Parasitology may be defined as a part of the main science, biology, which deals with small organisms (parasites) which live in/on other larger organisms (hosts). By this association, the parasite benefits while the host suffers. The science deals with morphological characters, biology (life cycle), diseases produced, control and preventive measures of the parasite.

Accordingly, the **parasite** is a small organism lives on the expense of another larger one (host) gaining access food and shelter and produce injury/disease to the later. Parasites vary in their habits, morphological characters, pathological lesions produced and preventive measures. Moreover, a **host** is a large organism harbour the parasite giving it food and shelter and it suffers from injury/disease. The diagnosis of a certain parasitic disease is based on the existence of the parasite itself and/or eggs/larval stages of the parasite in the diseased host. The most common and destructive diseases in tropical and subtropical districts occurred as a result of the presence of parasites.

Several forms of parasitic associations are developed:

1- Parasitism:

It is a mandatory complex association between the parasite and the host in which the parasite gains access food and shelter frrom the host which suffer from injuries or different pathological lesions.

e.g. *Fasciola gigantica* in the liver of cattle

2- Commensalism: (com= together, mensal= table)

It is an association in which the parasite gains benefits and the host doesn't and not suffer. e.g. *Entamoeba coli* in the colon of humans

3- Symbiosis: (sym= together, bio= live)

It is a relation in which both parasite and host, each is called symbiont, live together (obligatory) and gain benefits from each other.

e.g. some flagellates habit the gut of termite ants which feed on wood. Flagellates digest woods, by celluolase, and release cellulose which benefits for both.

4- Enquilines:

It is an association in which both parasite and host live in the same nests or habitats of other organisms resulting in no benefits or harms for them.

e.g. some bacteria carried on legs and wings of certain flies

5- Mutualism:

It is an association between two organisms (parasite and host), without which each can live alone inducing no harms to the other.

e.g. some protozoal colonies can live on the outer shell of some snails or on the external surface of some crustaceans.

* Veterinary helminthology is a division of the main science parasitology and it is defined as the science of studying helminths infecting domestic and wild animals and birds including morphology, development and control of the diseases produced. Helminths are eukaryotic, multicellular organisms that usually have digestive, circulatory, nervous, excretory, and reproductive systems. They acquire their name from a Greek Latin word termed **helmins** or **helminthos** referring to both parasitic and free living non-parasitic worms. They are characterized by bilateral symmetry, the presence of head and tail, as well as a tissue differentiation (ectoderm, mesoderm, and endoderm). More than 2000 species of helminths are recognized. The target of helminthologists is to reduce the harms/injuries induced by helminths.

Phylum: Platyhelminthes

(platy= flat, helminthes= worms)

• Platyhelminths, flatworms, are so called because most are dorsoventrally flattened.

• Most of them are parasitic and their physiology is characterized by the inability to synthesize fatty acids and sterols, and this explains why flatworms are most often parasitic. Moreover, flatworms can serve as hosts for other flatworms i.e. some cercariae (free-swimming transmission stages of trematodes) can penetrate planarians and encyst to become infective stages (metacercariae) for the next host in the complex life cycle.

• They are usually leaf-shaped or oval (trematodes), but some, such as tapeworms and terrestrial turbellarians are extremely elongated.

• They range in size from nearly microscopic to several meters in length.

• They are acoelomatic (no body cavity), but they have an internal parenchyma filled with reproductive organs and musculature with no circulatory or respiratory systems.

Class: Trematoda

(flukes, digeneans or digenetic trematodes)

• Parasitic species of the phylum Platyhelminthes.

• They are almost flattened and leaf-shaped. Some species are conical or worm-like.

• They have specialized organs for fixation and reproduction.

• The morphology and biology of digeneans considerably varies from ectoparasitic life in aquatic hosts to extreme endoparasitic life in internal organs of the higher vertebrates.

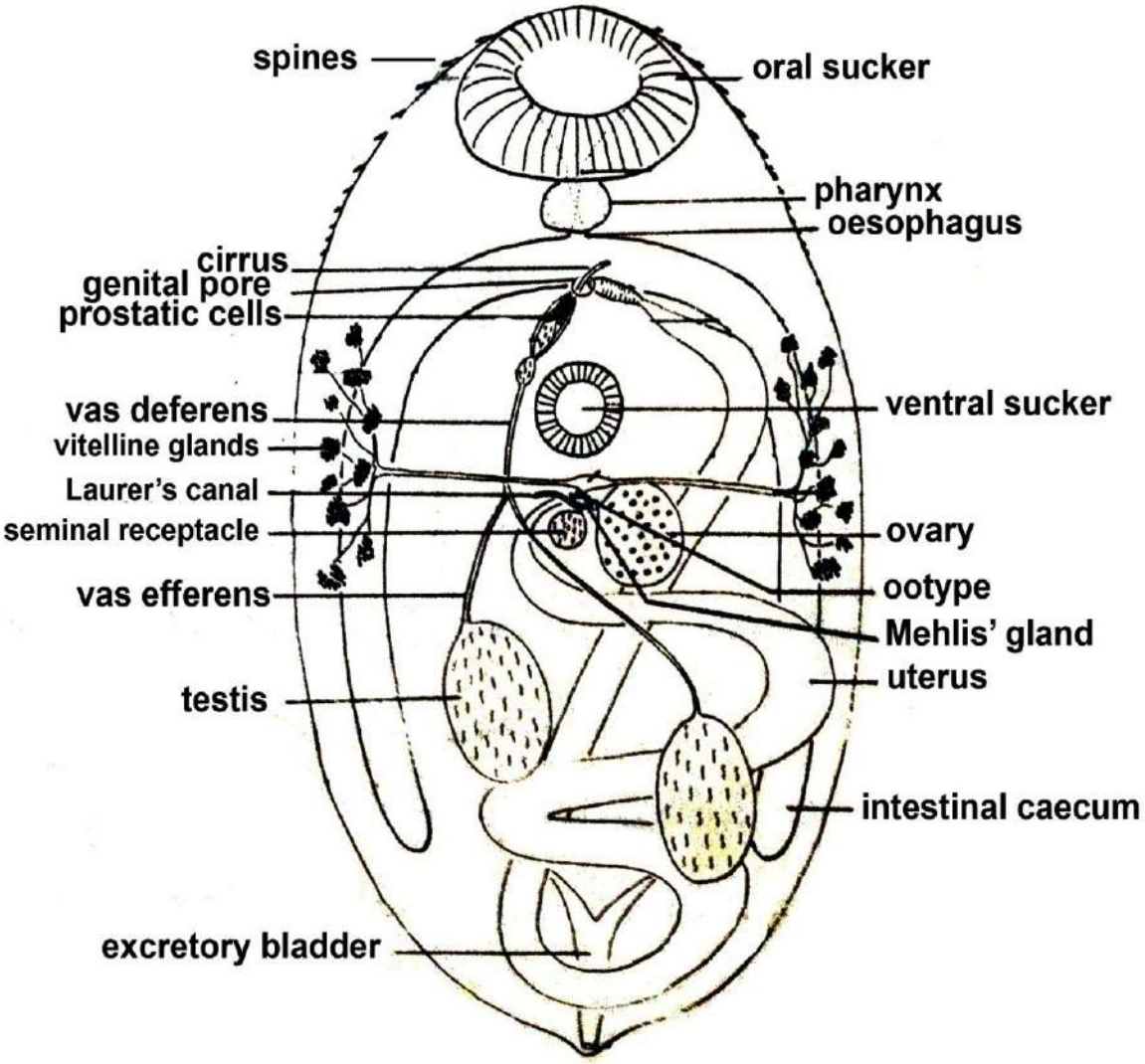


Diagram of a digenetic fluke

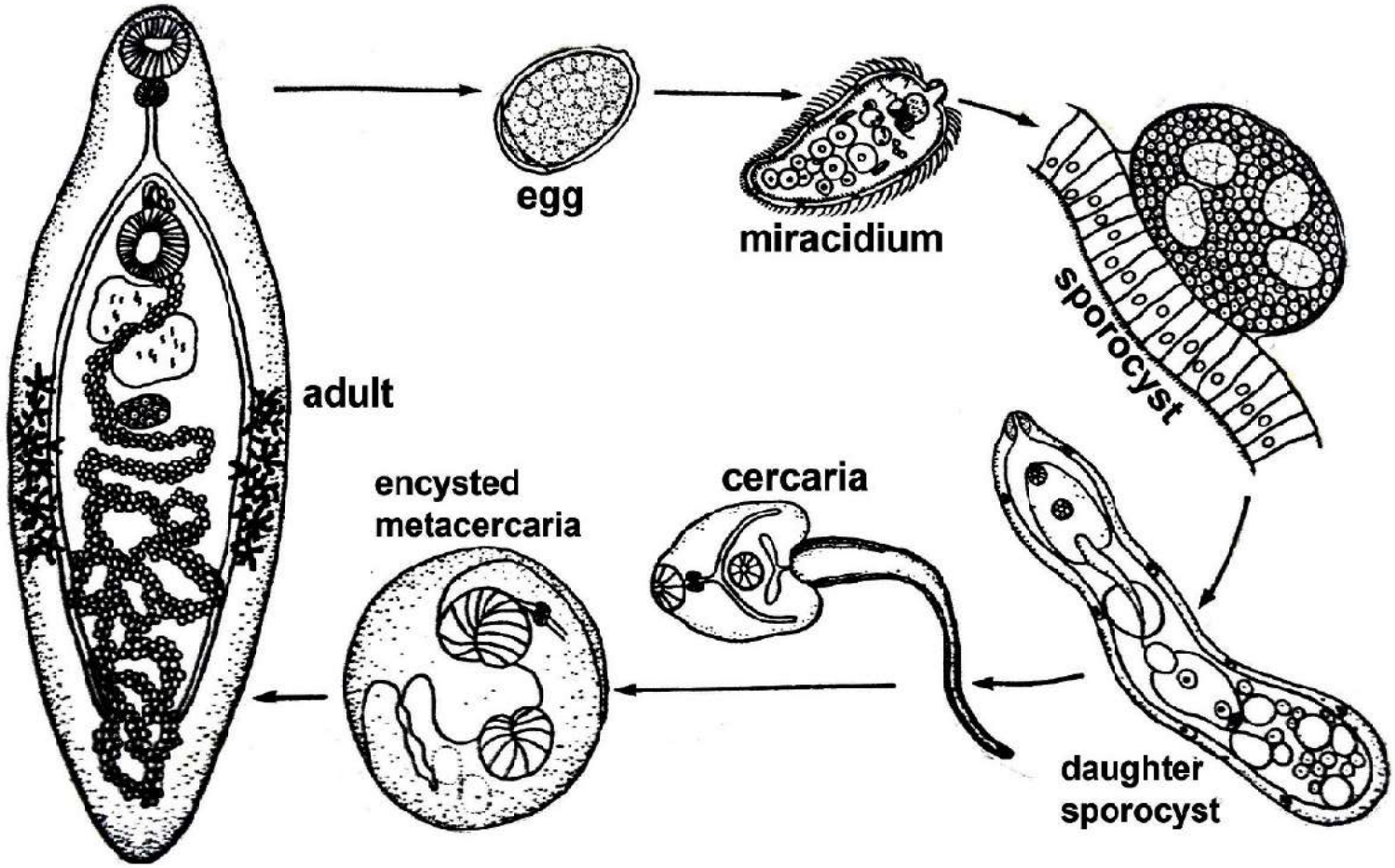


Diagram of a life cycle of a digenetic fluke

Classification of digenetic flukes

Subclass Digenea

Superorder Epitheliocystidia

Order Echinostomida

Superfamily Echinostomoidea

Family Fasciolidae

Genus *Fasciola*

Species ***F. hepatica***

F. gigantica

Genus *Fascioloides*

Species *F. magna*

Genus *Fasciolopsis*

Species *F. buski*

Genus Parafasciolopsis

Species *P. fasciolaemorpha*

Family Echinostomatidae

Genus *Echinostoma*

Species ***E. revolutum***

Genus *Echinochasmus*

Species *E. perfoliatus*

Superfamily Paramphistomatoidea

Family Paramphistomatidae

Genus *Paramphistomum*

Species ***P. cervi***

Genus *Cotylophoron*

Species ***C. cotylophorum***

Genus *Carmyerius*

Species ***C. gregarious***

Genus *Gastrodiscoides*

Species *G. hominis*

Family Gastrodiscidae

Genus *Gastrodiscus*

Species ***G. aegyptiacus***

Order Strigeida

Superfamily Schistosomatoidea

Family Schistosomatidae

Genus *Schistosoma*

Species ***S. bovis***

S. mansoni

S. hematobium

S. japonicum

Genus *Ornithobilharzia*

Species *O. turkestanicum*

Superorder Epithliocystidia

Order Opisthorchiida

Superfamily Opisthorchoidea

Family Heterophyidae

Genus *Heterophyes*

Species ***H. heterophyes***

Genus *Cryptocotyle*

Species *C. concava*

Genus *Metagonimus*

Species *M. yokogawi*

Family Opisthorchiidae

Genus *Opisthorchis*

Species *O. sinensis*

Order Plagiorchiida

Superfamily Plagiorchoidea

Family Dicrocoeliidae

Genus *Dicrocoelium*

Species ***D. dendriticum***

Genus *Platynosomum*

Species *P. fastosum*

Genus *Eurytrema*

Species *E. pancreaticum*

Family: Fasciolidae

General characters of the family:

1- Large, broad, flat and leaf-like flukes habits in the biliary system and the intestine of mammals particularly herbivores and humans.

2- Members have scaly or spiny cuticle. Oral and ventral sucker are close together.

3- Intestinal caeca are much branched. Gonads are branched.

4- Genital pore is median, directly anterior to the ventral sucker.

5- Vitellaria are well developed and much expensive occupying most of the postacetabular space in the lateral fields, and may extend medially.

6- Eggs are laid unembryonated, thin-shelled and operculated.

(1) Genus: *Fasciola*

Species of this genus produce a disease called fasciolosis, liver fluke disease, liver rot of liver distomiasis. The most common species are *F. hepatica* and *F. gigantica*.

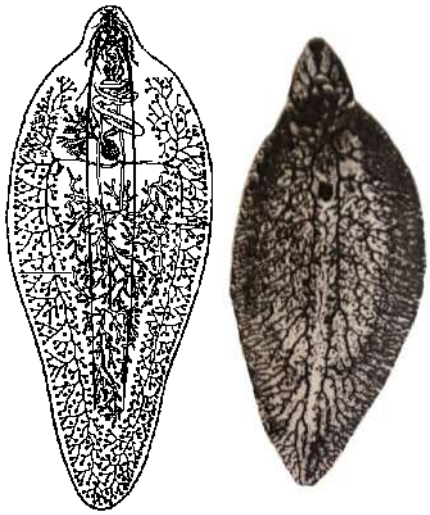
Fasciola hepatica

Common name: Sheep liver fluke.

Distribution: Cosmopolitan in distribution.

Habitats: Bile ducts, gall bladders and liver.

Hosts: Sheep, cattle, goats, horses, rabbits, hares and humans.



Morphological characters:

i. Grossly:

- Grayish-brown when fresh change to gray-colored fluke on preservation.
- It measures 3.0 x1.3 cm.
- Leaf-shaped, broad anteriorly than posteriorly and the 2 sides of the body are so far apart to make a characteristic V-letter shape. The anterior part has a well-developed cone-shaped projection followed by well distinct broad shoulders.

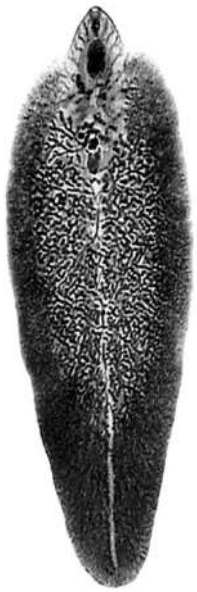
ii. Microscopically:

- Scaly cuticle.
- The oral sucker is nearly equal to the ventral one.
- The ventral sucker is situated at the level of shoulders.

- A short oesophagus is completely surrounded by a muscular pharynx.
- The intestine bifurcates at the level of shoulders or ventral sucker into 2 blind caeca. The inner wall is branched into small nodules or rudimentary ends.
- Testes are branched, tandem in position occupying the middle field in about the second and third quarters of the body.
- Well-developed cirrus and cirrus sac. The later encloses a prostate gland and a seminal vesicle.
- The ovary is branched, situated anterior to the testes shifted to the right side of the middle.
- The uterus is in the form of convoluted tubules full of eggs lying anterior to the testes.
- Vitellaria are small follicles extending from the level of shoulders to the posterior part of the worm along both lateral fields.
- Common genital pore is situated anterior to the ventral sucker (cirrus and uterus pour into it).
- Snail intermediate hosts are species of lymnaieds, particularly *Lymnaea truncatula*, *Lymnaea cailliaudi*, *Lymnaea stagnalis*, *Lymnaea tomentosa*.

Fasciola gigantica

Common name: Cattle liver fluke.



Distribution: Africa, Asia, Hawaii, Pakistan.

Habitats: Bile ducts and gall bladders.

Hosts: Cattle, buffaloes, sheep, goats and other herbivores.

Morphological characters:

i. Grossly:

- Grayish-brown when fresh change to gray-colored fluke on preservation.
- It measures 2.5-7.5 x 0.4x1.2 cm.
- Typical leaf-shaped differs from *F. hepatica* in that:

• More longer. Smaller cone-shaped projection.

• Shoulders are less prominent. The two sides of the body are more or less parallel. More transparent body.

ii. Microscopically:

It is similar to that of *F. hepatica* except:

- The cuticle is covered with sharp spines. The oral sucker is smaller than the ventral sucker.
- The intestine bifurcates at the level of shoulders or ventral sucker into 2 blind caeca. The inner wall is branched into T-Y shapes.

- Snail intermediate hosts are species of lymnaieds, particularly *Lymnaea stagnalis*, *Lymnaea cailliaudi*, *Lymnaea auricularia*.

Life cycle of *Fasciola* spp.: (*F. hepatica*)

• A two-hosts life cycle.

• It lasts approximately 5 months.

• Eggs pass with bile to the duodenum, then discharge with the feces of infected host to outside. An egg is large-sized (150 x 90 µm), oval, thin-shelled, operculated, golden yellow containing ill-developed embryo consists of one embryonic cell masked by several yolk cells (laid unembryonated).

• The egg hatching occurs at the exterior. Several factors affect such process including temperature and humidity. A high temperature encourages hatching (at 26 ºC eggs hatch in approximately 10-12 days while in winter, the process may lasts for 90 days) although the higher temperature in the hot summer leads to the cessation of the egg development. At lower temperatures, eggs may survive till the environmental conditions will be available for hatching and development.

• Once hatching occurs, the next developmental stage, the miracidium, is released. It is a triangular-shaped structure with ciliated cuticle, broad anterior part, anterior spine, a pair of eye spots, primitive gut and several germinal balls of actively dividing cells. In water, it swims for few hours searching for the corresponding aquatic snail (the larger the snail size, the larger numbers of developmental stages) of lymnaeids (within 24-36 hours, if the snail is not found, the miracidium dies) where it penetrates after casting off cilia and develops into the next stage.

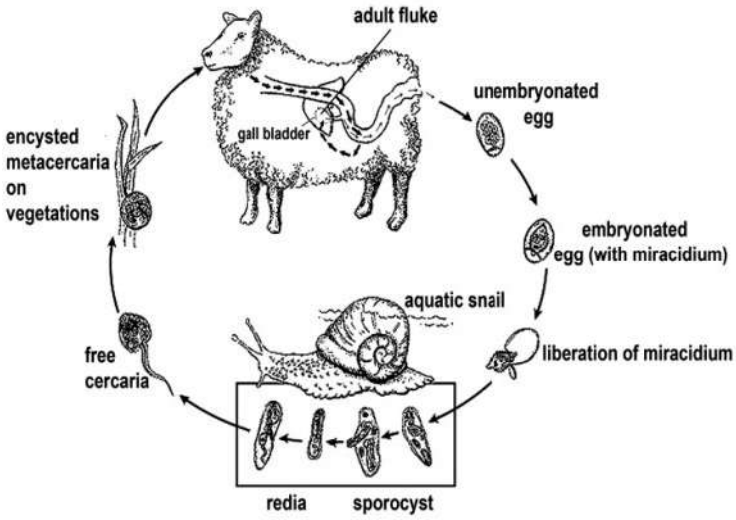
• The sporocyst is elongated sac of undifferentiated mass of actively dividing cells (germinal balls) measuring few millimeters and give rise to the next developmental stage. Each sporocyst produces 5-8 rediae.

• The redia is located at the hepatopancreas of the snail. It is a cylindrical body, more active than the sporocyst and feed. It measures 1-3 mm in length and consists of a muscular pharynx,

simple gut, circular head collar anterior birth pore, 2 caudal processes and several masses of actively dividing germinal balls which further give rise to the next developmental stage.

• The cercaria is leptocercus (with a simple tail) with head: tail is 1:3 (the length of the tail is twice as that of the body), oral and ventral suckers, simple intestinal caeca, dark cytogenous glands and no eye spots. Cercariae get out the snail after spending 4.5-7 weeks from the time of infection.

• Outside the snail, once the cercariae are liberated, within few hours they lost their tails and encysted by a wall secreted by the head cytogenous glands and they are collected on edges of vegetations or below the water surface forming the **infective stage**, encysted metacercariae. Each of the latter is deep brown and small-sized structure of 0.2 mm in diameter with a thick cyst wall and none of the internal structures could be observed. Encysted metacercariae may survive infective for several months in natural conditions and extended in laboratory conditions. The survival time decreases when the temperatures rises from 10 ºC to 35 ºC. Hot climates kill the encysted metacercariae. Stagnant water and narrower water canals contain higher numbers of the metacercariae.



• Following the ingestion of the infective stages, excystation occurs in the duodenum (pepsin, trypsin, bile salts and Co_2 facilitate such process) with the liberation of immature flukes, which penetrate into the peritoneal cavity within 24 hours post ingestion of encysted metacercariae.

• On 4-6 days of infection (inside the final host), the majority of immature flukes reach the liver capsule and penetrate into the parenchyma staying for 5-6 weeks.

• On the 7^{th} week, they gain access to the bile duct (predilection site) forming adult worms.

• On the 8^{th} week, eggs are deposited in feces.

• In a less common way, immature flukes may gain access to the liver via the portal circulation.

• For *Fasciola gigantica*, the same life cycle occurs except:

1- Lymnaeids are specific for the species.

2- The development inside the snails takes a longer time.

Pathogenecity:

It depends on the number of encysted metacercariae ingested, showing pathological lesion in both hepatic parenchyma and bile ducts:

A) Acute fasciolosis:

A less common from and often pass unnoticed in sheep.

• Traumatic hepatitis by simultaneous migration of large numbers of immature flukes.

• Extensive destruction of the liver parenchyma associated with a marked hemorrhage.

• Rupture of the liver capsule with a hemorrhage in the body cavity.

• Accordingly, infected animals may **die** within few days with enlarged, pale and friable liver,

• Hemorrhagic tracts (containing immature flukes) and fibrinous clots on the liver surface.

- Complications:

Flukes predispose to a bacterial disease, Black Disease, caused by an anaerobic bacteria normally inhabitant in sheep (aged 2-4 years), *Clostridium novyii*, but it proliferates in necrotic lesions induced by the flukes.

B) Subacute fasciolosis:

More marked cellular reactions with an immunity to further infection. Early fibrosis is noticed.

C) Chronic fasciolosis:

The most common form (in cattle).

• The main lesion is the **biliary cirrhosis** with fibrotic liver.

• Bile duct walls are greatly thickened with cholangitis.

• Hyperplasia of the bile ducts epithelium (by sharp scales of the flukes) which further completely denuded leaving them as fibrotic tubes.

• Bile ducts are usually calcified, with a blockage of their lumen even protruding from the surface, so as to be difficult to be cut by a knife. This lesion resembles the stem of clay-pipe and the condition is termed **pipe-stem liver**.

• Sometimes, flukes may wander in other organs, as lungs, showing **calcified** flukes with infiltration of purulent gelatinous exudates.

Clinical signs:

A) Acute fasciolosis: (often in sheep)

• Infected animals die suddenly.

• If they survive, they become anorexic with painful to touch abdomen, blood-stained froth from the nostrils and blood discharge from anus.

A) Chronic fasciolosis: (often in cattle)

• Anaemia, off color and vigorous behavior.

• Loss of appetite, depression, emaciation and pale mucous membranes.

• Oedema in the intermandibular space of some animals (sheep) giving rise to a condition termed **bottle-jaw**.

• Dry skin doughy to touch.

• Dry wool, easily to be detached in patches.

• Enteritis, diarrhea or constipation (enteric symptoms usually in cattle).

• Obstructive jaundice due to occlusion of the bile ducts.

• In humans, a condition termed **halzoun-syndrome** is a common due to ingestion of raw liver with an establishment of the whole or a part of the adult fluke in the mucous membrane of the nasopharynx or oesophagus causing inflammatory reactions causing respiratory and regurgitation problems.

Diagnosis:

• In the laboratory, by the detection fasciolid eggs by the use of sedimentation technique.

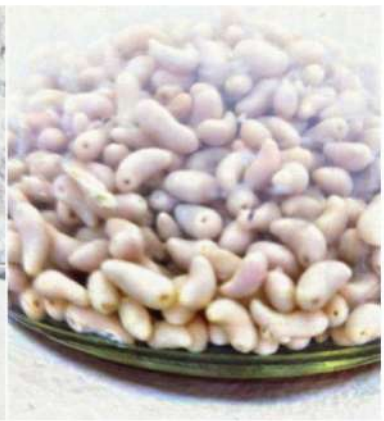
• In the abattoirs, meat inspection reveals the flukes in hepatic parenchyma and bile ducts.

Treatment: By the use of drugs of choice; triclabendazole, albendazole, levamizole.

Family: Paramphistomatidae

General characters of the family:

1- Large, broad and thick flukes appear circular on cross section often parasitize ruminants (**rumen flukes**) as well as fish, reptiles and amphibians.



2- The ventral sucker is well-developed lies just in front to the posterior extremity, so called **posterior sucker**. No pharynx. Smooth cuticle. Short oesophagus.

3- Simple intestinal caeca reach to the posterior part of the fluke.

4- Testes are lobed and usually tandem in position in the middle of the worm, lying anterior to a small ovary which is situated in the posterior third. Uterus is coiled and runs forward anteriorly. Vitellaria are well-developed in the form of compact masses fill along the lateral fields from the level of intestinal bifurcation till the posterior sucker.

(1) Genus: *Paramphistomum*

Species: *P. cervi*

Hosts: Cattle, buffaloes, sheep, goats.

Habitats: rumen and reticulum.

Epidemiology: Cosmopolitan in distribution.

Morphological characters:

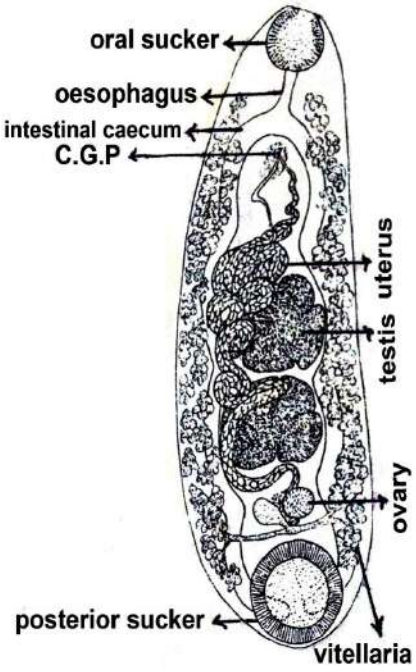
i. Grossly:

Light red when fresh and thick conical of pear-shaped flukes, appear convex anteriorly and more concave posteriorly. It measures 5-12 x 2-5 mm.

ii. Microscopically:

As in general characters of the family with the posterior sucker is large and subterminal.

Intermediate host: Snails, *Bulins liratus*, *Planorbis planorbis*, *Indoplanorbis exustus* and *Lymnaea bulimoides*.



(2) Genus: *Cotylophoron*

Species: *C. cotylophorum*

Similar in morphological characters, distribution and biology to *P. cervi* except:

• **Genital sucker** is present surrounding the common genital pore.

• Snail intermediate hosts are *Fossaria parva*, *Bulins schakoi* and *Indoplanorbis exustus*.

(3) Genus: *Carmyerius*

Species: *C. gregarious*

Similar in morphological characters, distribution and biology to *P. cervi* except:

• It measures 7-10 x 2-3 mm.

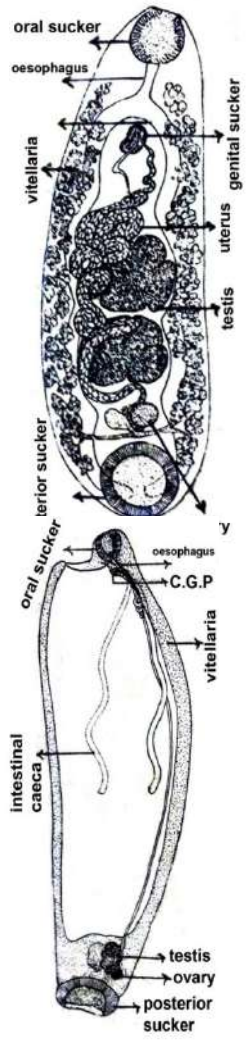
• The posterior sucker is relatively smaller and spherical.

• Uniquely, the intestinal caeca reach only to end of the 2nd third of the body (or a short distance behind the middle).

• Testes lie horizontally i.e. opposite to each other at the posterior part of the fluke.

• The ovary is in between the testes.

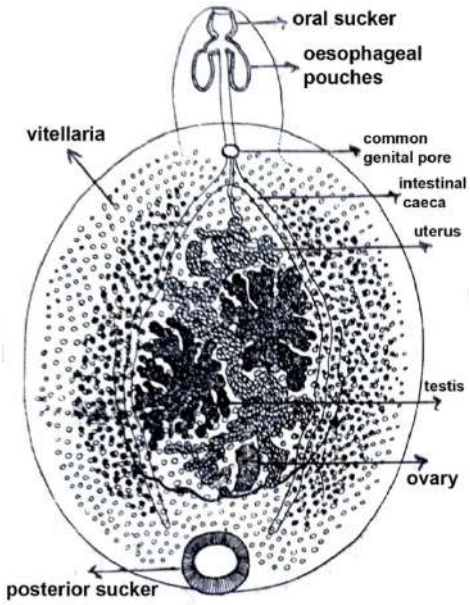
• Snail intermediate host is *Biomphalaria alexandrina*.



Family: Gastrodiscidae

Genus: *Gastrodiscus*

Species: *G. aegyptiacus*



Hosts: Equines and pigs.

Habitats: The large and small intestines.

Epidemiology: Africa and India.

Morphological characters:

i. Grossly: Pink-colored and fleshy when fresh. The body is divided by a constriction into small nearly anterior cylindrical part and large discoidal ventrally concave posterior part. It measures 9-17 x 8-11 mm.

ii. Microscopically:

• The cuticle is smooth except the ventral surface which is covered by large number of regularly arranged papillae.

• The oesophagus is represented by 2 posteriolateral oesophageal pouches.

• The intestinal caeca are simple and reach the posterior part of the fluke.

• Pharynx, common genital pore, ovary and vitellaria are similar to those in *P. cervi*.

• Testes are obliquely tandem (slightly diagonal) behind the middle of the worm.

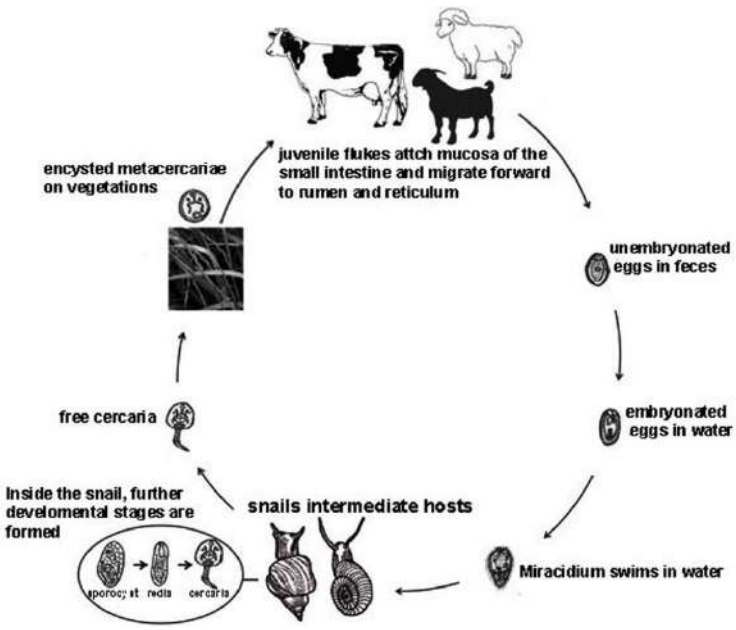
• The posterior sucker is small and subterminal.

Intermediate host: The aquatic snails *Cleopatra bulimoides* and *Cleopatra cyclostomoides*.

The life cycle of paramphistomes: (approximately 3 months)

• The adult flukes discharge unembryonated eggs (similar to fasciolid egg) with the feces of infected hosts. Each is oval, larger (176 x 100 µm) than *Fasciola* spp. eggs, grayish, thin-shelled, operculated with a knob at the opposite pole and the embryo is in the form of clear several embryonic cells.

• Hatching of eggs occur with the release of miracidia searching for the corresponding snails intermediate host (according to species). Inside the snails, miracidia develop into other stages



(sporocysts, rediae and cercariae).

• The morphology of those developmental stages is quite similar to those of fasciolids. Few exceptions are found; each redia carries 15-30 cercariae which are similar in type and morphology to those of *Fasciola* spp. but darker in color containing pigments so called **cercaria pigmentata**. Encystment occurs on water vegetations (as in *Fasciola* spp.). The infective stage, encysted metacercariae on vegetations, is ingested by the susceptible hosts.

• Excystation occurs in the duodenum and the juvenile flukes remain attached to the intestinal mucosa for 6-8 weeks and migrate forward to the rumen and reticulum (predilection site), staying for further few months forming adult flukes.

<u>Pathogenicity</u>:

Adult flukes in the fore-stomach are non-pathogenic, while the pathological effects are attributed to juvenile (immature) flukes in the duodenum. They are embedded in the duodenal mucosa with their suckers inducing necrosis and hemorrhage. Catarrhal and hemorrhagic duodenitis and jejunitis associated with a destruction of the intestinal glands. Destruction of the adjacent lymph nodes and organs. Anemia, emaciation and odema.

<u>Diagnosis</u>:

• The history of the presence of immature flukes in fluidy feces.

• Demonstration of paramphistomatid eggs in feces by the use of sedimentation technique.

Family: Dicrocoeliidae

(1) Genus: *Dicrocoelium*

Species: *D. dendriticum*

Common names: lancet fluke, little liver fluke.

Host: Sheep, goats, cattle, pigs and may be humans.

Habitats: Bile ducts and gall bladders.

Distribution: Cosmopolitan in distribution.

Morphological characters:

i) <u>Grossly</u>: Medium-sized fluke (6-10 x 2.0 mm) characterized by tapered ends, so the name lancet fluke is derived, with the widest portion at the middle. Uniquely, it is translucent and

flattened due to weal musculature and loose parenchyma, therefore, all internal organs could be easily seen even without staining.

ii) Microscopically:

• Smooth cuticle. The ventral sucker is slightly larger, or nearly equal, to the oral one and lies not far apart from it. The oesophagus is partially covered by a pharynx.

• Simple intestinal caeca not reach the posterior end.

• Testes are slightly lobed, tandem in position immediately behind the ventral sucker.

• The ovary lies just posterior to the testes.

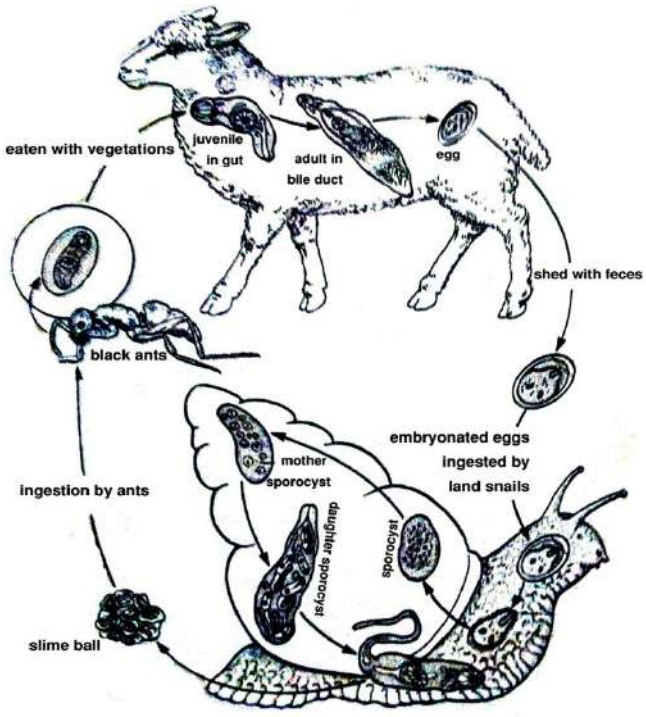
• Uterus is in the form of transverse coils full of brown eggs and occupy the central field just behind the ovary till the posterior end. The common genital pore lies just anterior to the ventral sucker. Vitellaria occupy the middle third of lateral fields at the area of the widest part.

Intermediate hosts:

i) 1st intermediate host: Land snails, *Zebrina detrita*, *Helicella ericetorum*.

i) 2nd intermediate host: Field ants or black ants, *Formica fusca*.

Life cycle: (approximately 5-6 months)



• Embryonated eggs (each is small 45 x 30 µm, oval, thick-shelled, yellowish to dark brown, operculated with no knob and contains fully developed embryo) are ingested by the land snails (1st intermediate host) inside them they hatch and precedes to give miracidia, mother sporocysts and daughter sporocysts (no redial stages). Mother sporocysts have no cuticle, while daughter ones have a cuticle and a birth pore.

• By the 3rd month, leptocercus cercariae, termed **cercariae vitrina**, are released from the mantle cavity of the snails in masses of 200-400 cercariae held together by thick mucoid gelatinous exudates. Each mass is called **slime ball**. The later pass out by the effect of low temperature and drop on vegetations or soil. On the later, black ants (2nd intermediate host), ingest slime balls and encysted metacercariae (infective stages) are developed in the gut of ants.

• Sheep, goats, cattle and other final hosts acquire the infection by grazing on vegetations containing encysted metacercariae. After the excystation in the small intestine, juvenile flukes migrate to the bile ducts via the portal circulation (full growth of adult flukes within 7 weeks post excystation). Four weeks further, eggs are laid.

Pathogenecity:

Similar to that of fasciolids but in lower manner:

• In heavy infections, bile ducts are greatly distended and occluded resulting in jaundice.

• Biliary cirrhosis may occurs associated with proliferation of biliary epithelium.

• Anemia, emaciation, odema and enteritis.

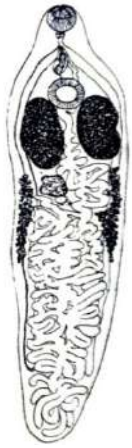
N.B.

Control of dicrocoelids are difficult as:

• Eggs may survive for months even in low temperatures.

• Land snails are less susceptible to molluscidies than aquatic snails.

(2) Genus: *Platynosomum*
Species: *P. fastosum*



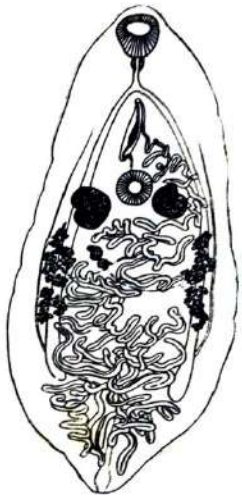
Similar to *D. dendriticum* but:

• In bile ducts of cats. Less lanceolate.

• Testes are horizontal in the anterior third.

• The 1st intermediate host is the snail *Sublina otona*, while the second is the lizard, *Anolis cristatellus*.

(2) Genus: *Eurytrema*
Species: *E. pancreaticum*



Similar to *D. dendriticum* but:

• In pancreatic ducts of sheep, goats, cattle and buffaloes.

• It measures 8-15 x 5-8 mm.

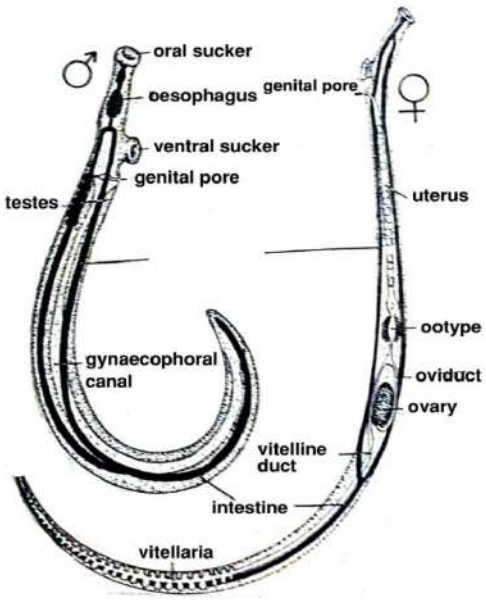
• Large suckers, particularly the oral one.

• Testes are horizontal just behind the ventral sucker with the ovary posterior to them. The common genital pore lies just behind the level of intestinal bifurcation.

• The 1st intermediate host is land snails *Bradybaena* sp. and *Cathaica* sp., while the second is the grasshopper *Conocephalus maculatus*.

Family: Schistosomatidae

General characters of the family:



1- Blood flukes of both mammals and birds.

2- Unisexual (separated sexes) and elongated flukes. Females are more slender and longer.

3- The name *Schistosoma* is derived means **split body** i.e. the body of the adult male carries ventrally located gutter-like groove called **gynaecophoral canal** formed by incurved lateral edges of the body along the entire length for enlodgement of females particularly during copulation.

4- Weak suckers lie close together (pedunculated ventral sucker).

5- Short oesophagus. No pharynx. Instead, clusters of unicellular oesophageal glands are present.

6- Simple intestinal caeca. The bifurcation begins at the level of the ventral sucker and they have the property of union and reunion ending with **one** fold in females and **2 folds** in males.

7- Numerous testes lie in front and below the level of the ventral sucker. According to number of testes, several species are recognized:

- *S. bovis* …….. 3-7
- *S. mansoni* ……. 6-9
- *S. hematobium* ….. 4-5

8- Both male and female genital pore lies a short distance behind the ventral sucker.

9- Ovary is an elongate compact mass (approximately 1 mm length) lies at the middle.

10- Vitellaria occupy the posterior half of the body behind the ovary.

11- Uterus is straight and runs forward, full of small number of large-sized (170-175 x 50-70 µm) eggs which are spindle or ovoid, thin-shelled, embryonated and non-operculated.

12- No redial or encysted metacercarial stages. Furcocercus cercaria is the infective stage.

<u>Size, egg, habitats and characteristics</u>:

***Schistosoma* (*Bilharzia*): *S. bovis*:**

• ♂ is 9-22 x 1-2 mm, ♀ is 12-28 x 2 mm.

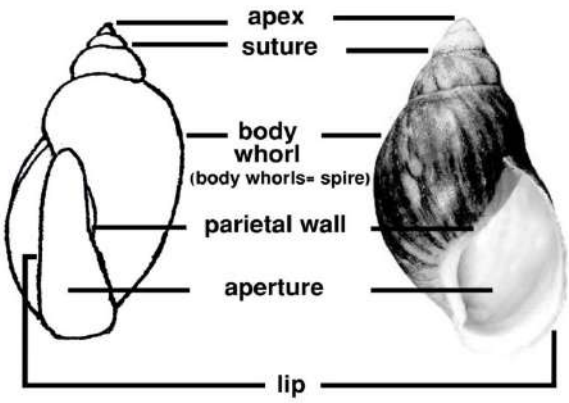
• The egg with terminal spine.

• It habits the portal and mesenteric vessels of cattle, buffaloes, sheep, goats and camels. The dorsum of males has tubercles.

Snails

• The snails are considered to be intermediate hosts because animals and humans harbour the sexual stages of the parasites and the snails harbour the asexual stages. The transfer of the infection requires no direct contact between snails and the definitive hosts.

• Many species of freshwater snail belonging to the family Planorbidae are intermediate hosts of highly infective flukes (digenetic trematodes). Freshwater snails are also intermediate hosts of food-borne fluke infections affecting the liver, lungs and intestines of animals/humans.



Class: Cestoda

(Cestodes or tapeworms)

General characters:

• Adult cestodes are endoparasitic, ribbon-like, segmented and elongated flatworms.

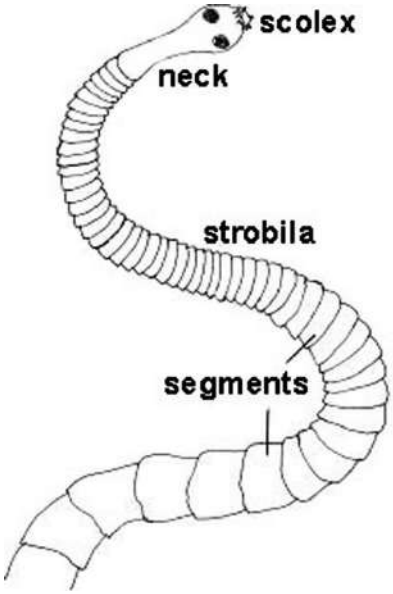
• Digestive, circulatory and respiratory systems are absent.

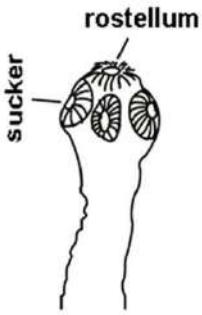
• No body cavity (acoelomata). Hermaphrodite. Indirect life cycle (intermediate host is needed).

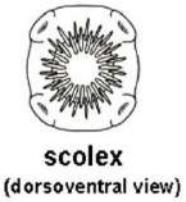
• They habit in the intestinal tract of mammals (final host) and their larval stages encysted in the tissue of either vertebrates or invertebrates (intermediate host).

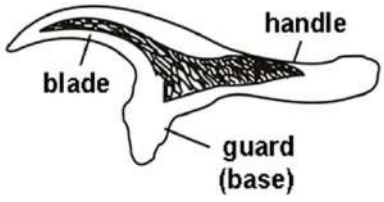
• They vary in length from few millimetres to several meters. They are dorsoventrally flattened.

• The body consists of scolex (corresponding to a head) followed by neck then the strobila









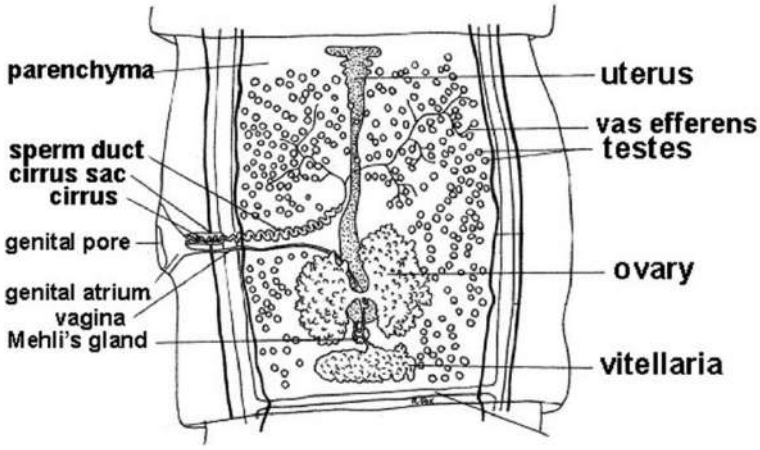
structure of a hook

The reproductive system

Tapeworms are hermaphrodites where both male and female genital organs are found in each mature segment. The first to develop in the mature segment is the male genital organs. Fertilization of eggs either takes place by cross-fertilization between segments of the same or different individual or mainly by self-fertilization of the same segment. Post fertilization, all organs undergo atrophy except the uterus filled with fertilized eggs. The gravid segment pass out of the final host singly or in the form of a short chain. Eggs get away through the uterine pore (in pseudophyllideans) or through the breakdown of the gravid segment (in cyclophyllideans).

a- Male genital system

It consists of number of testes located in the medullar parenchyma. From each one a single vas efferens extends and joins another forming the vas deferens, which forms a seminal vesicle for the storage of spermatozoa ending in a cirrus that is enclosed by a cirrus sac.



b- Female genital system

It consists of a single lobed or unlobed ovary located at the posterior aspect of the mature segment from which an oviduct originated. The oviduct leads to the ootype where different components of the egg are formed. The ootype is surround by the Mehli's gland and it receives the common vitelline duct which is a single duct formed by the union of many primary vitelline ducts that originate from the vitelline glands (these glands may be a single compact mass or numerous scattered follicles throughout the parenchyma) and also receives the duct of seminal receptacle which is an enlarged portion of the vaginal tube opens into the common genital pore. The uterus is a tube leaving the ootype and open to the outside either by the genital pore in case of the pseudophyllidea or it is a blind sac as members of the cyclophyllidea. The male and female genital pores located near each other in a shallow sinus on the lateral or on the ventral border of the segment.

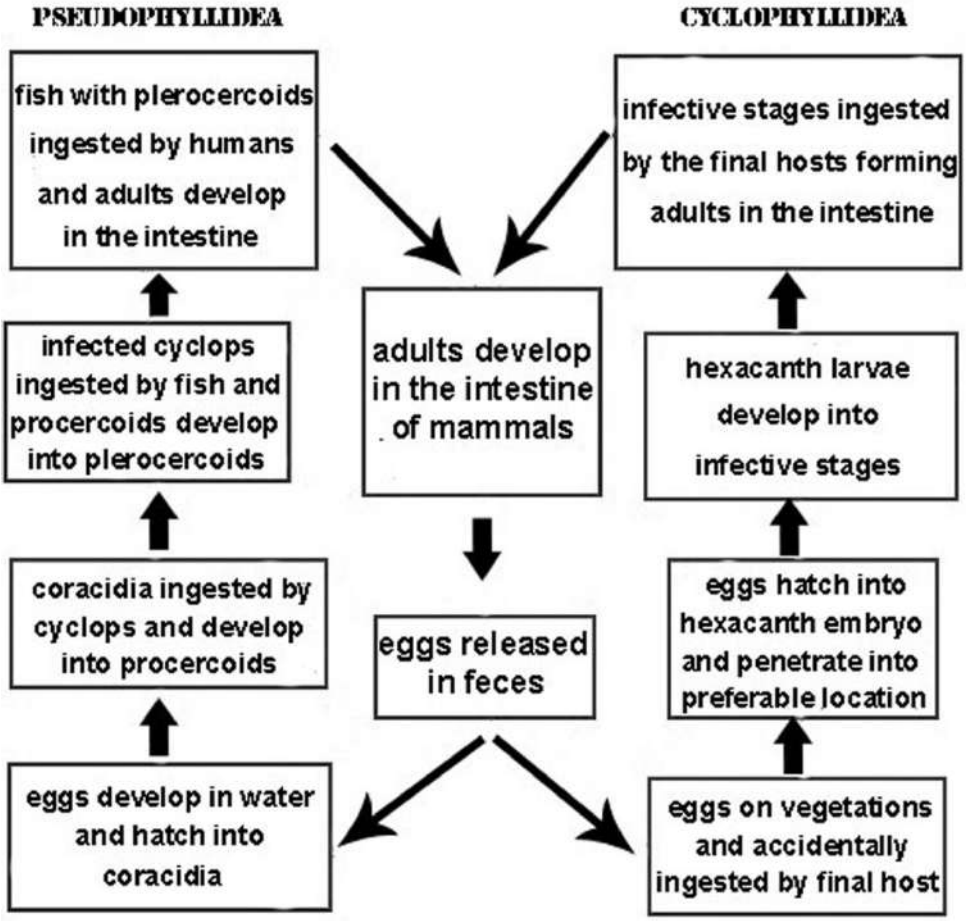
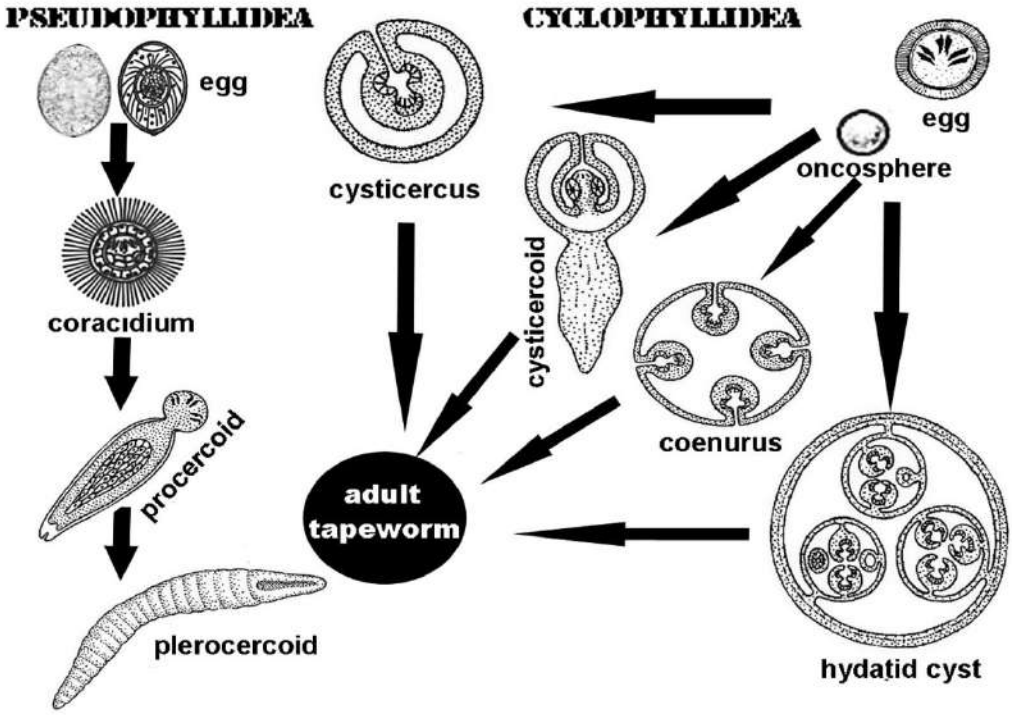


Diagram of life cycle in cyclophyllidea and pseudophyllidea



c) Genus: *Echinococcus*

Species: *E. granulosus*

(**Dwarf tapeworm of dogs**)

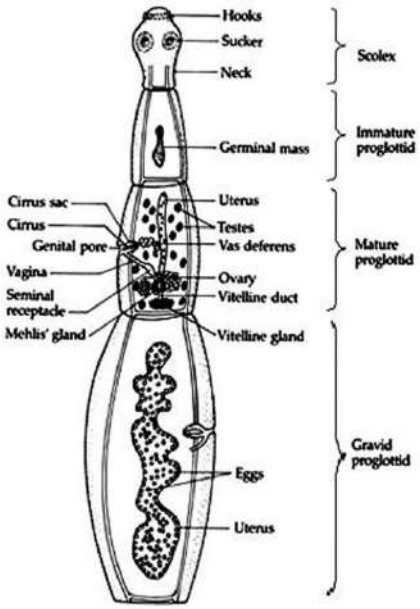
Hosts and habitats:

Small intestine of dogs, wolves, foxes and closely related carnivores.

Larval stage and intermediate host:

Hydatid cyst occurs in most of internal organs including bones in all domestic/wild mammals as well as humans.

Morphology of adult worms:



• The smallest tapeworm occurring in carnivores of about 2-6 mm in length. The adult worm usually consists of a 3 or in rare case 4 segment.

• The scolex bears 4 muscular suckers and a rostellum armed with 30-60 alternatively-sized taenoid hooks arranged in two rows.

• Following the neck, one immature segment, one mature segment containing 40-50 testes and a kidney-shaped ovary.

• The last segment is one or rarely 2 gravid segments representing more than half the length of the whole adult worm where uterus appears as a longitudinal median stem with 12-15 lateral pouches filled with embryonated eggs.

• This gravid segment usually disintegrates in the intestine so eggs only are found in feces. An egg is a typical taenoid egg i.e. subspherical, brown color with radial striated embryophore surrounding the hexacanth embryo.

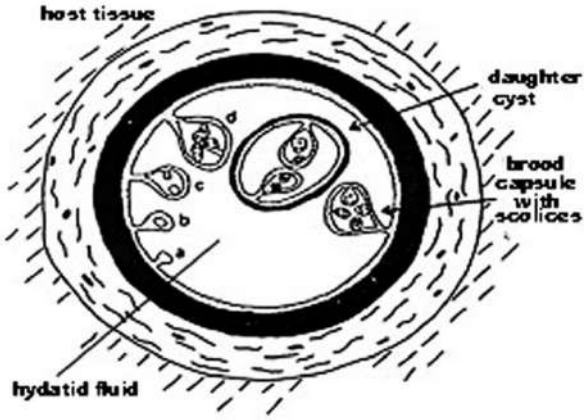
<u>Life cycle</u>:

• Dogs, the final host, discharge eggs (in feces) which are swallowed by the intermediate hosts, humans and domestic/wild mammals.

• In the intermediate hosts, digestion of eggs shell occurs in the duodenum with liberation of the hexacanth embryos (hooklets facilitate penetrating the duodenal wall) that reach the lymphatic or mesenteric veins and carried via the blood stream to various parts of the body. They may enter the portal vein, liver then pass to the lungs or other organs. Several hours (12 hours) after ingestion, they reach the liver and develops to mature hydatid cyst within several months.

• The mode of infection to the final host is by the ingestion of **fertile** hydatid cyst which will grow to adult worms in small intestine after 6-7 weeks.

Morphology of metacestodes (hydatid cyst):



• The hydatid cysts can be found in all parts of the body, including bone marrow, so the shape and size is dependent upon the location. In domestic animals, hydatid cysts is chiefly present in liver and lungs.

• The hydatid cyst is a spherical vesicle but its shape depending on the organ in which it grew.

• This cyst is filled with a pale yellow transparent fluid contains proteins which show degree of similarity to the host serum. The liver cyst encloses bile pigment while that in kidneys have traces of urine.

• The hydatid cyst varies in size from hen's egg to child head.

• The cyst wall consists of two layer outer thick, laminated, fairly thick representing cuticle and inner germinal layer from it arise a number of small vesicles called **brood capsules** that contain scolices. Fully developed cysts are formed within 5-6 months. Each scolex provided with 4 suckers beside rostellum armed with double rows of alternatively-sizes taenoid hooks.

• Brood capsules are easily detached from the wall and float freely in the cyst fluid and named **hydatid sand**. They may rupture releasing scolices into the cyst fluid.

• When brood capsules are absent, the hydatid cyst called **sterile**, but the presence of brood capsules keep it as **fertile**. The germinal layer may also give endogenous daughter cysts, by detached fragment from brood capsules or from scolices to be a cyst structurally similar to the original hydatid cyst. Daughter cysts may be budded outward and so called exogenous daughter cysts as a result of enclosing a piece of germinal layer within the cuticle due to uneven growth. If the hydatid cyst ruptures, all brood capsules, scolices and the germinal layer can form a new one.

<u>Pathogenesis</u>: (**cystic echinococcosis** or **hydatidosis**)

• The adult worm is non-pathogenic except when found with large number causing enteritis. The harmfulness of the cyst depends on the location and the severity of infection when the cyst gradually increases in size impairing the health of the host.

• In domestic animals, both liver and lungs cysts are symptomless and the main significance that they are diagnosed only during meat inspection in abattoirs but the growing cysts can cause pressure atrophy in the kidney, pancreas, CNS or marrow cavity of the long bones with a multiplicity of clinical symptoms.

• In humans, cysts in liver and lungs are frequently pathogenic causing respiratory symptoms and dyspnea if found in one or both lungs and digestive disturbance, gross abdominal distension or ascites. If cysts are found in the liver, exogenous daughter cysts may be formed in the omentum. In such concern, a cyst ruptured is a risk of death as a result of **fatal anaphylactic shock** and if the patient survived, the released daughter cysts from the rupture one can develop elsewhere of the body particularly omentum.

Order: Mesocestoididea

Family: Mesocestoididae

Genus: *Mesocestoides*

Sp. *M. lineatus*

Hosts and habitats: Small intestine of dogs, cats, foxes and wild carnivores.

Morphology of adult worms:

The adult tapeworm is small to medium-sized. The scolex bears 4 muscular suckers (no rostellum). The mature segment has a single set of genital organs with the genital pore in the dorsal aspect. The gravid segment has the uterus breaks down into a single par-uterine organ filled with eggs.

Life cycle and intermediate host:

• Two intermediate hosts are needed, the first is oribatid mites in which the cysticercoids developed. Infected mites are ingested by the second intermediate host as rodents, dogs, cats, birds, amphibians and reptiles in which tetrethyridium develops within the liver and peritoneal cavity. The final host is infected by ingesting the second intermediate host containing tetrethyridium and adults develop within 20 days.

Order: Anoplocephalidea

General characteristics:

• Scolex carries 4 cup-shaped muscular sucker only (no rostellum). Mature segments are broader than long with one or two sets of genital organs. Numerous testes and a marginal common genital pore. Some species are provided with interproglottidal (intersegmental) glands distributed at the posterior margin of the segments.

• Gravid segments are broader than long in which all organs undergo atrophy except the uterus which may be persist or replaced by one or two par-uterine organs.

• No vitelline glands in some species.

• The egg has three coverings, an outer vitelline covering, a middle albuminous coat and an inner chitinious membrane which is pear-like bearing in one side a pair of hooks (**pyriform apparatus**).

• The intermediate host is oribatid mites. The larval stage (metacestode) is cysticercoid.

• This order includes 2 families: Family Anoplocephalidae and family Thysanosomidae.

Family: Anoplocephalidae

This family includes genera *Anoplocephala*, *Paranoplocephala*, *Moniezia* and *Cittotaenia*.

Genus: *Anoplocephala*

sp. *A. magna*

Hosts and habitats: The small intestine particularly jejunum and rarely stomach of horses and donkeys.

Morphology:

• The scolex is large bearing four cup-shaped muscular suckers only.

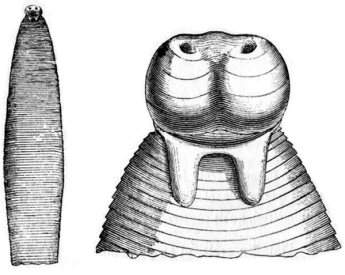
• Short neck. The mature segment has a single set of genital organs with a unilateral common genital pore. In the gravid segment, all organs undergo atrophy except the uterus, which appears as a transverse sac filled with eggs.

• The adult worm measures 80 x 2 cm with very short segments that overlapping each other.

sp.: *A. perfoliata*

The most common tapeworm in equines.

It resembles *Anoplocephala magna* except:



• It habits the small and large intestine of horses and donkeys.

• The scolex is smaller and provided with 4 cup-shaped muscular suckers as well as a **lappet** behind each sucker.

• In the gravid segment, the uterus appears as a transverse sac which is large and lobed.

• Adults measures up to 8 x 1.2 cm.

Genus: Paranoplocephala

Spp.: *P. mamillana*

Hosts and habitats: The small intestine and rarely stomach of horses and donkeys.

Morphology: It resembles genus *Anoplocephala* except it is much smaller, up to 60 x 5 mm. The sucker is located dorsally and ventrally in the scolex with a slit-like opening.

Life cycle of *Anoplocephala* spp.

• Equines (final hosts) detach gravid segments or eggs in feces.

• The intermediate host (oribatid mites) ingests eggs and the metacestodes (cysticercoids) develops inside it within 2-4 months after ingestion.

• The final host is infected by ingesting oribatid mites containing cysticercoids which develop to adult worms in the intestine of equines in 4-6 weeks.

Pathogenecity of *Anoplocephala* spp.:

• In common, the light infection is symptomless, however, heavy infection causes ill health or my leads to death. Perforation of the intestine due to infection with *Anoplocephala* spp.

• *A. perfoliata* is frequently found close to the ileocecal orifice attached by its scolices to the cecal wall causing appearance of ulcerative lesions in the form of small, dark, depressed areas associated with oedema and rarely excessive granulation tissues formation leading to a partial occlusion of the ileocecal valve. *A. magna* is the most pathogenic as it produces catarrhal or haemorrhagic enteritis when found in large numbers.

• *Paranoplocephala mamillana* is rarely pathogenic.

Genus: *Moniezia*

M. expansa

Hosts and habitats:

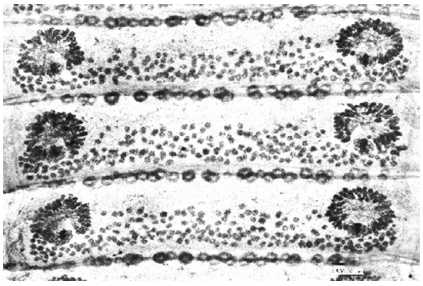
The small intestine of sheep, goats, cattle and other ruminants.

Morphology:

• The adult worm measured 6 x 1.5 cm.

• The scolex is relatively small bearing 4 prominent suckers.

• The segments are broader than long.



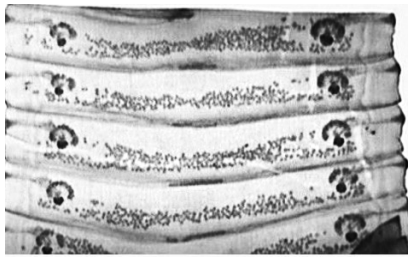
• The mature segment has double sets of genital organs.

• The ovaries and the vitelline glands are found median to the longitudinal excretory canal forming a ring on either side while testes are distributed in the central field of the segment or accumulate towards the sides. Intersegmental glands in the posterior border of the segment in the form of row of small pits.

• In the gravid segment, all organs undergo atrophy except the two uteri form all together a reticular network filled with eggs.

• The eggs are triangular in shape to some extent with a well-developed pyriform apparatus.

Moniezia benedeni



Hosts and habitats: The small intestine of ruminants mainly cattle.

Morphology:

• It is similar to *Moniezia expansa* except:

• It is broader up to 2.6 cm. The intersegmental glands appeared near to the mid-line of the segment as short continuous row.

Moniezia denticulata (**Moniezia alba**)

Hosts and habitats: The small intestine of cattle, sheep and other ruminants.

Morphology: Similar to *Moniezia expansa* with the **absence** of intersegmental glands.

Moniezia trigonophora

Hosts and habitats:

The small intestine of camels and other ruminants.

Morphology:

Similar to *Moniezia expansa* except:

• Testes appear as two pyramids on either side of the segment medial to the excretory canal.

• Intersegmental glands in the middle of the posterior margin of each segment.

Moniezia palida

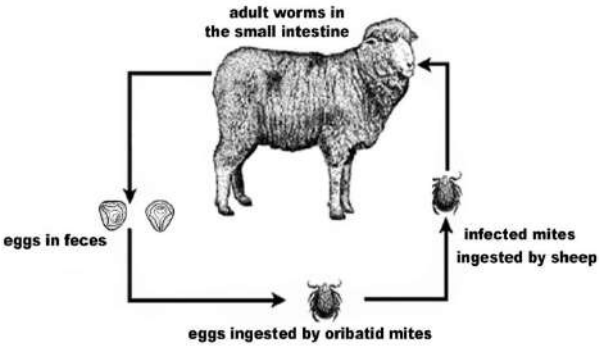
Hosts and habitats: The small intestine of equines.

Morphology:

• The worm measures 140 x 2 cm. The uterus extends lateral to the excretory canals.

• The intersegmental glands are linear and indistinct.

<u>Life cycles of *Moniezia* spp</u>.:



• Final host pass gravid segments and/or eggs in feces.

• The intermediate host (oribatid mites) ingests gravid segments and/or eggs which develop inside oribatid mites to cysticercoids within 4 months.

• The final host can be infected by ingesting oribatid mites with herbage and the pre-patent period is 35-40 days.

• There is a noticeable seasonal prevalence of *Moniezia* infection because of mites over-wintered in pasture. Monieziasis is common in young lambs and calves through their first summer on the pasture. Lambs become infected very early in life and may pass segment in feces as soon as 6 weeks age. Infection is not common in elderly and is generally light.

Pathogenicity of *Moniezia* species:

• Heavy infection is a common, however, one or few worms can produce disease because of their large size. Lambs, kids and calves under 6 months become infected and show symptoms but the adult animals rarely harbor the parasite.

• Symptoms in young animals appear in the form of vigour, strength, rough coat then animals become anemic and edema may develop. Constipation may occur but in severe cases the intestine may be nearly a solid mass of worms which may cause diarrhea and unthriftiness or leading to an intestinal obstruction.

• Commonly, a chain of segments was found to hang out through the anal opening.

• Decreased wool and meat production is associated with many deaths.

• Monieziasis in lambs is associated with a high prevalence of enterotoxemia.

Family: Thysanosomidae

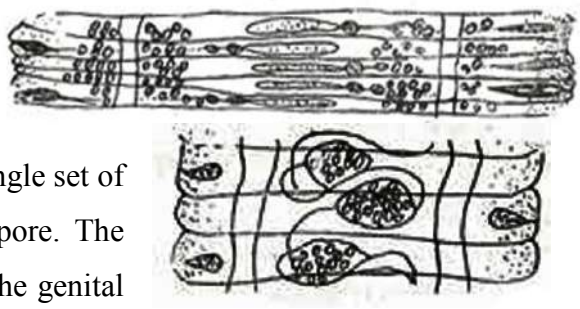
1- Genus: *Avitellina*

A. centripunctata

Hosts and habitats:

The small intestine of sheep, goats, cattle, and other ruminants.

Morphology:



• The adult tapeworm measured 3 m x 3 mm.

• The scolex has 4 suckers only. The segments are very short with ill-distinct segmentation so the worm appears non-segmented macroscopically. The mature segment has a single set of genital organs with irregularly alternating common genital pore. The ovary is spherical in shape and poral (i.e in the same side of the genital pore). The uterus appeared as a simple transverse sac in the middle of the segment. Testes are collected in 4 groups on either side (medial and lateral) of the excretory canals. Vitelline glands are **absent**. The gravid region of the adult tapeworm is narrow and cylindrical. In the gravid segments, all organs undergo atrophy except uterus, which breaks down into a large thick-walled par-uterine organs, one in each segment. Par-uterine organs appear macroscopically as a median opaque white line and the wide excretory canals take the shape of transparent lines on either side. Eggs have no pyriform apparatus.

Pathogenecity:

They are not highly pathogenic. Heavy infection produces marked symptoms. They found in adult animals more frequent than the *Moneizia* spp.

2- Genus: *Stilesia*

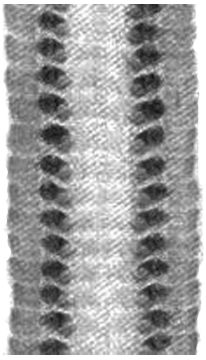
S. hepatica

Hosts and habitats: Bile ducts of sheep, goats, cattle and wild ruminants.

Morphology:

• The adult tapeworm measures up to 50 cm x 2 mm.

• The scolex is large has 4 prominent suckers only followed by a broad neck.



• Segments are short although more visible than that of *Avitellina*.

• Mature segment has a single set of genital organs. Testes are present on either side median only (2 groups) to the excretory canals. The uterus consists of 2 portions that connected by the inter-uterine transverse duct in the middle field. No vitelline glands.

• Each gravid segment has two uteri leading to the presence of two par-uterine organs.

• Eggs have no pyriform apparatus.

Pathogennecity:

It is mostly non-pathogenic. The particular significance of this tapeworm is the condemnation of the affected liver at meat inspection as the liver shows slight cirrhosis and thickened wall of bile ducts.

S. globipunctata

Hosts and habitats: Small intestine of sheep and goats.

Morphology:

• The adult tapeworm measures 45-60 cm long and up to 2.5 mm width.

• Testes on either side lateral to the excretory canals and they are from 4-7 in number.

Life cycle of family Thysanosomidae:

• The final host passes gravid segments and/or eggs in feces.

• The intermediate host (oribatid mites) ingests these gravid segments and/or eggs.

• Eggs hatch in the intestine of the vector and cysticercoids develop in the body cavity within 2-5 months. The final host can be infected by ingesting oribatid mites with herbage.

• Adult worms develop within 4-6 weeks after ingestion of infected oribatid mites.

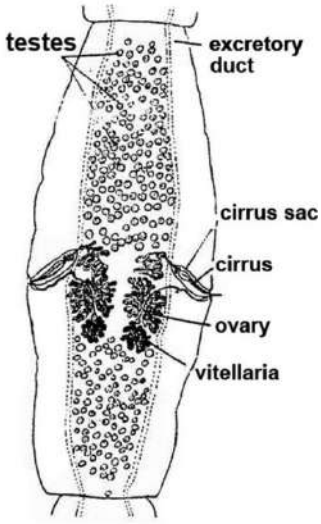
Family: Dipylididae

This family includes two genera of veterinary medical importance, *Dipylidium* (in dogs and cats) and *Choanotaenia* (in fowls and turkeys).

Genus: *Dipylidium*

Species: *D.caninum*

Common name: The common dog tapeworm.



Distribution: Cosmopolitan in distribution.

Habitat: The small intestine.

Definitive host: Dogs, cats and occasionally humans, especially children.

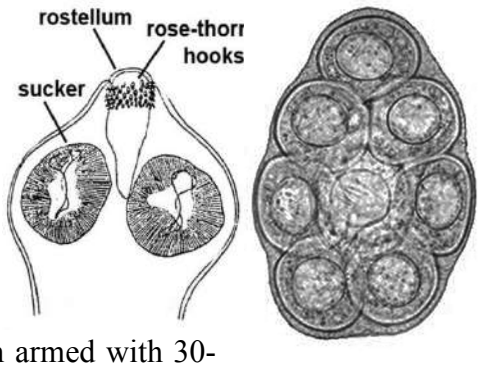
Intermediate host: Fleas (*Ctenocephalides canis*, *C. felis* and *Pulex irritans*) and the dog lice (*Trichodectes canis*).

Metacestode: Cysticercoid (cryptocystic type in fleas) inside the body cavity of the intermediate host.

Morphological characters:

i. Grossly:

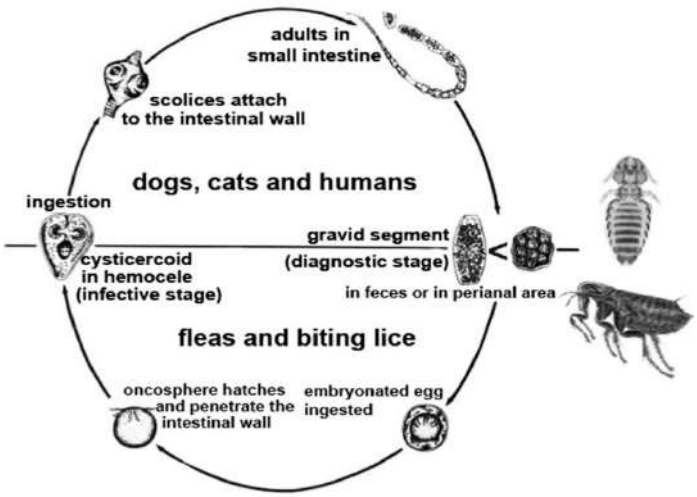
- *D. caninum* is a medium-sized tapeworm measuring up to 50 cm long and 2-3 mm width. It has a light reddish yellow color when fresh change to whitish on preservation. The body consisted of 60 to 175 elliptical segments. Each one is longer than broad with narrow ends resembling the cucumber seeds, so, the term cucumber seed tapeworm is derived.



ii. Microscopically:

- The scolex is a small measuring less than 0.5 mm in diameter and it facilitates attachment. It has four suckers and retractable rostellum armed with 30-150 tiny rose-thorn-shaped hooks arranged in 3-5 rows**.**
- Each mature segment is hermaphroditic contain double sets of male and female genital organs and two genital pores which are bilaterally situated.
- The two ovaries are horse-shoe-shaped, behind Mehli's glands then the vitelline glands forming a compact mass resembling bunch of grapes on both sides.
- Testes are numerous and scattered in the whole segment inward the excretory canals.
- The gravid segments are creamy white, 10-12 mm in length and resemble cucumber seeds.
- Gravid segments are filled with egg capsules, each is spherical containing up to 20 hexacanth ova.
- The terminal segments often passed singly in feces. They drained off in the external environment with shrunken appearance, and resembling uncooked rice grains**.**

Life cycle:



• The adults are found attached to the small intestine of the definitive host. The gravid terminal segments passed out through feces and actively crawl about the anus of the host.

• The gravid segments (the diagnostic stage) are just found outside the definitive host, disintegrated and release single eggs which are ingested by the intermediate host, the larval stages of dogs and cat fleas (*Ctenocephalides* spp.), which have mandibulate mouthparts allowing it to ingest eggs, while the adult flea can′t acquire the infection as its mouth part adapted for piercing and sucking. All stages of biting dog lice, *Trichodectes canis*, including the adults, can ingest eggs which release the hexacanth embryo and develop into mature cysticercoids (infective stage) in the abdominal cavity of the flea or louse.

• The development of the cysticercoid in the louse takes about 30 days because it is permanent ectoparasite. While in fleas, it may extends over several months as larvae and adults in the cocoon are found on the ground.

• The adult flea/louse will then harbor the infective cysticercoid until a definitive host, such as a dog, becomes infected by accidental swallowing of the infected flea/louse when licking or biting themselves. The flea may contain an average of 10 cysticercoids (range 2-82). Human beings, particularly children, can also acquire the infection by accidentally swallowing an infected flea through the saliva of pets when dogs or cats licking their faces or through food contamination. In the small intestine of the definitive host, the cysticercoid develops into an adult tapeworm, which reaches the maturity about one month post infection.

Pathogenecity and clinical signs:

• The infection of dogs with *Dipylidium caninum* is mostly symptomless, unless they are present in large numbers. Sometimes, mild diarrhea, abdominal colic, anorexia, restlessness, constipation, rectal itching, and pain due to emerging segments through the anal cavity may occur. Massive infections in young animals may cause non-specific abdominal symptoms including constipation or diarrhea, weight loss, restlessness, abdominal pain and anal itching.

• A human infection with *D. caninum* is rare, but if an infection occurs, it is more likely to occur in young children. The later are at a greater risk of infection because of how they interact with their pets.

Diagnosis:

• In the laboratory, by the detection of characteristic cucumber seed shape of gravid segments as well as egg capsules in feces of the infected host.

• Fecal examination on fresh feces reveals the gravid segments quickly migrating outside the droppings. On necropsy, the adult worms could be detected in the intestine.

Subclass: Cotyloda (Pseudophyllidea)

Order: Diphyllidea

Family: Diphyllobothridae

(1) Genus: *Diphyllobothrium*

Species: *D. latum*

Common name: Broad fish tapeworm**.**

Distribution: Cosmopolitan.

Habitat: Small intestine.

Definitive host: Humans, dogs, cats, pigs and other fish-eating mammals.

Intermediate host: Two intermediate hosts are needed; first I.H (aquatic crustaceans) and second I.H (fresh water fish (perch, trout and pike).

Morphological characters:

• Adult measures 2-12 m long.

• The scolex has two shallow, longitudinal grooves called bothria (sucking organs) which are dorsoventrally present for attachment to the host gut wall.

• The scolex is not armed and attaches to the neck, from the neck grow many segments which contain the reproductive organs. There is only one set of reproductive organs in each segment.

• The numerous testes and vitellaria are scattered and the ovary is bilobed.

• Each segment has a centrally located rosette-shaped uterus opens ventrally in the uterine pore which is lying behind the genital pore. The permanent uterine pore is usually opening on the ventral side of the segment from which eggs are released.

• The eggs are light brown, oval, operculated (the operculum is ellipsoidal in shape), rounded at one end and are unembryonated (similar to fasciolid eggs) when passed in feces.

Life cycle:

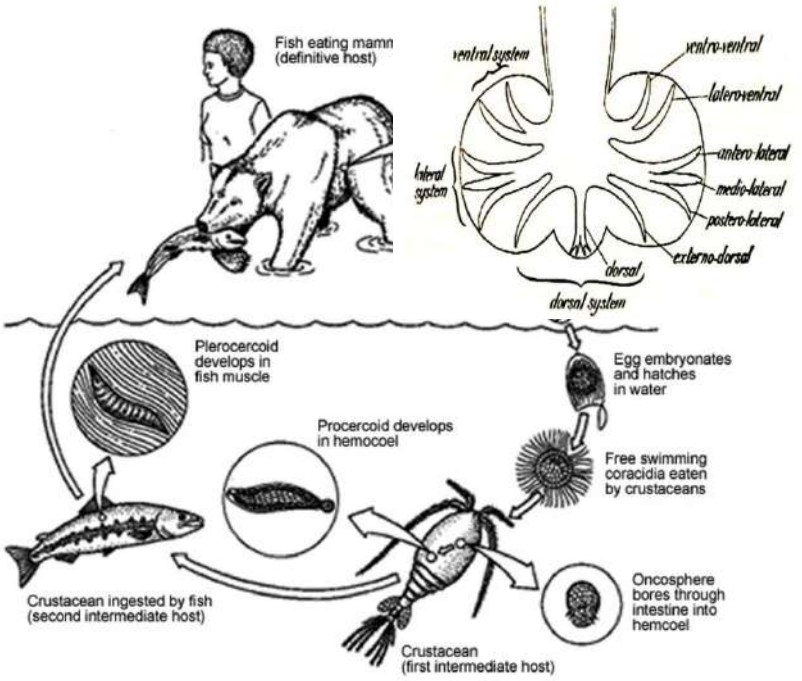
• Unembryonated eggs passed through the uterine pore in feces of the final host.

• In external environment, eggs develop and the ciliated coracicidium (the first developmental stage) emerges which is a six-hooked oncosphere covered with a ciliated embryophore.

• In fresh water, the motile coracicidium is eaten by the first intermediate host which is an aquatic copepod (crustacean).

• Within 2-3 weeks, the worm-like procercoid (the second developmental stage) develops in the haemocele of the first intermediate host (the copepod).

• The procercoid is ingested by the second intermediate host, such as fresh water fish (perch, trout & pike) and the procercoid develops into a plerocercoid within the viscera and musculature of the fish.



• The final host is infected with *D. latum* by eating the raw or under cooked fish and the plerocercoid develops to a mature tapeworm in the small intestine.

Pathogenicity and clinical signs:

• Diphyllobothriasis is apparently asymptomatic.

• Infected humans may suffer from weakness, fatigue, diarrhea, abdominal pain and in few cases macrocytic hypochromic anaemia (pernicious anemia) develops because most of tapeworms absorb large quantities of vitamin B12.

Treatment: The use of drugs of choice**;** praziquantel, a single dose of 35 mg/kg body weight eliminated all *D. latum* from infected host.

Class: Nematoda

(Roundworms)

Order: Strongylida (Bursate nematodes)

• Species have **copulatory bursae** at the posterior end of the males.

• There is a buccal capsule (well- or ill-developed) with/without teeth or cutting plates. Some species have a corona radiata (leaf crown) around the buccal capsule. Simple club-shaped-oesophagus, direct life cycle, and the infection occurs by the third stage filariform larvae.

• The copulatory bursa is a cuticular extension at the posterior end of the male worms and consists of 2 lateral lobes and a dorsal one. These lobes are supported by bursal rays (muscle fibers) which arranged into ventral, lateral and dorsal rays. Ventral rays are divided into

ventroventral and lateroventral rays. The lateral system consists of 3 rays; anterolateral, mediolateral and posterolateral rays. The dorsal system is composed of two externo-dorsal rays and a dorsal ray (divided). The bursa grasps the female worms during the copulation.

A) Superfamily: Strongyloidea

1) Family: Strongylidae

a- Genus: *Strongylus*

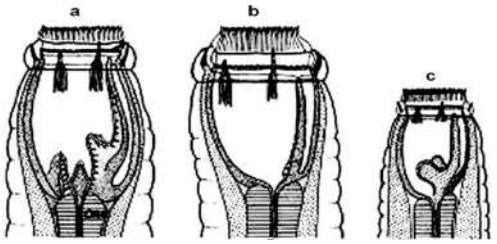
(Large strongyles of equines)

• Parasites of the large intestine (caecum and colon) of equines, commonly known as large strongyles. Common species are *S. vulgaris*, *S. edentatus* and *S. equinus*.

Hosts and habitats:

• They are robust dark red worms habit the mucosa of cecum (easily seen against the intestinal mucosa) and colon of equines and characterized by the well-developed buccal capsule and the male bursa.

• ***S. equnius*** is the largest strongyle of equines (2.6-4.7 cm long). They fairly rigid and dark gray. The large buccal capsule has **3** conical teeth at its base, one is larger and dorsally situated with a bifid tip, and the other two are smaller and subventral. Moreover, the buccal capsule has a well-developed leaf crowns (external and internal). A well-developed **dorsal gutter** is present.



• **S. *edentatus*** has a more or less wider head than the succeeding portions. The buccal capsule is wider anteriorly with **no** teeth. Leaf crowns and the dorsal gutter are present.
Its measures 2.3-4.4 cm long.

• ***S. vulgaris*** is uniquely **smaller** than previous species. It measures 1.4-2.4 cm long. The buccal capsule of is roughly oval and contains leaf crowns and **2** ear-shaped rounded teeth which are located subdorsally at its base. Leaf crowns and the dorsal gutter are present.

<u>Biology and pathogensis:</u>

• The embryonal development occurs **outside** the host. Eggs are oval with smooth thin shell, nearly transparent and the embryo in the early stage of development (4, 8, 16 and 32 cells).

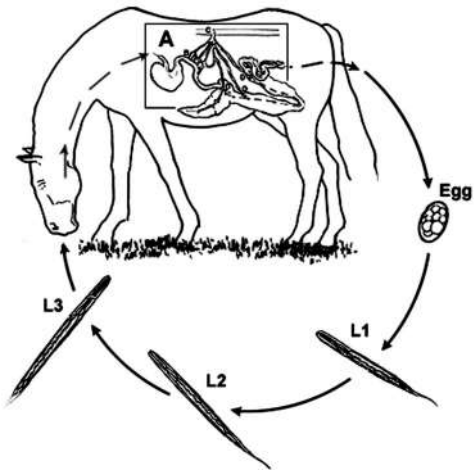
• The post embryonal development is **direct**.

• The infective stage is **L3** (it takes ~ 2 weeks from eggs to L_3).

• The route of infection is **per os**. The infection occurs by ingestion of sheathed L_3 (migration of L3 to form the adult worm differs according to the species involved):

1) *S. vulgaris*:

L3 penetrate the intestinal mucosa and moult to L4 that penetrate the tunica intema of submucosal arterioles and further migrate to the cranial mesenteric artery (including main branches) inducing thrombi and aneurysms. They return via the arterial system moulting to L5 (several months) and access the lumen of cecum and colon and encapsulated into 5-8 mm nodules. Rupture of such nodules releases immature adult parasites (L5) to the intestinal lumen forming adult worms. Some larvae may become trapped and encapsulated in mesenteric arterioles on their way back to the gut, and remain there to die eventually. The prepatent period is approximately 7 months.



Life cycle of migratory large strongyles in equines

2) *S. edentatus:*

L3 penetrate the intestinal mucosa and pass via the portal system to the liver parenchyma within few days. Two weeks later, they moult to L4 and further migrate in the liver parenchyma. After 6-8 weeks post infection, L4 escape from the liver by migrating under the liver capsule, through the hepatic ligament and underneath the parietal peritoneum to the right flank. L5 are formed within 4 months and migrate, subperitoneally, to the wall of the large intestine where they are trapped in large hemorrhagic nodules which subsequently ruptured with the release of the young adult parasites into the intestinal lumen. The prepatent period is approximately 11 months.

3) *S. equinus* (less common):

L3 exsheath while penetrating the intestinal wall (cecum and ventral colon) and become encapsulated in subserosal nodules (within one week), where they moult to L4. The later travel across the peritoneal cavity to the right lobe of the liver (a closely position to the cecum) where they migrate within the parenchyma for 6 weeks. Afterwards, they migrate back to the large intestine by leaving the liver and crossing the abdominal cavity directly or by first passing through the pancreas (closely associated with the right lobe of the liver) and then the abdominal cavity, where the last moult to L5 occurs. Finally, young adults return to the intestinal lumen by direct penetration of the intestinal wall. The prepatent period is about 9 months.

Pathogenicity of equines strongylosis:

• They are especially pathogenic in susceptible foals.

• Adult worms are destructive feeders on the mucosa of the cecum and colon (bloody diarrhea) and parasitic larvae undergo extensive migrations causing significant damage to adjacent organs. Based on the number of worms, continuous inflammations of the mucosa as well as the blood loss are given. Some worms are associated with nodules formation, while others produce toxins. *Strongylus vulgaris* is of a particular risk during its migration in the cranial mesenteric artery. It may be the cause of numerous cases of equine colic due to embolism of the small arteries supplying the gut or due to pressure on the nerves of the coeliac and anterior mesenteric plexuses.

b- Genus: *Triodontophorus*

(***T. serratus, T. tenuicollis*** and ***T. brevicauda***)

(Small strongyles of equines)

• Non-migratory blood sucker worms in the colon and cecum of horses and donkeys.

• They are large-sized, 1-2.5 cm long (so, they are closely similar to *S. vulagris*), having subglobular buccal capsule, **3** pairs of teeth at its base and a well-developed dorsal gutter.

• The life cycle of small strongyles includes:

- The embryonal development occurs outside the host.
- The post embryonal development is direct.
- The infective stage is L3.
- The route of infection occurs per os.
- The development inside FH is restricted to the gut mucosa (histotropic migration).

c- Genus: *Oesophagodontus*

(Small strongyles of equines)

• *O. robustus* occurs in the large intestine of equines. It measured 1.5 -2 cm long and the buccal capsule has three tooth-like folds at its base. There is a slight constriction between the anterior end and the rest of the body. No dorsal gutter. The parasitic development is non-migratory.

2) Family: Trichonematidae (cyathostomes or cyathostomins)

Genus: *Trichonema*

spp. ***T. alveatum*, *T. labiatum*, *T. labratum***

(Small strongyles of equines)

• They are small, stout worms measured 4-15 mm long. They vary from white to dark red color, with a short cylindrical buccal capsule without teeth.

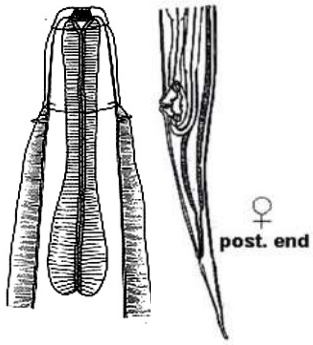
• The dorsal gutter is short and do not reach the anterior border of the buccal capsule. Leaf crowns are present. The adult worms habit the large intestine of equines and non-migratory. The life cycle is short (25 days).

3) Family: Chabertidae

a) Genus: *Oesophagostomum* (Nodular worm)

spp. ***O. columbianum, O. venulosum*** and ***O. radiatum***

Morphology:



• The anterior end has a shallow buccal capsule. There is a large cervical alae and a shallow groove (cervical groove) little behind the anterior of the worm.

• Anterior to the cervical groove, the cuticle is expanded to form a unique cervical vesicle. The copulatory bursa is well-developed and spicules are long. The vulva is near the posterior end of the body.

Hosts and habitats*:*

The adult worms habit the colon of sheep, goats and cattle.

Biology and pathogenesis:

• The embryonal development occurs outside the host.

• The post embryonal development is direct. Eggs develop to the L1 (rhabditiform) on the ground (within 18 hrs) and moult to L2 then to L3 within one week.

• The infective stage is L3. The host is infected by swallowing L3 (sheathed) with the forage. They enter the epithelial mucosa and lie coiled (encyst) next to the muscularis mucosa.

• After 4 days, they undergo the 3rd moulting, changing to L4. The presence of L3 and L4 as well as the presence of discarded cuticular sheaths, result in small gritty lesion (**nodules**).

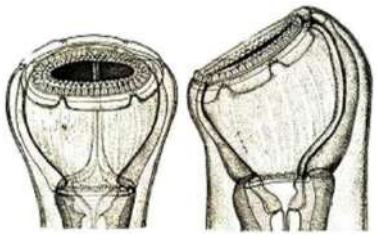
• Inflammation is localized around larvae. Nodules have small openings through which pus is discharged into the intestine. The intestinal wall shows numerous nodules and tracks.

• Within further 3-4 days, larvae migrate from nodules into the lumen of the intestine, where they moult to L5 and develop to adults.

b) Genus: *Chabertia*

sp. ***C. ovina***

• Stout white worms habit colon of sheep, goats and cattle, having a large, bell-shaped and empty buccal capsule which is slightly bent ventrally. The oral opening is surrounded by a double row of small cuticular elements representing the leaf crowns.



• The adult male and female worm measure 1.5 and 2 cm long, respectively. A short transverse cervical groove lies a short distance behind the posterior level of buccal capsule. The male bursa is well developed. Spicules are equal. The vulva opens at the posterior extremity.

Biology and pathogenesis:

• The embryonal development occurs outside the host.

• The post embryonal development is direct. The infective stage is L3.

• Development in the host with extensive histotropic migration in the wall of the small intestine and L3 change to L4 and develop to L5 in the lumen of the caecum, then adults pass to the colon. Adult worms cause parasitic gastroenteritis via ingesting large plugs of mucosa resulting in local hemorrhages and loss of protein through the damaged mucosa. In heavy infections, the wall of the colon becomes odematous, congested and thickened with small hemorrhages at the sites of worm attachment. Clinical signs are bloody diarrhea, anaemia and loss of weight.

B) Superfamily: Trichostrongyloidea

(1) Family: Trichostrongylidae

a- Genus: *Trichostrongylus* (Black scour worm)

Small, thin (thread) and hair-like worms (males 4-6 mm and females 5-7 mm long). They are difficult to be seen by necked eyes. Ill-defined buccal capsule. The excretory notch is in the oesophageal region (unique feature). They have prominent excretory pore. No cervical papillae. The male posterior end has a well-developed bursa (large lateral lobes and a small symmetrical dorsal one) with short and stout spicules and a gubernaculum. In females, the vulva is short distance behind the middle of the body with a prominent lip (no vulvar flap).

Hosts and habitats:

Trichostrongylus spp. habit the small intestine except *T. axei* (abomasum) and *T. tenuis* (cecum of game birds).

1- ***T. axei***: in abomasum of sheep, cattle, camels and in the pyloric region of stomach of horses, pigs and humans.

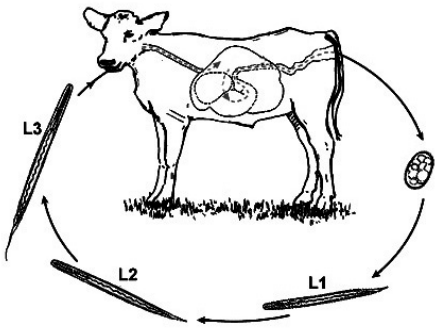
2- ***T. colubriformis****:* in the duodenum of sheep, cattle and other ruminants.

3- ***T. capricola***: in sheep and goats.

4- ***T. retortaeformis***: in the intestine of rabbits.

5- ***T. tenuis***: in the caecum of chicken and other domesticated birds.

Biology and pathogenesis:



• The life cycle is direct and non-migratory. Embryonal development occurs outside the host. Post embryonal development is direct.

• The infective stage is L3 (within 1-2 weeks).

• Infection occurs by ingestion of the infective (sheathed) L3. They exsheathed in the abomasums, then penetrate (histotropic phase of migration) deeply between the intestinal villi (for intestinal species) or abomasal glands (for gastric species), where they moult to L4 and L5. Then, young adults emerge onto the mucosal surface where they become mature and copulate. The prepatent period in animals is about 3 weeks.

• *Trichostrongylus* spp. is the most common cause of parasitic gastroenteritis in tropics. Infected animals shed large numbers of eggs/gram.

b- Genus: *Ostertagia*

(Small brown stomach worms)

• Adult worms habit the abomasum of cattle (*O. ostertagi*), sheep and goats (*O. circumcincta* and *O. trifurcata*). Worms are recognized, in clear abomasal debris, by their reddish-brown color. They are up to 1 cm long and difficult to be grossly seen.

• Ill-defined buccal capsule with small lateral cervical papillae.

• In male, the bursa has an accessory bursal membrane, short and stout spicules with bifid tips and prebursal papillae. Gubernaculum is present. In females, the vulva is usually covered by a vulvar flap.

Biology and pathogenesis:

• The life cycle is direct and non-migratory.

• Embryonal development occurs outside the host.

• Post embryonal development is direct. • The infective stage is L3 (within 2 weeks).

• The infection occurs per os.

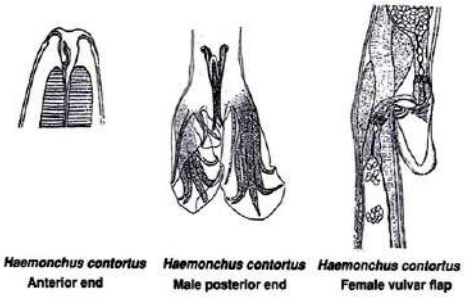
• Development inside the definitive host occurs with histotropic phase of migration in the abomasal mucosa (The entire parasitic life cycle usually completed in 3 weeks).

• *Ostertagia* spp. cause anorexia, severe diarrhea of green color, necrosis in abomasal wall and loss of appetite. Hyperplasia of gastric glands and mucosa forming coalesced nodules (Morocco leather or Cobblestone appearance).

c- Genus: *Haemonchus*

(Wire worms, large stomach worms, Barber's pole worms)

• *Haemonchus* is a blood-sucking abomasal nematode which may be responsible for extensive losses in sheep (*Haemonchus contortus*) and cattle (*Haemonchus placei*), especially in tropical and subtropical areas.



• Adults are easily identified because of their specific location in the abomasum, bright red color, and their large size (2.0–3.0 cm).

• In fresh female specimens, the pink (blood-filled) intestine of the worm twisted around the paler reproductive tract (ovaries) (**Barber's pole worm**).

• Anteriorly, both sexes have a very small buccal capsule containing a dorsal tiny lancet which is used for piercing the small blood vessels during feeding. In *H. contortus*, anterior prominent lateral cervical papillae are present.

• In males, the bursa has large lateral lobes with a small asymmetrical dorsal one (the later has a unique inverted Y-shaped dorsal ray). Gubernaculum is present.

• In females, the vulva is usually protected by a cuticular large and linguiform flap.

Biology and pathogenesis:

• The life cycle is direct and non-migratory.

• Embryonal development occurs outside the host.

• Post embryonal development is direct.

• The infective stage is L3.

• The infection occurs per os.

• Development inside the definitive host occurs with histotropic phase of migration in the abomasal mucosa. The prepatent period is approximately 3 weeks in sheep and 4 weeks in cattle. In severe haemonchosis, animals suffer from **anaemia**, dark colored feces and sudden death (in acute infection), severe gastric haemorrhage in hyperacute stage, weakness, unthriftiness, emaciation and bottle- jaw.

d- Genus: *Cooperia*

Adult worms habit the small intestine of cattle (*C. oncophora, C. punctata,* and *C. pectinata*) sheep and goats (*Cooperia curticei*).

Morphology:

• Relatively small worms (less than 9 mm long), light red-colored and coiled when fresh. The main common features are the small cephalic vesicle (inflated anterior end) and the marked anterior transverse cuticular striations. Cervical papillae may be present.

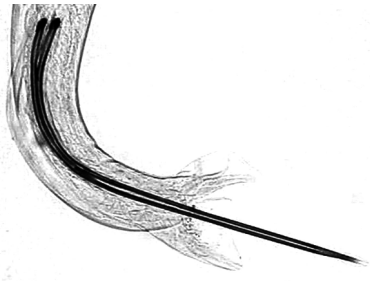
• The male bursa is relatively large. It has a small dorsal lobe with the dorsal ray bifid for half its length. Spicules are brown-colored, short and stout with distinct wing-like expansions in the middle region. Gubernaculum may be present.

• The females have a long tapering tail and a vulvar flap may be present.

Biology and pathogenesis:

Typical life cycle of Trichostrongyloids. The prepatent period is up to 3 weeks. Diarrhea, dehydration, loss of condition, weakness, loss of appetite and loss of weight are common clinical signs.

e- Genus: *Nematodirus* (Thin-necked worm)



• Adult worms habit the small intestine of sheep, goats (*Nematodirus filicollis*, *Nematodirus spathiger,* and *Nematodirus battus*) cattle (*Nematodirus helvitianus*) and camels (*Nematodirus cameli*).

• Adults are slender, about 2 cm long. The body is always much twisted and a group of worms give the appearance similar to that of the cotton wool. The anterior end has a distinct cephalic vesicle (inflated) which is transversely striated with no cervical papillae.

• Spicules of the male are long, slender with fused tips. No gubernaculum. The female tail is short, truncate with a small spine (It possesses a vulvar flap).

• The egg is ovoid, colorless and large, measuring twice the size of the typical trichostrongyle egg. Female of *N. battus* is exceptionally has a long pointed tail and its large egg is brownish with parallel sides.

Biology and pathogenesis:

• Unlike other trichostrongyloids, the development to L_3 occurs within the egg (post embryonal development is inside the egg).

• Infection occurs by ingestion of L_3 which enter the mucosa of the small intestine where the two parasitic moults take place between the villi within 4-10 days post-infection.

• The prepatent period is approximately 15 days. *Nematodirus* causes parasitic gastroenteritis, diarrhea, loss of body weight and dehydration.

(2) Family: Dictyocaulidae

Genus: *Dictyocaulus*

(Lungworms)

• The taxonomic position of these worms in trichostrongylids rather than metastrongylids is referred to being that they are geohelminths, while metastrongylids are biohelminths.

• Adult worms habit the trachea and bronchi (unique feature) of cattle (*Dictyocaulus viviparus*), sheep, goats, (*Dictyocaulus filaria)* horses and donkeys (*Dictyocaulus arnfieldi*). They are the major causes of parasitic bronchitis in their hosts.

Morphology:

• The adults are slender, thread-like, milk-white-colored and up to 8.0–10 cm (males 3.5-4.5 cm and females 4.5-6.5 cm) long.

• Small and shallow buccal capsule.

• In the male bursa, the medio- and posteriolateral rays are fused except at their tips. Spicules are stout, dark brown and **boot-shaped**. Female vulva lies behind the middle of the body. The egg measures 120 x 80 µm and contains a fully developed larva when freshly laid.

Biology:

• Ovivivіparous females produce eggs which hatch immediately while they are in the air passages or in the gut after passing up the trachea and being swallowed. However, in *D. arnfieldi.* hatching does not occur until soon after the egg being passed in the feces.

• L1 migrate up the trachea and swallowed, then pass out in feces. The preparasitic stages do not require feeding. L3 is reached within 5 days, then, they leave feces to reach the herbage.

• Infection is by ingestion of L3 which then penetrate the intestinal mucosa and pass to the mesentric lymph nodes where they moult to L4 which then travel via the lymph and blood to the lungs (lymphatic migration) and break out of capillaries into the alveoli about one week after infection. The final moult occurs in bronchioles few days later, and young adults then move up the bronchi and develop to maturity.

• The prepatent period is about 3- 4 weeks.

Pathogenecity:

They produce a disease called dictyocaulosis (verminous bronchitis or lung verminosis). Almost respiratory signs: intermittent coughing, particularly during exercises. In severely affected animals, dyspnea is obvious. Catarrhal bronchitis and pneumonia are frequent. Other clinical symptoms such as foaming around the mouth, loss of appetite, diarrhea and fever due to secondary bacterial infection and even death may occur.

Order: Ascaridida

Superfamily: Ascaroidea

i) Family: Ascaridae

1- Genus*: Ascaris*

sp. ***Ascaris* (*Toxocara*) *vitulorum***

Common name and hosts: Ascarids of cattle and buffaloes, particularly calves.

Distribution: Tropical and subtropical areas.

Habitat: Small intestine.

Morphology:

• The largest worms infecting cattle (♂ 25 cm and ♀ 30 cm long and 7 mm thick).

• It is a whitish-colored and translucent, so internal organs could be easily seen by naked eyes.

• A narrow anterior end, so it appears **smaller** than the succeeding parts. Laterally, 2 characteristic wing-like projections (alae) are present. Club-shaped oesophagus.

• Eggs are subglobular, grayish, 70x80 µm, having a thick shell with finely pitted albuminous layer and contain a single cell.

Life cycle:

• Embryonal development occurs at the exterior.

• Post embryonal development is direct.

• The infective stage is the egg containing L2.

• The route of infection per os.

• The development inside the final host occurs with hepatopulmonary migration (see page 137).

• The prenatal and transmammary infections are the main sources of infections to calves. Larvae have somatic migration then they become dormant. In pregnancy, dormant larvae mobilized from the tissues in the 8th month of pregnancy, reach the blood stream then to the

fetus through the placenta (prenatal infection). Other larvae reach mammary glands and the newly born calves get the infection via dam's milk (transmammary infection).

• The prepatent period in calves is 3-4 weeks. In adult cows, it is longer, depending on the migration and dormancy periods.

Pathogenesis and clinical signs:

• It is usually non-pathogenic for adult cows. Otherwise, it is harmful to calves (characteristic butyric acid or acetone odor on breath and/or urine is common) if untreated.

• Migrating larvae in adults, particularly in lungs, are often associated with secondary bacteria and subsequent pneumonia. In calves, adult worms (in the small intestine) absorb nutrients of the host causing diarrhea (often putrid), colic, enteritis, loss of appetite and weight. Due to the large size of the worms, massive infections may obstruct the gut and even perforate.

• Occasionally, worms could migrate via the bile duct causing cholangitis.

Diagnosis:

• Detection of eggs in feces of calves.

Prevention and control:

• Avoid grazing of cows in pastures contaminated by *T. vitulorum* eggs.

• Treatment with broad spectrum anthelmintics e.g. benzimidazoles

sp. ***A. suum***

Common name: Large intestinal nematode.

Distribution: Cosmopolitan.

Host and habitat: Small intestine of pigs.

Morphology and general characters:

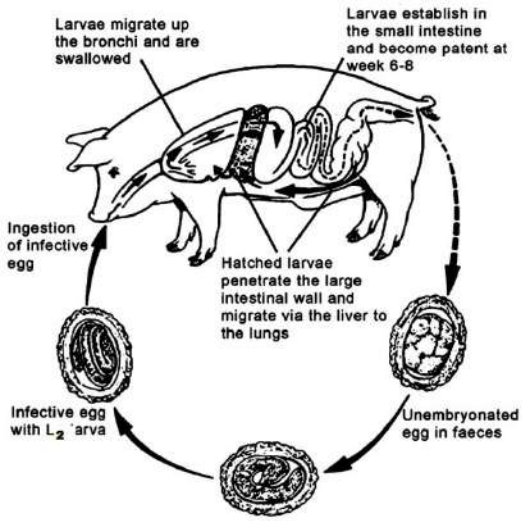
• Males are up to 25 cm and females up to 40 cm long, whitish in color, and **quite** thick.

• Anteriorly, 3 lips with the diameter is **more or less equal** to the succeeding parts. It has a club-shaped oesophagus.

• The male tail is ventrally curved, with a pair of equal spicules and numerous pre- and post-cloacal papillae. The vulva opens in the first third of the body. Eggs are oval/ovoid-shaped, golden brown/dark greenish brown in color, thick-shelled with mammillated albuminous layer (prominent projections) and 50-70×40-60 µm. The freshly deposited egg contains one cell.

• It is worthy to mention that *A. suum* is zoonotic. Visceral larva migrans due to larvae migration has been described.

Life cycle:



• One adult female produces 200,000 to one million eggs daily. Eggs can develop to the infective stage in 3-4 weeks. Under optimal conditions, eggs may survive for years, but they are highly resistant to chemical agents.

• The pattern of the life cycle is similar to *T. vitulorum*.

Pathogenesis and clinical findings:

• It may significantly reduce the growth rate of young pigs. Rarely, the intestinal mechanical obstruction may occur.

• Hepatic hemorrhage and fibrosis are due to larval migration through the liver leads to accumulation of lymphocytes seen as white spots (**milk spots**) under the capsule. Lesions become visible 7-10 days post infection and disappear within 1-4 weeks.

• In heavy infections, migratory larvae may cause pulmonary edema. Susceptible pigs show abdominal breathing (**thumps**). Unthriftiness and weight loss may be noticed.

• The previous infection generally the induces development of acquired resistance to reinfection.

Diagnosis: Detection of eggs/worms in feces. As pigs are coprophagic, a low egg count (<200 eggs/g) may indicate coprophagy rather than an actual infection.

Treatment: Benzimidazoles and probenzimidazoles, dichlorvos, ivermectin, levamisole, and pyrantel are effective.

sp. ***A. lumbricoides***

Large worms habit the small intestine of **humans** with the life cycle is similar to that of *A. suum*.

2- Genus*: Parascaris*

sp. ***P. equorum***

Common name and hosts: Ascaris of equines.

Distribution: Cosmopolitan.

Habitat: Small intestine.

Morphology:

• Adult worms are stout, whitish in color, up to 30 cm long, with **3 prominent lips** are well-marked off from the succeeding part of the worm body (interlabial septum is present).

• Eggs are spherical/subglobular, deep brown, measuring up to l00 µm, the shell is thick, provided by coarsely pitted albuminous layer and the one cell-embryo occupies small egg space.

Life cycle:

• The life cycle is similar to that of *A. suum*. Large numbers of infective eggs can remain viable for years in contaminated soil. Adult animals usually harbor few worms.

• The principal sources of infection for foals are pastures, paddocks, or stalls contaminated with eggs from other infected foals. The prepatent period is 10-12 weeks.

Clinical signs:

In heavy infections, migrating larvae may produce respiratory signs (summer colds). In heavy intestinal infections, foals show unthriftiness, loss of energy, and occasionally colic. Intestinal obstruction and perforation have been reported. Intestinal stages compete for absorption of essential amino acids.

Diagnosis: Demonstration of eggs in feces.

Treatment: Most foals become infected soon after birth. Treatment should be started when foals are 8 weeks and repeated until they are yearlings. All broad-spectrum equine anthelmintics are effective against the adult and immature worms.

Superfamily: Habronematoidea

Family: Habronematidae

Genus: *Habronema*

Common name: Stomach worm of equines.

Distribution: Cosmopolitan.

Hosts and habitats: Stomach of equines and donkeys.

The common species are *Habronema musca*, *H. microstoma* and *H. megastoma*.

Morphological characters:

• Small slender white worms. Males are up to 2.2 cm and females up to 3.5 cm long.

• *H. megastoma* is smaller (males up to 1 cm and females up to 1.3 cm long) and the head is constricted off from the body and inside large nodular lesions in the fundus.

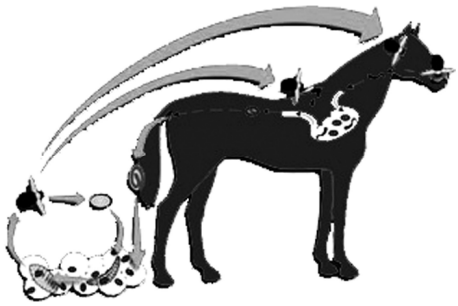
• Characteristically, pharynx may be cylindrical-shaped (*H. musca*), funnel-shaped (*H. megastoma*) or inverted-funnel-shape with a dorsal and a ventral tooth (*H. microstoma*).

• Male tail has a spiral twist.

• Females are oviviviparous, produce larvated eggs which are elongate and thin-shelled. Eggs may hatch before being passed in feces.

Life cycle:

• Larvae in feces pass and ingested by the larval stages of various muscid flies in the manure. *Musca* species is for *H. musca* and *H. megastoma*. *Stomoxys calcitrans* and *Stomoxys calcitrans* are for *H. microstoma*.

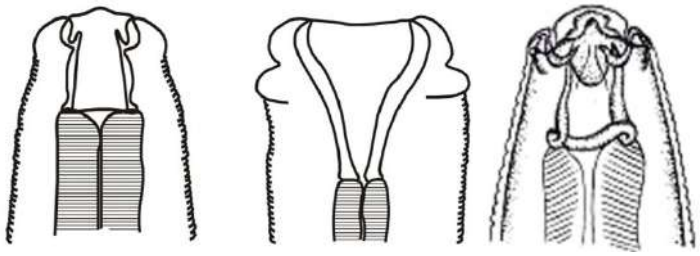


- Development to L_3 (**infective stage**) occurs parallel to the development of maturity of the fly intermediate host (**synchronized development**).

• When the infected fly feeds around the mouth of the horse, L_3 larvae escape onto the lips, nostrils or skin wounds, or the whole fly may be swallowed by the horse.

• Development of the larvae to adults occurs in approximately two months (prepatent period).

Pathogenecity of habronemiasis:



• Adult *H. megastoma* induces large tumors in the gastric wall. These tumors may interfere mechanically with the function of the stomach.

• Other species occur **free** in the stomach penetrate into the mucosa, irritate the wall and produce chronic catarrhal gastritis and ulcers of the gastric wall, then they produce digestive disorders.

• **Cutaneous habronemiasis: (Summer sores):** When infested flies feed on wounds in the skin of horses. Larvae escape from the mouth parts and enter the wounds. Irritation of the larvae prevents healing and a large pulpy mass of tissue appears that may persist throughout the summer. Since the etiology of the granulomas is larvae from infested flies, they occur during the warm season when these insects are active, hence, summer sores is derived. If flies put the larvae on the eye canthus, it leads to granular or nodular conjunctivitis.

Diagnosis: Demonstration of larvated eggs/larvae in feces of infected horses.

Treatment: Albendazole and its derivatives. Minimization of flies in the stables.

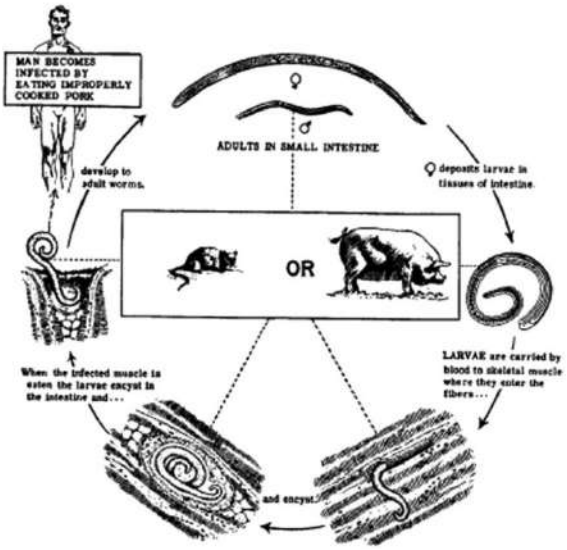
Order: Enoplida

Genus: *Trichinella* (*T. spiralis*)

Common name: Spiral worm.

Distribution: Cosmopolitan.

Hosts and habitats: It is the smallest nematode of humans and the largest intracellular parasite of the small intestine. Pigs, humans and rats are the main hosts.



Morphology:

• The males measure 1.5 mm in length by 36 µm in diameter. No spicules. The size of females are approximately twice than that of males (measuring 3 mm in length by 36 µm in diameter).

Life cycle:

• Adult worms live around the columnar epithelial cells of the small intestine and the larvae live in striated muscle cells of the same mammal.

• The worm can infect species of mammals that consumes encysted larval stages.

• For completion of the life cycle, an infected host must die and ingested by another. When an animal ingests meat containing infective *Trichinella* cysts, the gastric acid dissolves the hard covering of the cyst and releases larvae. The later pass into the columnar epithelium of the small intestine and, in 1-2 days, become mature (molts about 4 times). After copulation, males die and adult females produce larvae.

• The female is larviparous, laying her living larvae within the small intestine (5-6 days after infection). Larvae penetrate the intestinal wall and wander through the lymphatic system to the circulatory system, then to survive in skeletal muscles (as maseters, intercostals, diaphragm). Within the muscle cell, worms curl up and the cell is now called a **nurse cell complex**. Soon, a net of blood vessels surrounding the nurse cell, providing nutrition for the larva inside. The **nurse cell-parasite complex** may survive for as long as the host remains alive. The cyst measures 0.5 x 0.25 mm with the longitudinal axis is parallel to that of muscle fibers. Ingesting raw or undercooked meat that contains the parasite is the source of infection.

Clinical signs: (trichinellosis)

Migrating juveniles cause pain as they invade muscle tissue. Oedema, cardiac and pulmonary difficulty, pneumonia, nervous disorders, deafness and delayed or lost reflexes may occur. Adult worms may induce dysentery.

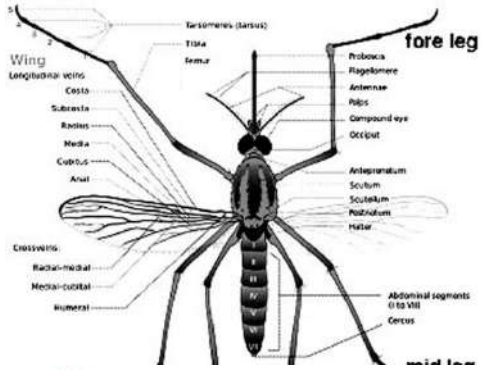
Diagnosis: Muscle biopsy or blood examination could identify trichinosis.

(Arthropoda)

i. Family Culicidae

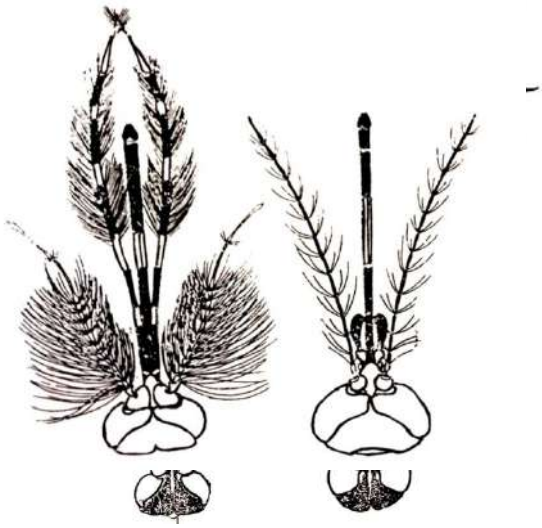
(mosquitoes)

General characters:



• Very slender, grayish to black insects of 4-10 mm long attack humans, birds and reptiles.

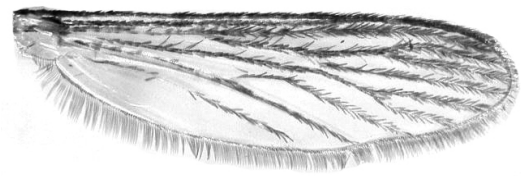
• The body is composed of head, thorax and abdomen (slender abdomen and long slender legs). All parts are covered by scales and hairs.



• Mouth parts are adapted for piercing and sucking (blood) in females. It consists of a single grooved labium, labrum-epipharynx (roof of the food channel), ventral hypopharynx (floor of the food channel), 2 mandibles and 2 maxillae (see page 11). Mandibles and maxillae act by serrated ends to make a wound. Parts of food channel inject saliva to induce tissue lysis, hyperemia and prevent blood coagulation. Then, blood is pumped to the channel, to the pharynx and to the alimentary canal. In males, mouth parts are adapted for sucking only (nectars) due to **lack of mandibles and maxillae**.

• All types of eyes.

• Long antennae of 14-15 segments covered by hairs i.e. **plumose** (long and dense) in males and **pilose** (short and few) in females.



• Maxillary palps are stiff (not pendulous), 4-semented each and scaly.

• Thorax is composed of pro- meso- and metathoracic segments. Mesothorax is the largest with its dorsum is covered by a chitinous structure that is divided by a suture into scutum and scutellum. The later is an important criterion for identification (**one** lobe in *Anopheles* and **trilobed** in *Culex* and *Aedes*). Long and slender legs end with claws and small pulvilli.

• Fore wings are well developed and hind ones are adapted for halteres. Wings are narrow and longer than broad. Wing venation revealed that the 2nd, 4th and 5th longitudinal veins are

bifurcated (at the apex), while the 1st, 3rd and 6th veins are simple (unbranched) (no cross veins). All wing veins and margins are scaly.

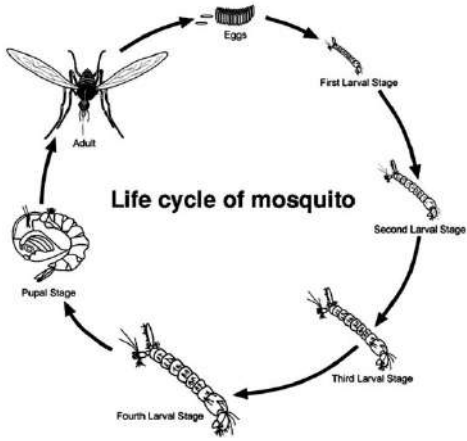
• Long, slender and scaly abdomen. Complete metamorphosis.

• Larvae and pupae are aquatic (with posterior spiracles).

Biology of mosquitoes: (1-2 weeks)

• Eggs are laid on collections of water which may be stagnant or running, polluted or fresh, turbid or clear, small or large. Water temperature and decayed matters affect eggs laying.

• Within 1-3 days (according to the temperature), eggs hatch to larvae that feed on suspended or floated organic matters.



• The larvae moult 3 times to give rise the 4th larval stage which moult to the pupa. The larval period lasts for 5-10 days and the pupal period is 2-3 days depending on temperature.

• Adults emerge via a T-shaped slit of the pupae. This occurs by making a straight cut in the pupal skin from the dorsum of the abdomen supported by another cut in the area between the cephalothorax and abdomen. Accordingly, adult fly drags itself gradually, spreads wings and stand with legs on the pupal skin or floating materials.

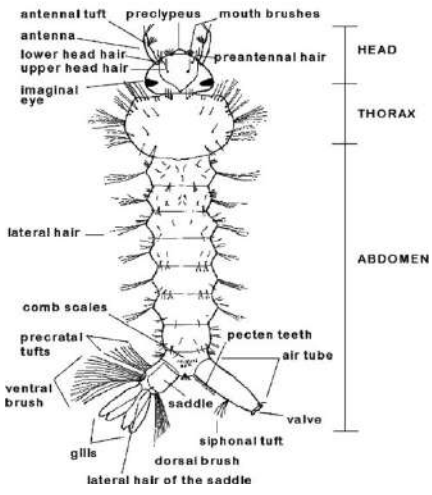
• Adult males emerge earlier than females. Females require blood meals for egg laying.

• The life span of the adult is 4-40 days depending on environmental conditions.

Morphology of larva:

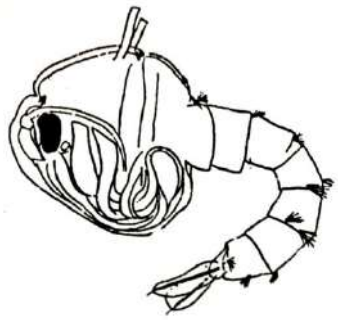
• It is composed of head, thorax and abdomen.

• The head is a well-developed and box-like with unsegmented antennae and a mouth brush. The thorax has indistinct segmentation carrying 3 lateral tufts of bristles indication thoracic segments.



• The abdomen consists of 10 segments. The first 7 segments are similar. The 8th segment carries a row of spines, **comb**, and respiratory siphon that carries bilateral lines of spines, **pectin**, and terminates with a respiratory spiracle. The 9th segment is rudimentary. The 10th segment is termed anal segment that end with the anus, at the tip, which is surrounded by 4 finger-like membranous anal gills. It is provided with **a ventral brush** (upper) and a **dorsal brush** (lower).

Morphology of pupa:



• Comma-shaped organism provided with a bulbous anterior cephalothorax and an elongated posterior segmented abdomen (it has a rudimentary mouth parts). The cephalothorax carries dorsally a pair of trumpet-like respiratory tubules termed **respiratory trumpets** terminate with spiracles.

• The abdomen consists of 9 segments, the first 7 are similar. The 8th segments bears distally a pair of long and oval plates, paddles or fins, in between the 9th segment lies.

**** <u>Blowfly strike</u>: (fly strike)**

Definition

Cutaneous myiasis in sheep caused by various species of blowflies (genera *Lucilia*, *Calliphora*, *Chrysomya* and *Phormia*) usually appears from early June to late September. It is an important cause of sheep losses worldwide, particular in the United Kingdom, Australia, New Zealand, Ireland and South Africa with a significant welfare concern.

Clinical signs

Fly strike is usually visible as discoloured, moist areas of wool associated with the presence of maggots and is foul-smelling. Affected animals are restless, dull and reluctant to graze, and kick at the struck area.

Causes:

a- <u>Primary flies</u>: Flies initiate a strike in a **living** tissue. e.g. *Lucilia*. Blowflies usually occur in waves, with the odour from the first strike attracting other flies.

b- <u>Secondary flies</u>: Flies attack **necrotic** tissues of sheep that has been previously struck. e.g. *Calliphora*, *Chrysomya*. In this case, the condition is aggravated and lesions become severe because of larval competition to get food. Larvae of *Chrysomya* are predaceous to other larvae or even themselves.

Factors affecting the condition:

1- The prevalence of blowflies.

2- Sheep susceptibility.

3- Climatic conditions (temperature, humidity and rainfall).

Types:

According to the area affected, strike may be body strike, tail strike, wound strike, ….etc.

Pathogenesis and complications:

• Maggots require alkaline medium for development, so, wounds attract blowflies. Moist wool, scales, and pasty skin encourage the bacterial growth leading to decomposition.

• The putrefaction attracts more flies and larvae feed on inflammatory exudates.

• The condition is aggravated in areas soiled with urine/feces.

• Larvae secrete proteolytic enzymes that digest and liquefy host tissues.

• In large wound, larvae form S/C deep tunnels.

• Affected sheep stand with the head down, and if occurs in buttock, animals jerk hind limbs.

• Rapid diagnosis and treatment is essential. If untreated, strike will rapidly deteriorate causing an increased respiratory and heart rate, ammonia toxicity, coma and death.

Myiasis

Definition:

A pathological condition results from invasion of tissues of humans or animals by all stages, particularly **larvae**, of dipterous flies causing tissue damage and diseases.

Classification:

I. Patton's classification:

According to the fly habits, myiasis may be:

A) Specific myiasis: (obligate sarcobiots)

Flies are obligatory tissue parasites. They larviposit in/near **living** tissues (obligatory sarcobiots). It may be subclassified into:

Section i

Larvae penetrate unbroken skin causing cutaneous myiasis. e.g. 1) *Cordylobia* sp. which oviposits on the ground or clothing. Larvae do not penetrate unbroken skin, only wound or cause diseased tissues. 2) *Dermatobia* sp. which oviposits on the sides of blood sucking arthropods.

Section ii

Larvae penetrate the broken skin causing cutaneous and wound myiasis as well as nasal ocular and vaginal myiasis. Females are attracted by foul-smelling odour from shed blood or damaged tissues. e.g. *Wohlfahrtia magnifica*, *Chrysomya bezziana*.

Section iii

Females oviposit/larviposit on particular parts of the body, then they access to certain tissues/organs. e.g. *Oestrus*, *Hypoderma*, *Gastrophilus*.

B) Semi-specific myiasis: (facultative sarcobiots)

Females (normally not parasitic) oviposit/larviposit on decaying animals and vegetable matters, but may attack mucous membranes, broken skin, wounds and diseased tissues (facultative sarcobiots). Females are attracted by specific odour from discharge of diseased tissues/wounds. e.g. *Calliphora*, *Lucilia*.

C) Accidental myiasis:

Females oviposit/larviposit in vegetables and organic matters, but, occasionally they do so on human and animal food, and so, larvae find their way to the alimentary canal. e.g. *Piophila casei*, *Musca*, and *Fannia*.

II. Bishopp's classification:

According to habitats (type of invaded tissue/organ), myiasis may be:

- Intestinal. e.g. *Musca*, *Muscina* and *Piophila casei*.
- Gastric. e.g. *Gastrophilus*, *Eristalis tenax*.
- Urogenital. e.g. *Fannia* (lays eggs on urethral opening).
- Cutaneous: Traumatic (wound) myiasis in which larvae invade wounds or ulcers e.g. members of family Calliphoridae.
- Ocular. e.g. *Oestrus ovis* (L_1).
- Nasopharyngeal. e.g. *Wohlfahrtia* and *Sarcophaga*.

III. Other classification:

1- Obligate myiasis: larvae attack alive hosts. e.g. *Lucilia*.

2- Facultative myiasis: larvae become parasitic under certain conditions. e.g. Flesh flies.

3- Dermal myiasis: larvae attack skin, either obligate of facultative. e.g. *Cordylobia*.

4- Internal myiasis: larvae attack gut or deep tissues. They often obligatory. e.g. *Hypoderma*.

5- Pseudomyiasis: the presence of dead larvae may lead to a misdiagnosis of the true case. e.g. housefly larvae are accidentally eaten by animals and may appear in feces.

Suborder: Sarcoptiformes

Group (1) Oribatidae (Oribatid mites, beetle mites) (Cryptostigmata)

Non-parasitic tiny mites live in soil on roots of plants lower parts of plant stem and attracted to the mucoid materials covering fecal pellets of sheep. They are often ingested by sheep and other grazing animals. They act as intermediate host for the cestodes, family Anoplocephalidae.

Group (2) Acaridae (Astigmata) (Itching mites)

They induce all types of mange of domestic animals (except demodectic mange) and scabies of humans as well as scaly disease in birds. They include 2 families of veterinary medical importance; Sarcoptidae and Psoroptidae.

Family: Sarcoptidae (Burrowing mites)	**Family: Psoroptidae (Non-burrowing mites)**
Habits	
- Not-host specific. - Species burrow more or less deeply into the substance of the skin living in tunnels and cause marked thickening of skin rather than scab formation. They prefer areas not covered with hairs.	- Host specific. - Species do not burrow but they are parasitic on the skin surface causing the formation of thick heavy scabs rather than skin thickening. They prefer areas covered with hairs/wool.
Morphology	
- Body is globose (broad oval) or roughly circular in outline. The adult male measures 0.2 mm and the female is 0.4 mm in diameter. - The dorsal surface has a large area of spines and backward pointing scales (transverse ridges and triangular scales or spines). - Mouth parts are anteriorly protruded and sheathed. - Four pairs of short, 5-segmented and telescoped (not extend beyond body margins) legs are present; 2 pairs arise anteriorly and 2 pairs posteriorly. - Bell-shaped suckers (caruncles) are carried out on **non-segmented** stalks (pedicels) on tarsi of some/all legs. In **females**, legs 3, 4 end with bristles (no	- Oval body (more elongated). - No dorsal spines. - Legs are strong and extend beyond the margin of the body. - Suckers are carried out on **segmented** (in *Psoroptes* only) stalks. - Leg 4 of males is **shorter** ending with hairs. - Leg 3 of females bears **2 long terminal bristles** (in *Otodectes*, leg 4 ends with hairs). - In males, the posterior part of the body has **2 adanal suckers** and is **bilobed**. - Anterior legs are distinctly stronger than posterior ones.

suckers), while in **males** the 3rd leg only ends with bristles. Long apodemes (dark-colored plates associated with base of legs) are found in legs 1 and 2 on the first segment and joined in a Y shape, while they are shorter and not joined in legs 3, 4. - Terminal anus (dorsal in *Notoedres*). - The posterior margin of males is **not** bilobed.	
Common species	
1- Genus *Sarcoptes*. 2- Genus *Notoedres*. 3- Genus *Cnemidocoptes*.	1- Genus *Psoroptes*. 2- Genus *Otodectes*. 3- Genus *Chorioptes*.
Life history (incomplete metamorphosis)	
Females deposit 2-3 eggs/daily in skin tunnels. Eggs hatch in 3-4 days to give larvae which migrate to the skin surface and burrow into the intact stratum corneum to give nymphs (2 nymphal stages), and then adults. Larvae and nymphs may often be found in moulting pouches or in hair follicles and are similar to adults, only smaller. Under the most favorable of conditions, about 10% of eggs eventually give rise to adult mites. Males are rarely seen; they make temporary shallow pits in the skin to feed until they locate a female's burrow and mate. Transmission occurs primarily by the transfer of the impregnated females during skin-to-skin contact.	The development from eggs through the larval and nymphal stages to mature adults occurs entirely on the skin and takes about 10 days.

Differences between Ixodidae and Argasidae:

Characteristics	Ixodidae (Hard ticks)	Argasidae (Soft ticks)
Hosts	Only mammals	Mammals and birds
Habits	Permanent ectoparasites	Temporary ectoparasites
Scutum	Present	Absent
Capitulum	Terminal and can be seen dorsally	Subterminal and cannot be seen dorsally
Mouth parts	Protrude anteriorly and could be seen from the dorsal aspect	Situated ventrally and cannot be seen from the dorsal aspect
Pedipalps	Segments are fixed	Segments are movable
Spurs	Present	Absent
Festoons	May present posteriorly	Absent
Eyes	Present marginally to the scutum	Usually absent
Spiracles	Posterolateral to the 4thcoxa	Anterolateral to the 4thcoxa
Pulvilli	Always present	Rudimentary or absent
Sexual dimorphism	Easy and marked	Difficult
Examples	*Boophilus annulatus*, *Rhipicephalus sanguineus*, *Hyalomma* species	*Ornithodoros moubata*, *Argas persicus*

Veterinary Protozoology

Order: Kinetoplastorida

Genus *Trypanosoma*

I. Anterior station group (salivaria group)-African trypanosomes

Subgenus	Species/Group	Development/transmission
Duttonella	***Vivax* group** *T. vivax* (ruminants, equines) *T. uniforme* (cattle, sheep, goats) *T. viennei* (cattle) *T. caprae* (goats)	In tsetse flies: development in proboscis only. - It can persist by mechanical transmission. - Monomorphic with free flagellum. - Large and terminal kinetoplast.
Nannomonas	***Congolense* group** *T. congolense* (ruminants, equines) *T. simiae* (pigs, monkeys) *T. suis* (pigs)	In tsetse flies: development in midgut and proboscis. - Small without free flagellum. - Medium and terminal kinetoplast.
Trypanozoon	***Brucei* group** *T. brucei brucei* (all animals) *T. brucei rhodesiense* (humans) *T. brucei gambiense* (humans)	In tsetse flies: development in midgut and salivary glands. - Oral transmission in carnivores. - Pleomorphic (slender, intermediate, short stumpy) with/without free flagellum. - Small and subterminal kinetoplast.
	***Evansi* group** *T. evansi* (camels, equines) *T. equiperdum* (equines) *T. equinum* (equines)	Mechanical transmission (by tabanids). In *T. equiperdum* venereal transmission occurs.

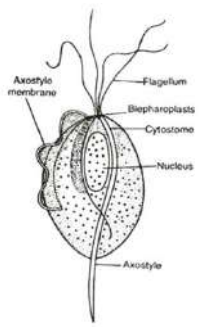
II. Posterior station group (stercoraria group)-American trypanosomes

(*Cruzi* group)

Subgenus	Species/group	Development/transmission
Megatrypanum	*T. melophagium* (sheep) *T. theileri* (cattle, antelopes)	- Large mammalian tryoanosomes with typical kinetoplast near the nucleus. - Vectors are hippoboscids or tabanids.
Herpetsoma	*T. lewisi* (rats) *T. rangeli* (humans, dogs, monkeys)	
Schizotrypanum	*T. cruzi* (humans, dogs, cats)	

Genus *Trichomonas*

Species *T. vaginalis*



Morphology:

• Ovoid/pear-shaped organism with 4 anterior flagella and no posterior free flagellum.

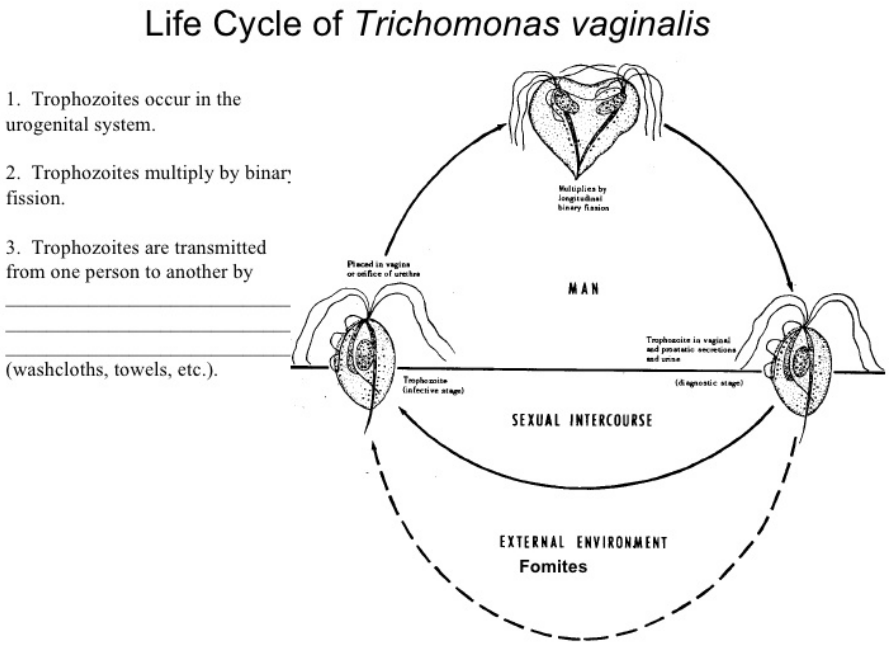
• Large anterior nucleus.

• The undulating membrane extends from the base of flagella posteriorly to about half-length of the parasite.

Hosts and habitats: Vagina, prostate gland and urethra of humans.

Pathogenesis: Males are usually carriers (symptomless except urethritis in rare cases). Females suffer from burning micturition.

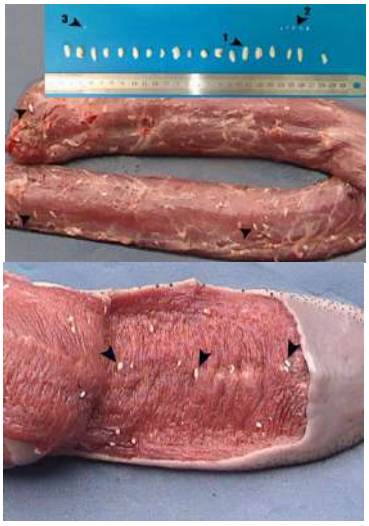
Treatment: Hygienic conditions, iodine solutions and antibiotics.



Phylum: Apicomplexa (syn. Sporozoa)

Genus *Sarcocystis* (syn. *Sarcosporidia*)

General characters:



It resembles *Toxoplasma* but:

• It is obligatory heteroxenous tissue cyst-forming coccidian parasites with a prey animals (herbivores) serving as the intermediate host and a predator (carnivores) serving as the definitive host. Humans act as incidental intermediate hosts.

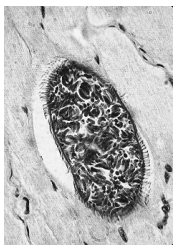
• Sporulation occurs **within** the definitive host.

• The infective stage is **disporocystic tetrazoic oocyst**.

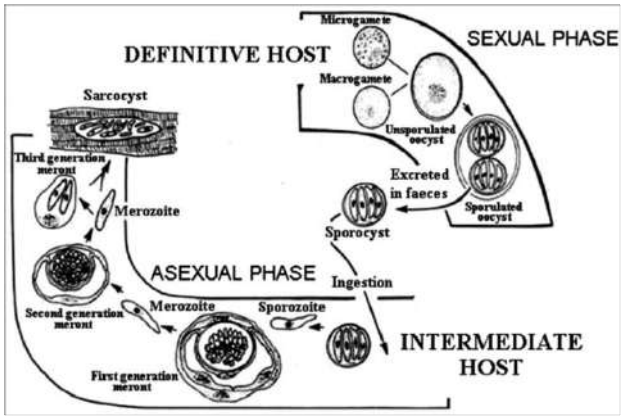
Life cycle:

• Infected cat sheds sporulated oocyst. The cyst wall is very thin (fragile) and easily to undergoes rupture, so, sporocysts, rather than oocysts, are often seen in feces. Moreover, sporocystic walls may rupture releasing sporozoites.

• Sporocysts/sporozoites are ingested by the proper intermediate host inside which sporozoites penetrate the intestinal wall with the formation of 2 or more schizont generations, then merozoites circulate in blood reaching the endothelial lining of blood vessels of internal organs forming tachyzoites (**endopolygony**).



• Tachyzoites circulate to the skeletal muscles, particularly oesophagus, heart and diaphragm and multiply by **endodyogony** and change to bradyzoites. A mass of the later is called a true cyst (**sarcocyst** or **Miescher's tubule**). It is either macroscopic (few centimeters) or microscopic (few micrometers), spindle-shaped, parallel to the longitudinal axis of muscle fibers. The covering is either thin or thick wall consisting of an outer homogenous layer and inner nucleated layer. From the later, a number of septa (trabeculae) derived to divide the internal cavity into several compartments of different sizes. Metrocytes (mother cells of bradyzoites) derived from the nucleated layer and give rise to bradyzoites (merozoites). The number of the later decreases towards the center. Each bradyzoite (**Rainey's corpuscle**) is banana-shaped, the anterior end is more pointed containing granules surrounding a vacuole, the posterior end is broader and the nucleus is either centrally located or shifted posteriorly. A mature cyst is formed within 4 months. The tissue of intermediate host containing infective sarcocyst is ingested by the appropriate definitive host, within which the sarcocyst ruptures with liberation of bradyzoites that penetrate the **lamina propria** of the small intestine and form gametes (**no schizonts**). Fertilization between macrogametes and flagellated microgametes occurs with the production of zygote forming unsporulated oocysts which soon sporulate (infective stage) endogenously followed by shedding of sporocysts in feces.



Commons species:

Cattle

• *S. bovicanis* (*S. cruzi*).

• *S. bovifelis* (*S. hirsuta*).

• *S. bovihominis*.

Buffaloes

• *S. fusiformis* (cats-buffaloes). Macroscopic.

• *S. levinei* (dogs-buffaloes). Microscopic.

Equines • *S. equicanis*.

Sheep *S. ovicanis*. *S. ovifelis* (*S. tenella*).

Family: Babesiidae

Genus *Babesia*

Species	Host	Morphology	Vector
B. bigemina	Cattle, buffaloes	Trophozoite is large (4-5 μm), pyriform, rounded, oval or irregular. Pyriform members occur in pairs with an acute angle. They are highly pathogenic.	*Boophilus microplus* *B. annulatus* *B. decoloratus*
B. bovis	Cattle	Similar to *B. bigemina* but smaller, in the center of RBCs. Vacuolated (signet-ring shape) forms are common.	*B. annulatus* *B. decoloratus*
B. divergens		Similar to *B. bovis* but smaller, tend to locate at the periphery with a relatively large angle. European sp.	*Ixodes ricinus* *Haemaphysalis longicornis*
B. major		Similar to *B. bovis* but larger.	*H. punctata*
B. motasi	Sheep, goats	Similar to *B. bigemina*. Paired pyriform trophozoiets are common. Highly pathogenic in sheep.	*H. punctata* *Rhipicephalus* spp.
B. ovis	Sheep	Small babesiae. The majority are rounded and tend to be at the periphery. Less pathogenic.	*Rh. bursa*
B. caprae	Goats	Similar to *B. ovis*.	*Rhipicephalus* spp.
B. caballi	Equines	Large-sized, resembling *B. bigemina* with an acute angle	*Dermacentor* spp. *Rh. bursa*
B. equi (*N. equi*)		Small-sized, mostly are rounded. Pyrifom shapes found in **tetrads** forming **maltese-cross** shape.	
B. canis *- B. canis canis*	Dogs	**Large**-sized, usually pyriform/amoeboid containing	*Rh. sanguineus*

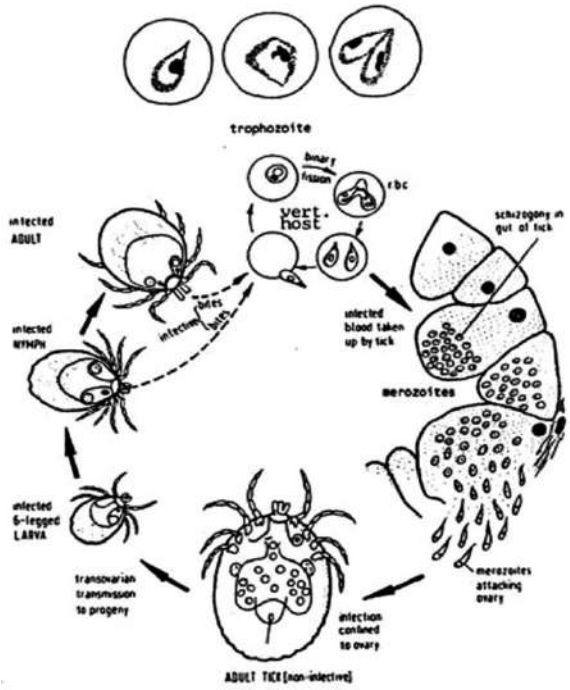
- *B. canis rossi* - *B. canis vogeli*		vacuole. Multiple infections of up to 16 merozoites are found.	
B. gibsoni		**Small**-sized and pleomorphic (mostly rounded).	*Rh. sanguineus* *Haemaphysalis* spp.
B. felis	Cats	Small-sized, mostly rounded/irregular (rarely pyriform).	*H. leachi*
B. microti	Rodents	Simialr to *B. equi*.	*Ixodes* spp.

Life cycle: (*B. bigemina*)

• Following inoculation by ticks vector (*Boophilus* spp.), released **sporozoites** (often in transovarian species) penetrate the cell membrane of erythrocytes.

• Once inside, they become **trophozoites** which undergo binary fission to give 2-4 **merozoites**.

• The later break out RBCs wall and immediately invade another intact cells with repeated schizogony and consequently multiple merozoites. This asexual cycle occurs indefinitely until the host dies or eliminates the parasites.



• Some merozoites remain unchanged except taking an unusual shape and act as **gamonts** (gamont precursors). They are called ray bodies (**Strahlenkorper** in dogs). They produce gametes often in the gut lumen of tick vector.

• During the passage from the host to the midgut, 2 populations of ray bodies develop from the gamonts. Ray bodies undergo further multiplication to from large aggregations of multinucleated cells. Once the division is completed, uninucleated ray bodies with thorn-like structure are differentiated into micro- and macrogametes.

• After tick engorgement (within 2-4 days), gametes fuse together in pairs (initial syngamy) forming a spherical zygote that will be motile, **ookinete** or **primary kinete**.

• The later invades the gut epithelium with further multiplication (asexually) to form more club-shaped ookinetes (**vermicules, sporokinetes or large merozoites**) which escape into the hemolymph and invade a variety of tissues (**including uterus, ovaries and oocytes**) where

successive series of secondary schizogony occur to form more vermicules. These cycles continue till the infected tick **dies**.

• Kinetes invade salivary glands and acini and undergo asexual division (**sporogony**) to form multinucleated stages (**sporozoites** or **small merozoites**) which are released in the salivary gland lumen mixed with saliva. Thousands of sporozoites (broad anteriorly and narrow posteriorly) are formed and become active within 5 days after taking the blood meal.

Family: Theileriidae

Genus *Theileria*

Item	(1) *Th. parva*	(2) *Th. annulata*
Disease	East Coast fever, African Coast fever, bovine theileriosis	Egyptian fever, Mediterranean Coast fever, tropical theileriosis
Hosts	Cattle, water buffaloes	Cattle, water buffaloes, sheep, goats
Distribution	Eastern, central and southern Africa	North Africa, South Africa
Location	Lymphocytes and RBCs	
Structure	• Rod/comma-shaped are usually inside RBCs. Rounded forms may be found. • Multiplying forms in lymphocytes and cells of RES (spleen, L.Ns) are called **Koch's blue bodies** (Koch's bodies). Each is circular or irregular with blue cytoplasm and numerous nuclei appear as red chromatin granules on staining with Romanowsky stain. Two types of schizonts: **macroschizonts** (macromerozoites) and **microschizonts** (micromerozoites). Inside RBCs, parasites multiply by binary fission forming 2 merozoites.	• Rounded/oval forms are often found inside RBCs. Rod/comma-shaped organisms may be found. • Multiplying forms in lymphocytes of L.Ns and spleen produce **Koch's blue bodies** either intracellular or in their lumen. • Inside RBCs, parasite multiplication produces 2-4 daughter merozoites.
Vectors	*Rh. appendiculatus*, *Hyalomma excavatum*	*Hyalomma excavatum*
Pathogenesis	It is highly pathogenic for cattle (particularly imported species). Adults are more affected showing enlargement of	• Mortality rate of 10-90%. • Enlargement of of L.Ns, spleen and liver.

	L.Ns and spleen, hemorrhages on mucous and serous membranes (due to release of toxic metabolic products) with ulcers on the abomasal wall and red streaks on the intestinal walls.	• Marked anemia, bloody diarrhea and icteric mucous membranes. • The disease may appear in: - Peracute form: death within 2-4 days. - Acute form: weakness, decreased milk production and enlargement of L.Ns. - Chronic form: irregular fever, anemia, icterus and severe emaciation.