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
Anatomy

Flatworms are 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 of flatworms 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.

All except the simplest flatworms have nephridial tubules, called protonephridia, usually distributed throughout the body. Such structures consist of an external opening and a tubule that branches internally, terminating in a number of blind, bulb-shaped structures called flame bulbs, which bear tufts of cilia. They function as excretory and osmoregulatory organs.
For excretion and osmoregulation, protonephridia (singular protonephridium) 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.
Cestodes: The tapeworms

No digestive Tract
No mouth
Attachment organs limited to anterior end
Extremely specialized
All are parasitic

Adults known in humans from time of Aristotle
Larval forms often not associated with the adults.
Tapeworms are ribbon-shaped multisegmented flatworms that dwell as adults entirely in the intestine. The larval forms lodge in skin, liver, muscles, the central nervous system, or any of various other organs. Their life cycles involve a specialized pattern of survival and transfer to specific intermediate hosts, by which they are transferred to another human host. Each pattern is characteristic of a given tapeworm species.

The common gut-dwelling adult cestodes are well adapted to the human host, induce few symptoms, and only rarely cause serious pathology. This belies fearsome stories of tapeworms stealing food and causing ravenous hunger (far more commonly, the appetite is depressed). Larval cestodes, however, develop in human organs or somatic tissues outside of the gut and are more pathogenic.

Adult cestodes elicit little host inflammatory or immune response in contrast to the strong responses elicited by the larval stages in tissues. Adult cestodes are often acquired by ingestion of meat from intermediate hosts. Extraintestinal infection with larvae results from ingestion of eggs of fecal origin. Diagnosis of infection with adult cestodes is based on identification of eggs and segments (proglottids) in feces. Larval infections are more difficult to assess; serology and biopsy are helpful. Control depends on sanitation, personal hygiene, and thorough cooking of meat and fish.
Characterized by scolex: hooks, sucking depressions, glandular area

Three types of sucking depressions:

- Bothria: shallow sucking grooves typical of the Pseudophyllidea
- Bothridia: 4 leaflike flexible structures found in Tetraphyllidea
- True suckers/acetabula in the Cyclophyllidea

After the scolex: monozoic (single segment)

polyzoic (many segments)

Each segment called a proglottid

Everything behind the scolex called strobila
Generally the immature proglottids are nearest the scolex, then the sexually mature proglottids, then gravid proglottids whose uteri are full of eggs – characteristic of the Eucestoda.
No Digestive System:

All nutrients move through the outer surface. This is not a inert, hard cuticle, but a living, multinucleate, tegument.

Microtriches: increase surface area, maintain orientation
Tapeworm body is continuous, and filled with parenchyma

Muscle layers segregate areas within the proglottids to an outer cortex and inner medulla- contains reproductive organs

Pairs of dorsal and ventral excretory/osmoregulatory canals run through the entire strobila from scolex to last proglottid
Most are monoecious:

Protandry: male reproductive systems mature first and may help prevent fertilization within the same proglottid

BUT all proglottids come from same zygote: and are genetically identical. But if sperm and ova develop at different times there may be increased opportunity for genetic change.

Self and cross fertilization have been demonstrated in several species.

Males: numerous testes that produce sperm, vasa efferentia lead from tesitis to a common vas deferens. Some have special seminal vesicle for storage. Male copulatory organ- cirrus- surrounded by cirrus pouch.

Female: ovary produces ova, a single oviduct, the ootype, the duct from the seminal receptacle, and the uterus. The uterus leads from the ootype and may have a uteropore to release eggs. Proglottids with no uteropore detach when gravid and break up to release eggs.

Most often the cirrus pouch and the vagina enter a common chamber, the genital atrium and share a common opening with the exterior- genital pore.
Nervous system: two long nerve trunks that go from the scolex to the end of the strobila

Transverse components in each proglottid

Genital atrium well supplied with nerve endings

The scolex contains dorsal and ventral commissures, as well as accessory nerves in the holdfast organs

In the scolex are chemosemsory cells
Nutrition:
Acquire nutrients via diffusion, active transport and endocytosis
Therefore the outer surface is very active: digestive-absorptive interface
Some nutrients enter via simple diffusion
Amino acids: active transport- energy required
Enzymes produced on tapeworm surface:
intrinsic enzymes: phosphohydrolase – glucose-6-phosphate→glucose
Glucose taken up at specific sites for carbohydrate movement
Other enzymes secreted to neutralize the effects of hosts’ digestive enzymes
Pseudophyllidea

Scolex has dorsal and ventral grooves - bothria
Proglottids wider than long
Midventral genital apertures
Separate uteropore
Eggs are operculate and unembryonated when released

Some of the largest tapeworms known - up to 20m

In humans an example is *Diphyllobothrium latum*
Cosmopolitan, subarctic/temperate zones
About 9 million cases worldwide
*Diphyllobothrium latum* is known as the broad fish tapeworm and is found infecting fish of Northern Europe, a closely related species *D. ursi* is found in the North Eastern U.S and in northern regions of Canada *D. dendriticum* has been found to be the predominant species. There are many different host species, mainly those carnivores which eat fish, and this includes man.

These worms can reach to a length of 10-30 metres and can shed in the region of one million eggs per day. They shed their spent proglottids. The scolex is finger-shaped with bothria on the dorsal and ventral surfaces. The proglottids are wider than they are long with numerous testis and vitellaria with a bilobed ovary. The gravid proglottids have a characteristic rosette shaped uterus.
Diphyllobothrium latum- largest cestode to infect humans
20-25 m long
4000 proglottids

Eggs released in feces- 3 weeks to develop, coracidium formed
Hatching affected by light- coracidium escapes egg, lives 1-5 days
MUST be ingested by a copepod- embryo leaves the ciliated covering, penetrates the gut, enters the hemocoel, transforms into a procercoid, develops over 14 days
Second intermediate hosts are planktivorous fish- eat copepods, procercoid migrates from fish gut to extra intestinal tissues, forms pleurocercoid- in almost any tissue.
Important tissues include: muscle and roe.
These can be passed to larger fish- pleurocercoid migrates from gut to tissue
**Definitive hosts** ingest raw or poorly cooked fish.
Pleurocercoid attaches to intestine- grows to adult, grow 5 cm/day
Eggs produced within the first month and may last 30 years
The eggs are ovoid with an operculum at one end and a knob at the other. When they are released into the intestine they are only partially embryonated and require from 8 days to several weeks for the infective coracidium to develop. This free-living stage emerges through the operculum and is ingested by a copepod, *Diaptomus* sp. It loses its cilia and penetrates through the gut wall into the coelum. Here it takes up nutrients from the host and develops into the procercoid. It measures about 0.5 mm and is largely undifferentiated. They remain in the copepod until they are eaten by the second intermediate host, usually a Pike or salmon where it penetrates the gut and makes its way to the muscles and becomes a plerocercoid. If the second intermediate host is small and is eaten by a larger predatory fish (Pike) then the plerocercoid migrates to the muscle of this fish also which is a paratenic host. The plerocercoid can be up to a few cm in length, and is usually coiled within in the muscle cell. **It can easily be seen as a white mass in uncooked fish muscle.**
• When the plerocercoid is eaten by the definitive host it passes through the stomach and the scolex becomes embedded in the mucosa of the small intestine and develops rapidly producing eggs within 10-14 days.

• People generally become infected when uncooked fish are eaten and it is particularly prevalent in those cultures which eat a lot of freshwater fish and prepare it by methods other than cooking. In regions with poor sanitation where untreated sewage is released directly into rivers and lakes, infected fish with high prevalence and intensity rates are common.

• You can be infected by eating raw, lightly cooked, under-processed freshwater or certain migratory species of salmon, perch, pike, pickerel, and turbot. The popularity of eating raw fish dishes, such as sushi and sashimi, helps to spread this disease. Cooks who sample their fish dishes before they are properly cooked put themselves at risk of being infected.

• Chronic infestations may produce vague discomforts, water retention, abdominal swelling, etc. The tapeworms may be so numerous and large as to block the colon. In some people severe anemia occurs, and the tapeworm may absorb most of the available B12. Folate availability is reduced and symptoms may include neurological problems: numbness and vision problems,
In the fall of 1980 a large outbreak of fish tapeworm occurred along the East Coast. The outbreak affected as many as 32 individuals and was thought to be due to the consumption of salmon brought fresh from Alaska. \cite{MorbidityMortalityWeeklyReport, 30: 331-338, July 17, 1981}. In September and October, 1981, 4 separate outbreaks of fish tapeworm were documented in Alaska; Fairbanks (3 patients), Bethel (1 patient), Anchorage (1 patient), and Haines (1 patient). Epidemiologic investigation failed to uncover any common source linking these 4 outbreaks. In each case individuals had eaten raw or undercooked Red Salmon (Sockeye) in addition to other fresh water fish.
Required Conditions:

Aquatic environment for egg development- high dissolved oxygen, relatively free of organic matter

Water temp 4-24 (optimal =15-20)

Shallow coastline for copepod-coracidia contact

Deep oligotrophic lakes have low infection rates in fish

Shallow eutrophic lakes have higher infection rates

Human factor: An individual may shed 2-40 million eggs/day

If 5% live through sewage treatment 100K eggs survive daily
Gravid proglottids of Diphyllobothrium latum.
D. Latum in humans

General abdominal discomfort, diarrhea, weakness

Anemia associated with $B_{12}$ deficiency

Epidemiology / Control

Eliminate intermediate hosts- copepods & fish

Treat infected people

Sewage systems

Cook fish, freeze for 3 days, cure in 10% saline for 5 days
This environment (gut) seems very harsh; being acidic and full of digestive enzymes. Tapeworms are well adapted not only to survive this environment but use it to their benefit.

Tapeworms have no digestive canal of their own; they have to take up nutrients across their surface. The type of cells present and the structure of the tapeworm surface both reflect the ability to absorb nutrients this way. There are a number of factors that keep the tapeworm from being digested in the intestinal environment:

A distinct outer surface, manufactured by the tapeworm, which is replaced continuously with a turnover time of approximately 6 hours

Absorption of host enzymes at the outer surface of the tapeworm.

Direct inhibition of the activity of host digestive enzymes.

Apart from its own enzymes, which can be found on the surface of the tapeworm and are used to break down molecules into forms that can be absorbed, (e.g. glucose, other sugars, nucleosides, etc.), certain host enzymes have also been found adsorbed to the worm surface. For example, the host enzyme alpha-amylase absorbs to the surface of the worm, and is used to break down starch. Other host enzymes, such as trypsin and chymotrypsin are inactivated at the surface of the worm. So, in effect, the tapeworm can avoid digestion by hijacking some host digestive enzymes, and inactivating others.