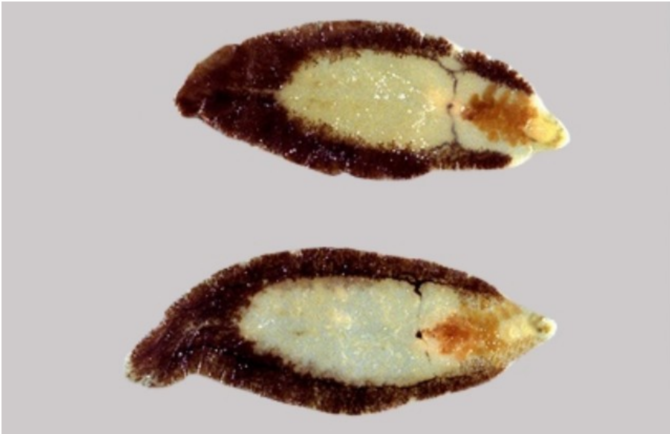
Developmental cycle and mode of transmission: Digenean trematodes have indirect life-cycles, involving mammalian definitive hosts and molluscan intermediate hosts. Transmission between the two hosts occurs within water, via the formation of motile and encysted larval stages. Adult flukes may live for several years in their hosts and they produce hundreds to thousands of eggs each day which pass out of the liver in bile and are shed in host faeces. The eggs embryonate in water in a few days to form miracidia which hatch out in 9-10 days in warm weather (longer when colder). Miracidia actively seek snail hosts by chemotaxis, and must penetrate snail tissues (usually through the foot) within a few hours or die after 24 hours. *F. hepatica* exhibits high intermediate host-specificity and will only develop in freshwater amphibious lymnaeid snails. These snails are pulmonate (with lungs), small (0.5-2.5 cm long) and delicate; their shells being thin, fragile, lacking an operculum and the apertures located on the right-hand side (dextral). They live in freshwater and/or wet soils and survive dry periods by burrowing and aestivating (parasites can survive for months in aestivating snails). Various lymnaeid genera and species (whose classification is undergoing considerable revision) are suitable intermediate hosts; the most common vectors for *F. hepatica* being *Galba* (*Lymnaea*) *truncatula* in most continents, *Austropeplea* (*L.*) *tomentosa* in Australia, *A.* (*L.*) *viridis* in China, *Pseudosuccinea* (*L.*) *columella* in the Americas, *Fossaria* (*L.*) *viator/viatrix* and *F.* (*L.*) *diaphana* in South America, and *F.* (*L.*) *bulimoides* in North America; and those for *F. gigantica* being *Radix auricularia* in many countries, *Radix natalensis* in Africa, *R. rubiginosa* in Malaysia, and *L. acuminata* and *L. rufescens* in India. These aquatic/amphibious snails vary in their habitat preferences, some preferring wet mud, others free water. They can readily colonize transient habitats, such as puddles in depressions, wheel ruts and hoof marks, especially after heavy rainfall, irrigation or flooding. These snails breed readily when mean daily ambient temperatures are above 10-15°C, a similar temperature threshold required for parasite development within the snails. Once miracidia penetrate the tissues of a snail, they transform into the 'larval' stages which undergo massive asexual multiplication (formerly and inappropriately called polyembryony). The miracidia lose their cilia, glands and eyespots and become simple sac-like sporocysts that lack digestive organs and feed by absorption. Germinal cells within the sporocyst develop into 5-8 small elongate rediae which emerge from the mother sporocyst. Rediae have mouths and guts and feed on snail tissues. Germinal cells within rediae develop into another generation of daughter rediae (usually during summer months). Those daughter rediae ultimately produce the motile single-tailed cercariae. Each redia produces 14-20 cercariae which emerge through the redial birth pore and then escape from the snail (usually by migrating through the digestive gland into the pulmonary sac where they pass out into water). Cercariae begin emerging 5-7 weeks after infection and several hundred (sometimes thousands) of cercariae may be produced. Within 2-3 days, emergent cercariae swim to suitable substrates (such as blades of grass) and form encysted metacercariae by shedding their tails and secreting thick cyst walls. Metacercariae are quiescent infective stages which can survive in water for several months or on sodden herbage for several weeks (they usually encyst within 10 cm of the waterline). Mammals become infected when they ingest metacercariae with food or water (many human infections have been linked to the consumption of watercress, water lettuce and alfalfa). Metacercariae excyst in the small intestines releasing juvenile worms which penetrate the gut wall and migrate around the body cavity for several days. They then move to the liver and burrow through the capsule into the parenchyma where they feed and grow for 5-8 weeks before entering the bile ducts where they feed on mucosa, blood and bile. Worms become sexually mature and begin producing eggs 6-14 weeks after infection. Even though each adult fluke is hermaphroditic, cross-fertilization is common with copulation occurring in the bile ducts. Adult flukes can live for many years in sheep but not in cattle, although infections in domestic animals exhibit marked seasonal variation. Acute disease is most common in sheep during summer-autumn while chronic disease is most common in cattle during autumn-spring.

Differential diagnosis: Fasciolosis may be suspected in domestic animals grazing in endemic regions on the basis of clinical signs and history (illthrift, anaemia, deaths). Infections are conventionally diagnosed by coprological examination for fluke eggs in faecal samples, usually following their concentration by sedimentation techniques (fluke eggs are 'heavy' and do not float well in many floatation media). Despite the fecundity of mature flukes, faecal egg counts may vary due to sporadic egg production/release and the intermittent flow of bile into the intestines. Serial samples should therefore be examined. Blood biochemical tests can also be used to show elevated plasma levels of hepatic enzymes, notably glutamate dehydrogenase (GLDH) during acute stages and gamma glutamyl transpeptidase (GGT) during chronic stages. Medical imaging techniques may be used to reveal worms in bile ducts and assess attendant pathology (burrow tracts, duct dilation), including radiology, ultrasound, computerized tomography (CT) and magnetic resonance imaging (MRI). Infections may be detected in carcases during meat inspection by observing characteristic fibrotic lesions in the liver and finding flukes in sectioned bile ducts. Immunological tests (enzyme immunoassays, Western blots) have been developed to detect host antibodies in serum samples (and even in bulk milk samples) or parasite antigens in faecal samples in attempts to facilitate early diagnosis. Molecular studies based on polymerase chain reaction (PCR) amplification of parasite gene sequences (ribosomal RNA, internal transcribed spacers, noncoding repetitive DNA fragments, mitochondrial cytochrome c oxidase subunit 1) are currently being used to examine parasite strain variation in definitive and intermediate hosts, identify putative virulence factors and screen for protective immunogens.

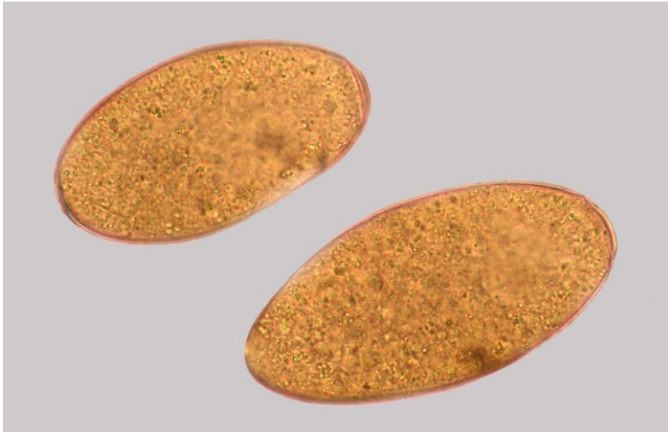
Treatment and control: Subacute and chronic infections may be treated with triclabendazole or bithionol, which show excellent trematocidal activity with few side-effects. A range of other anthelmintics show variable activity depending on the phase of infection, including other halogenated phenols (hexachlorophene, nitroxynil), other benzimidazoles (albendazole, mebendazole, luxabendazole, ricobendazole), probenzimidazoles (netobimin), salicylanilides (closantel, rafoxanide, niclofolan, oxyclozanide), sulfonamides (clorsulon), phenoxyalkanes (diamphenetide) and halogenated hydrocarbons (carbon tetrachloride, hexachlorethane), but their use may be confounded by issues with toxicity, residues and with-holding periods (esp. in lactating females). Strategic longitudinal drenching programs should be instituted for livestock depending on local conditions, particularly over summer-autumn periods to control clinical disease and minimize pasture contamination. Several forecasting models have been developed based on meteorological data (ground surface wetness or rainy days) to predict the distribution, timing and intensity of infections in livestock thereby facilitating timely interventions. Preventive measures are based on breaking the cycle of transmission by reducing faecal contamination of water bodies, reducing snail populations using molluscicides (usually copper sulphate), pasture management by draining or fencing off riparian habitats (especially swampy fields), strategic grazing by rotating and treating stock, reticulating water supplies to troughs rather watering stock from dams or streams, restricting access of livestock to aquatic vegetation, and avoiding using watercress in salads or as garnish. Farmers harvesting grass for penned stock should avoid sodden grass or should only cut grass 15 cm above the waterline. Snail control is often difficult, particularly in high rainfall areas where even temporary pools may harbour large snail populations (they aestivate in the ground during dry conditions). Feral or wild animals (such as rabbits) may also act as reservoirs of infection for domestic livestock.



Fasciola
liver, bile ducts
(acute/subacute nectrotic disease,
chronic fibrotic disease)
Definitive Hosts
(herbivores,
esp. ungulates)
ingestion
hermaphroditic
adult
(~ 30 mm)
excretion
egg
(~ 150 µm)
encysted
metacercaria
(~ 200 µm)
vector-borne transmission
endoparasitic in
tissues of vector
free-swimming
miracidium
(~ 170 µm)
free-swimming
cercaria
(~ 500 µm)
redia
(~ 1.5 mm)
sporocyst
(~ 1 mm)
Intermediate Hosts
(lymnaeid snails)
(visceral then glandular tissue)



Fasciola adult worms



Fasciola eggs

Fasciola miracidia

Fasciola redia

Fasciola cercaria

Fasciola snail vectors