Phylum Platyhelminthes

Class: Turbellaria- mostly free living
Class: Monogenia-all parasitic, most ectoparasites
**Class: Trematoda:** Digenea- two hosts, one always a mollusc
  - Aspidogastria- one host, mainly molluscs
  - Didymozoidea-tissue dwelling parasites of fish
Class: Cestoda- tapeworms
Class Trematoda

The parasitic flatworms of class Trematoda, also called flukes, have oral suckers, sometimes supplemented by hooks, with which they attach to their vertebrate hosts. Trematodes are second only to nematodes in abundance.

All trematodes are parasitic, and most adult trematodes parasitize vertebrates. Around 9000 species have been described. The adults of this group are dorso-ventrally flattened and they have both sexual and asexual reproductive phases.

Practically the entire interior is occupied by the reproductive system; the organism is capable of producing huge numbers of offspring. Trematodes of the order Digenea have complex life cycles involving two or more hosts. The larval worms occupy small animals, typically snails and fish, and the adult worms are internal parasites of vertebrates. Many species, such as the liver fluke *Clonorchis sinensis* and the blood fluke (*Schistosoma sp.*), cause serious diseases in humans.
Anatomy

Dorso-ventrally flattened. Beneath the outer covering are two layers of muscle, an outer circular layer, and an inner longitudinal layer; this arrangement permits an undulating form of locomotion.

A saclike digestive cavity, with a single opening to the outside that serves as both mouth and anus, is sometimes present; in the simpler forms it is absent or unbranched, but in higher forms it branches to all parts of the body. The major sense organs, when present, are concentrated in the head, or front end. Although a primitive nerve net is present in some of the simpler forms, others have several nerve cords extending from a brain along the length of the body. The latter pattern of organization is retained in the nervous systems of higher invertebrates, specifically annelids and arthropods.

The reproductive system is characteristically hermaphroditic (i.e., each individual produces both eggs and sperm), and cross-fertilization between individuals is typical. Trematodes and cestodes shed eggs almost continuously...
The **Trematoda**, or flukes, are all parasitic, and have complex life cycles specialized for parasitism in animal tissues. Members of one major group of flukes, the **Digenea** pass through a number of juvenile stages that are parasitic in one, two, or more **intermediate hosts** before reaching adulthood, at which time they parasitize a **definitive host**.
Nutrition

Digeneans have a well developed blind gut with often well developed muscular pharynx. Depending on the species, their diet consists of blood, mucus and surface epithelial cells. The amount of absorption through the tegument is limited although it is known that glucose and some amino acids are actively taken up. The surface of the tegument, other than the spines has no projections or microvilli to increase the area of absorption, although in some species the surface is pitted and appears a bit like a sponge and is another method for increasing the surface area. Generally these organisms have a glucose based metabolism. They are facultative anaerobes, metabolizing most of the glucose by glycolysis and excreting a number of short chained acids such as lactate, succinate and propionate.
• Flukes are able to absorb low molecular weight compounds through their teguments, there are specific transport mechanisms for amino acids, carbohydrates, and fatty acids. Digestion is a mixture of extra and intra-cellular and the flukes often produce very powerful proteases. In one group of digeneans, the 'stregeids', there is a spongy, pad like organ behind the ventral sucker, called the stregeid organ, it secretes proteolytic enzymes that digest the host mucosa and absorbs the products, so it is a digestive-absorbtive organ.

• The excretory system is composed of flame cells, which open into a single central duct, with an excretory pore at the posterior end, in some species there is a small bladder.
For excretion and osmoregulation, protonephridia are used. They resemble a network of two or more closed longitudinal branched tubules running the length of the body. These specialized structures control osmotic water balance and work in much the same way as kidneys removing liquid waste.

A protonephridium branching throughout the body is capped by highly specialized cells with cilia projecting into cup-like structures. Since the beating of the cilia is likened to a flickering flame, the name of this cell is "flame cell". Several of these flame cells are connected to cells with tubular function. Interstitial fluid loaded with nitrogenous waste is forced into the tubule and transported by the concerted action of flame cells producing a current along the tubular system to one or more excretory pores where waste is secreted. The protonephridium is an example of primitive kidneys and is considered as both an excretory and osmoregulatory system.
Trematode Reproduction

The worms are usually hermaphroditic containing both male and female sexual organs. The testis usual number 2 and come in a variety of shapes and open via the vas deferens into the seminal vesicle where the sperm are stored. The cirrus is the male copulatory organ which can invaginate into the cirrus pouch. In some species self fertilization can occur in others only cross-fertilization occurs. There is only a single ovary and a short oviduct which fuses together with the seminal receptacle and vitelline reservoir where the egg formation and fertilization occurs and is called the ootype. The egg then passes into the oviduct. The Mehlis' glands act as a template for egg shell formation. The vitellaria usually have a distinctive distribution pattern and the provide yolk cells and contribute to the egg shell formation. The Laurer's canal is vestigial and sometimes opens to the exterior.
Digeneans:

The digeneans are a group of specialised endoparasitic platyhelminthes. A common feature is that all have complex lifecycles, involving one or more intermediate hosts, the first of which is always a mollusc.

Typically the larval stages parasitize one or more species that are different from the definitive host of adults. Larval stages include miracidium, redia, cercaria, and metacercaria. As adults they are found in most vertebrates groups, including fish, amphibians, reptiles, birds, and mammals, acting as definitive hosts, where they may give rise to highly pathogenic infections. They may be located in most of the internal organs of these definitive hosts, including the lungs, bladder and blood stream, although the majority are found in the gastrointestinal tract, or closely associated organs such as the bile duct and liver.

Digeneans typically show a high degree of specificity towards their molluscan host and much lower specificity towards their vertebrate host or their second intermediate host, if they have one. This probably reflects a long term parasitic association with the mollusc.
Egg --- miracidium --- sporocyst or redia --- daughter sporocysts - cercariae ---

Metacercariae/mesocercariae - adults
Great variation in the trematode life cycle:

**Must include a mollusc**

May have 1-4 intermediate hosts

Alternates sexual reproduction in vertebrate host with asexual reproduction in molluscan host.

The molluscan host is almost always castrated:

--physically (rediae)

--chemically (sporocysts)
The miracidium is the name of the ciliated larval stage that is hatched from the digenean egg. In most cases the miracidium is usually a free swimming stage that seeks out the primary, and in some cases only, intermediate hosts of these parasites. In all cases these primary, or 1st intermediate hosts are molluscs. In the few examples where the miracidium is not a free swimming stage the eggs are ingested. Here the eggs hatch in the intestine of the mollusc liberating the miracidium, from where it immediately penetrates the intestinal wall to invade the molluscan tissues. In the free swimming miracidia the larval parasite exhibits distinct behavioural responses that enable it to enter the environment of, detect the presence of its hosts. These behavioural responses have principally been studied in the case of the schistosome miracidium,

Morphologically the surface of the miracidium is covered with a series of ciliated plates, which may be clearly seen using electron microscopy after removal of cilia. These ciliated epidermal plates (in some species the cilia being replaced by spines) are discontinuous, not being in contact with each other but being separated by extensions of the underlying subepidermal layer.
Miracidia possess a number of sensory organs, the most important of which are the dorsally situated **eye spots**, beneath which is found the cerebral mass. Below all of the structures is found the miracidium's large rounded germinal cells, which often are often grouped in clusters called germ balls. Finally the miracidia possess a protonephridial excretory system, basically similar to that found in the adult parasites. On examination of eggs containing mature miracidia it is the flame cell activity that is the first sign of the initiation of hatching of the egg.

On invasion of the molluscan tissue the miracidium sheds its ciliated plates, in almost all cases rapidly transforming into an endoparasitic form, the sporocyst, although in a few unusual groups the miracidium may contain a fully developed redia.
The **sporocyst** develops within the molluscan host as a hollow fluid filled germinal sac, into which protrude germinal masses. At the conical anterior of the sporocyst body a birth pore is located, from which subsequent generations of larvae emerge. The germinal masses develop internally into either daughter sporocysts, which are essentially the same as their parent sporocysts, or into a second larval stage, the redia.

Different species of trematode will undergo different patterns of larval development, although once sporocysts produce daughter sporocysts, rediae do not develop. In the schistosomes there are two generations of sporocyst in the snail host, but the redia stage is absent. In contrast in the lung fluke the parent sporocyst produces two generations of redia. In the organisms where there are two generations of sporocysts, these may be found in different locations within the body of their snail host, the locations differing between different species of trematode.

The daughter sporocysts when they emerge from the parental sporocyst migrate through the host tissues, localising near the molluscs digestive diverticulum. These cycles of asexual division within the mollusc result in an enormous increase in the reproductive potential of these organisms, unsurpassed within Metazoan organisms, whereby a single miracidium is capable of giving rise to many hundreds of thousands of cercariae. The sporocyst stage obtains nutrients by passage of soluble material across the sporocyst tegument.
The redia are the second larval form to develop within the molluscan host (but may be absent in some groups, such as the schistosomes). They are similar to sporocysts, containing germinal masses within a fluid filled sac, which may develop into either second generation daughter redia, or more commonly into the final larval stage within the mollusc, the cercaria.

They differ from the sporocysts however, in that they are a much more active form, and importantly they possess simple gut. The tissue they feed on is predominantly molluscan in origin, but the redia of some groups (e.g. those of the echinostomes) may actively seek out the developmental stages of other trematodes (e.g. schistosome sporocysts) within the same intermediate host.

The gut itself consists of a mouth, opening into a large muscular pharynx, which in turn opens into a simple rhabdocoel like intestine. Externally, behind the mouth many redia have a ridge-like collar, below which the birth canal opens and from which either cercariae or daughter redia emerge. Further along the body there a lobe like extensions of the body, which are thought to aid the movement of the parasite within its host's tissues.
The molluscan host is almost always castrated:
--physically (rediae)
--chemically (sporocysts)
The Larval Digeneans - the Cercaria

- **Gymnocephalus** (e.g. *Fasciola* sp.)
- **Trichocercous** (e.g. *Donax* sp.)
- **Furcocercous** (e.g. *Schistosoma* sp.)
- **Microcercous** (e.g. *Bithynia* sp.)

In almost all species of trematode it is the cercarial stage that emerges from the mollusc. Trematode cercariae exhibit considerable variation in structure, which is very important taxonomically, and reflects adaptations to the specific lifecycle of the parasite involved. Because of this great diversity of form, a system of cercarial classification has evolved, based on the gross morphology of these larval forms.
TREMATODA: FORM, FUNCTION, AND CLASSIFICATION OF DIGENEANS

- Miracidium
  - Sporocyst (mother)
    - Sporocyst (daughter)
      - Cercaria (penetrates definitive host)
        - Metacercaria
          - Adult
        - Adult
        - Metacercaria
          - Adult
    - Adult
  - Redia (mother)
    - Redia (daughter)
      - Cercaria
        - Metacercaria
          - Adult
        - Adult
    - Cercaria (eaten by definitive host)
      - Cercaria
        - Metacercaria
          - Adult
        - Adult
      - Cercaria
        - Metacercaria
          - Adult
        - Adult
    - Cercaria
      - Metacercaria
        - Adult
      - Adult

1. Diplostomum flexicaudum (Cort and Brooks 1928)
2. Trichobilharzia physalae (Talbot 1936)
3. Alaria mustelae Bosma 1931
4. Fasciola hepatica Linnaeus 1758
5. Metorchis conjunctus (Cobbold 1860)
6. Procerotrematops dickermani Anderson 1962
7. Stichorchis subtriquetra (Rudolphi 1814)
8. Caecincola parvulus Marshall and Gilbert 1905
egg → miracidium → sporocyst/redia → cercaria → encyst and form metacercariae
egg → miracidium → sporocyst/redia → cercaria → penetrate intermediate host, encyst and form metacercariae
egg → miracidium → sporocyst/redia → cercaria → actively penetrate host and develop - no metacercariae

(1) Diplostomum flexicaudum (Curt and Brooks 1928)
(2) Trichobilharzia physaelae (Talbot 1936)
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The sequence of asexually reproducing larval stages in the mollusc can produce extremely high overall reproductive rates. For example, a record was kept of a periwinkle, *Littorina* infected with the larval stages of *Cryptocotyle* (a digenean of birds). The snail produced an average of 1,300,000 cercariae annually for 5 years.

The reproductive potential of a single liver fluke, *Fasciola hepatica* has been estimated as $4 \times 10^8$ offspring. The nutritional cost to the snail of this intense parasite reproduction is high. Infected snails tend to grow more slowly, be more susceptible to stress and have a higher death rate and a lower reproductive rate than uninfected snails. However, in one or two cases, infection with digenean larvae has been shown to result in gigantism, infected snails being bigger than uninfected snails. The reason for this is not clear, in some cases, if not all, the increase in size is solely due to an increase in the thickness of the shell and not an increase in snail body tissue. A possibility is that these molluscs have been castrated by the digenean larvae, and the energy which would have gone into egg production has gone into shell growth.
Once cercariae exit the mollusc host they can:

1) encyst on vegetation or other substrates
2) penetrate intermediate hosts
3) penetrate definitive hosts

Metacercariae are cercariae which have shed their propulsive tails rounded up and formed a porous but rigid structure.

Cytogenous glands in the cercarial head produce the cysts. In the liver fluke *Fasciola hepatica*, there are four types of cystogenous gland, each responsible for producing one layer of the cyst wall. The degree of development that takes place in the metacercaria is very variable, ranging from virtually no development at all, to the production of viable eggs.
In one or two groups of digeneans the cercariae encyst inside the sporocyst, so infection of the final host requires the snail to be eaten. An interesting example is *Leuchochloridium*, the sporocysts of this digenean are brightly coloured with red and green rings. When the sporocyst contains encysted cercariae it migrates into the eyestalk of the gastropod where it causes a huge swelling which prevents the snail from withdrawing into its shell. The colours of the sporocyst are clearly visible through the eyestalk and the sporocyst also pulsates, both of which may attract the attention of birds that are the final host. In other species the coloured sporocyst breaks out of the snail and similarly attracts birds by being brightly coloured and moving.

http://www.vu-wien.ac.at/i116/i116more_links/Leucochloridium/leuco.htm
• Species where the metacercariae develop in the open on vegetation or on the surface of shells etc. This group are usually infective almost as soon as the cyst is formed, there is no growth.

• Species that do not grow in the intermediate host but require several days development before they become infective.

• Species which undergo several weeks of growth and differentiation before becoming quiescent in the second intermediate host.

• The metacercaria is often a very important phase in the life cycle of the parasite, it can provide a means of transmission to a definitive host that does not feed on the intermediate host (for example herbivores) or it can provide a link to hosts which are in a different environment from the mollusc, for example as a link between aquatic snails and birds which eat fish.
The Digeneans are a large and successful group of parasites. There are about 6,000 species known. They all have complicated life cycles involving at least one intermediate host, which is normally an aquatic snail as well as the primary host which is normally a vertebrate.

Digeneans as adults are flat worm shaped animals, the have two suckers. The first is the oral sucker, around the mouth, this has two functions, a) to hold the animal to its host and b) to assist in feeding. The second sucker is found a little way further down the animals body and it has only a single function, that of attachment.

Digeneans have what is called an 'alternation of generations' in their life cycle. This means the egg hatches into a larval form, this larval form reproduces asexually to produce numerous copies of itself. eventually these copies change into another larval form which in time grows into a sexually reproducing adult. This possession of an asexual generation means that a single egg can produce not just one infectious agent, but many, maybe even tens or hundreds of thousands.

Only about 20 of the 6,000 known species are infectious to mankind, but some of these species are important diseases with of 200 million people infected world wide.
LIFE CYCLES of FASCIOLOPSIS BUSKI, PARAGONIMUS WESTERMANNI and CLONORCHIS SINENSIS
Adapted and redrawn from NCDC
One of largest flukes: 30 x 13 mm