

= Flatworm =

The flatworms , flat worms , Platyhelminthes , Plathelminthes , or platyhelminths (from the Greek ????? , platy , meaning " flat " and ?????? (root : ??????-) , helminth- , meaning " worm ") are a phylum of relatively simple bilaterian , unsegmented , soft @-@ bodied invertebrates . Unlike other bilaterians , they are acoelomates (having no body cavity) , and have no specialized circulatory and respiratory organs , which restricts them to having flattened shapes that allow oxygen and nutrients to pass through their bodies by diffusion . The digestive cavity has only one opening for both ingestion (intake of nutrients) and egestion (removal of undigested wastes) ; as a result , the food cannot be processed continuously .

In traditional medicinal texts , Platyhelminthes are divided into Turbellaria , which are mostly non @-@ parasitic animals such as planarians , and three entirely parasitic groups : Cestoda , Trematoda and Monogenea ; however , since the turbellarians have since been proven not to be monophyletic , this classification is now deprecated . Free @-@ living flatworms are mostly predators , and live in water or in shaded , humid terrestrial environments , such as leaf litter . Cestodes (tapeworms) and trematodes (flukes) have complex life @-@ cycles , with mature stages that live as parasites in the digestive systems of fish or land vertebrates , and intermediate stages that infest secondary hosts . The eggs of trematodes are excreted from their main hosts , whereas adult cestodes generate vast numbers of hermaphroditic , segment @-@ like proglottids that detach when mature , are excreted , and then release eggs . Unlike the other parasitic groups , the monogeneans are external parasites infesting aquatic animals , and their larvae metamorphose into the adult form after attaching to a suitable host .

Because they do not have internal body cavities , Platyhelminthes were regarded as a primitive stage in the evolution of bilaterians (animals with bilateral symmetry and hence with distinct front and rear ends) . However , analyses since the mid @-@ 1980s have separated out one subgroup , the Acoelomorpha , as basal bilaterians ? closer to the original bilaterians than to any other modern groups . The remaining Platyhelminthes form a monophyletic group , one that contains all and only descendants of a common ancestor that is itself a member of the group . The redefined Platyhelminthes is part of the Lophotrochozoa , one of the three main groups of more complex bilaterians . These analyses had concluded the redefined Platyhelminthes , excluding Acoelomorpha , consists of two monophyletic subgroups , Catenulida and Rhabditophora , with Cestoda , Trematoda and Monogenea forming a monophyletic subgroup within one branch of the Rhabditophora . Hence , the traditional platyhelminth subgroup " Turbellaria " is now regarded as paraphyletic , since it excludes the wholly parasitic groups , although these are descended from one group of " turbellarians " .

Over half of all known flatworm species are parasitic , and some do enormous harm to humans and their livestock . Schistosomiasis , caused by one genus of trematodes , is the second @-@ most devastating of all human diseases caused by parasites , surpassed only by malaria . Neurocysticercosis , which arises when larvae of the pork tapeworm *Taenia solium* penetrate the central nervous system , is the major cause of acquired epilepsy worldwide . The threat of platyhelminth parasites to humans in developed countries is rising because of the popularity of raw or lightly cooked foods , and imports of food from high @-@ risk areas . In less developed countries , people often cannot afford the fuel required to cook food thoroughly , and poorly designed water @-@ supply and irrigation projects increase the dangers presented by poor sanitation and unhygienic farming .

Two planarian species have been used successfully in the Philippines , Indonesia , Hawaii , New Guinea , and Guam to control populations of the imported giant African snail *Achatina fulica* , which was displacing native snails . However , there is now concern that these planarians may themselves become a serious threat to native snails . In northwest Europe , there are concerns about the spread of the New Zealand planarian *Arthurdendyus triangulatus* , which preys on earthworms .

= = Description = =

== Distinguishing features ==

Platyhelminthes are bilaterally symmetrical animals : their left and right sides are mirror images of each other ; this also implies they have distinct top and bottom surfaces and distinct head and tail ends . Like other bilaterians , they have three main cell layers (endoderm , mesoderm , and ectoderm) , while the radially symmetrical cnidarians and ctenophores (comb jellies) have only two cell layers . Beyond that , they are " defined more by what they do not have than by any particular series of specializations . " Unlike other bilaterians , Platyhelminthes have no internal body cavity , so are described as acoelomates . They also lack specialized circulatory and respiratory organs , both of these facts are defining features when classifying a flatworm 's anatomy . Their bodies are soft and unsegmented .

== Features common to all subgroups ==

The lack of circulatory and respiratory organs limits platyhelminths to sizes and shapes that enable oxygen to reach and carbon dioxide to leave all parts of their bodies by simple diffusion . Hence , many are microscopic and the large species have flat ribbon @-@ like or leaf @-@ like shapes . The guts of large species have many branches , so nutrients can diffuse to all parts of the body . Respiration through the whole surface of the body makes them vulnerable to fluid loss , and restricts them to environments where dehydration is unlikely : sea and freshwater , moist terrestrial environments such as leaf litter or between grains of soil , and as parasites within other animals .

The space between the skin and gut is filled with mesenchyme , a connective tissue made of cells and reinforced by collagen fibers that act as a type of skeleton , providing attachment points for muscles . The mesenchyme contains all the internal organs and allows the passage of oxygen , nutrients and waste products . It consists of two main types of cell : fixed cells , some of which have fluid @-@ filled vacuoles ; and stem cells , which can transform into any other type of cell , and are used in regenerating tissues after injury or asexual reproduction .

Most platyhelminths have no anus and regurgitate undigested material through the mouth . However , some long species have an anus and some with complex , branched guts have more than one anus , since excretion only through the mouth would be difficult for them . The gut is lined with a single layer of endodermal cells that absorb and digest food . Some species break up and soften food first by secreting enzymes in the gut or pharynx (throat) .

All animals need to keep the concentration of dissolved substances in their body fluids at a fairly constant level . Internal parasites and free @-@ living marine animals live in environments with high concentrations of dissolved material , and generally let their tissues have the same level of concentration as the environment , while freshwater animals need to prevent their body fluids from becoming too dilute . Despite this difference in environments , most platyhelminths use the same system to control the concentration of their body fluids . Flame cells , so called because the beating of their flagella looks like a flickering candle flame , extract from the mesenchyme water that contains wastes and some reusable material , and drive it into networks of tube cells which are lined with flagella and microvilli . The tube cells ' flagella drive the water towards exits called nephridiopores , while their microvilli reabsorb reusable materials and as much water as is needed to keep the body fluids at the right concentration . These combinations of flame cells and tube cells are called protonephridia .

In all platyhelminths , the nervous system is concentrated at the head end . This is least marked in the acoels , which have nerve nets rather like those of cnidarians and ctenophores , but densest around the head . Other platyhelminths have rings of ganglia in the head and main nerve trunks running along their bodies .

== Major subgroups ==

Early classification divided the flatworms into four groups : Turbellaria , Trematoda , Monogenea

and Cestoda . This classification had long been recognized to be artificial , and in 1985 , Ehlers proposed a phylogenetically more correct classification , where the massively polyphyletic " Turbellaria " was split into a dozen orders , and Trematoda , Monogenea and Cestoda were joined in the new order Neodermata . However , the classification presented here is the early , traditional , classification , as it still is the one used everywhere except in scientific articles .

== = Turbellaria == =

These have about 4 @, @ 500 species , are mostly free @-@ living , and range from 1 mm (0 @.@ 039 in) to 600 mm (24 in) in length . Most are predators or scavengers , and terrestrial species are mostly nocturnal and live in shaded , humid locations , such as leaf litter or rotting wood . However , some are symbiotes of other animals , such as crustaceans , and some are parasites . Free @-@ living turbellarians are mostly black , brown or gray , but some larger ones are brightly colored . The Acoela and Nemertodermatida were traditionally regarded as turbellarians , but are now regarded as members of a separate phylum , the Acoelomorpha , or as two separate phyla . Xenoturbella , a genus of very simple animals , has also been reclassified as a separate phylum .

Some turbellarians have a simple pharynx lined with cilia and generally feed by using cilia to sweep food particles and small prey into their mouths , which are usually in the middle of their undersides . Most other turbellarians have a pharynx that is eversible (can be extended by being turned inside @-@ out) , and the mouths of different species can be anywhere along the underside . The freshwater species *Microstomum caudatum* can open its mouth almost as wide as its body is long , to swallow prey about as large as itself .

Most turbellarians have pigment @-@ cup ocelli (" little eyes ") , one pair in most species , but two or even three pairs in some . A few large species have many eyes in clusters over the brain , mounted on tentacles , or spaced uniformly around the edge of the body . The ocelli can only distinguish the direction from which light is coming and enable the animals to avoid it . A few groups have statocysts , fluid @-@ filled chambers containing a small , solid particle or , in a few groups , two . These statocysts are thought to be balance and acceleration sensors , as that is the function they perform in cnidarian medusae and in ctenophores . However , turbellarian statocysts have no sensory cilia , and how they sense the movements and positions of the solid particles is unknown . On the other hand , most have ciliated touch @-@ sensor cells scattered over their bodies , especially on tentacles and around the edges . Specialized cells in pits or grooves on the head are probably smell sensors .

Planarians , a subgroup of seriates , are famous for their ability to regenerate if divided by cuts across their bodies . Experiments show that , in fragments that do not already have a head , a new head grows most quickly on those closest to the original head . This suggests the growth of a head is controlled by a chemical whose concentration diminishes from head to tail . Many turbellarians clone themselves by transverse or longitudinal division , and others , especially acoels , reproduce by budding .

The vast majority of turbellarians are hermaphrodites (have both female and male reproductive cells) , and fertilize eggs internally by copulation . Some of the larger aquatic species mate by penis fencing , a duel in which each tries to impregnate the other , and the loser adopts the female role of developing the eggs . In most species , " miniature adults " emerge when the eggs hatch , but a few large species produce plankton @-@ like larvae .

== = Trematoda == =

These parasites ' name refers to the cavities in their holdfasts (Greek ????? , hole) , which resemble suckers and anchor them within their hosts . The skin of all species is a syncytium , a layer of cells that shares a single external membrane . Trematodes are divided into two groups , Digenea and Aspidogastrea (also known as Aspodibothrea) .

== = Digenea == =

These are often called flukes, as most have flat rhomboid shapes like that of a flounder (Old English *floc*). There are about 11 @, @ 000 species, more than all other platyhelminthes combined, and second only to roundworms among parasites on metazoans. Adults usually have two holdfasts, a ring around the mouth and a larger sucker midway along what would be the underside in a free @-@ living flatworm. Although the name " Digeneans " means " two generations ", most have very complex life cycles with up to seven stages, depending on what combinations of environments the early stages encounter? most importantly whether the eggs are deposited on land or in water. The intermediate stages transfer the parasites from one host to another. The definitive host in which adults develop is a land vertebrate, the earliest host of juvenile stages is usually a snail that may live on land or in water, and in many cases a fish or arthropod is the second host. For example, the adjoining illustration shows the life cycle of the intestinal fluke *metagonimus*, which hatches in the intestine of a snail; moves to a fish, where it penetrates the body and encysts in the flesh; then moves to the small intestine of a land animal that eats the fish raw; and then generates eggs that are excreted and ingested by snails, thereby completing the cycle. Schistosomes, which cause the devastating tropical disease bilharzia, belong to this group.

Adults range between 0 @. @ 2 mm (0 @. @ 0079 in) and 6 mm (0 @. @ 24 in) in length. Individual adult digeneans are of a single sex, and in some species, slender females live in enclosed grooves that run along the bodies of the males, and partially emerge to lay eggs. In all species, the adults have complex reproductive systems and can produce between 10 @, @ 000 and 100 @, @ 000 times as many eggs as a free @-@ living flatworm. In addition, the intermediate stages that live in snails reproduce asexually.

Adults of different species infest different parts of the definitive host, for example the intestine, lungs, large blood vessels, and liver. The adults use a relatively large, muscular pharynx to ingest cells, cell fragments, mucus, body fluids or blood. In both the adults and the stages that live in snails, the external syncytium absorbs dissolved nutrients from the host. Adult digeneans can live without oxygen for long periods.

== == Aspidogastrea == ==

Members of this small group have either a single divided sucker or a row of suckers that cover the underside. They infest the guts of bony or cartilaginous fish and of turtles, and the body cavities of marine and freshwater bivalves and gastropods. Their eggs produce ciliated swimming larvae, and the life cycle has one or two hosts.

== == Cercomeromorpha == ==

These parasites attach themselves to their hosts by means of disks that bear crescent @-@ shaped hooks. They are divided into Monogenea and Cestoda.

== == Monogenea == ==

Of about 1 @, @ 100 species of monogeneans, most are external parasites that require particular host species, mainly fish, but in some cases amphibians or aquatic reptiles. However, a few are internal parasites. Adult monogeneans have large attachment organs at the rear, haptors (Greek ?????? , haptain, means " catch "), which have suckers, clamps, and hooks. They often have flattened bodies. In some species, the pharynx secretes enzymes to digest the host's skin, allowing the parasite to feed on blood and cellular debris. Others graze externally on mucus and flakes of the hosts' skins. The name " Monogenea " is based on the fact that these parasites have only one nonlarval generation.

== == Cestoda == ==

These are often called tapeworms because of their flat, slender but very long bodies. The name "cestode" is derived from the Latin word *cestus*, which means "tape". The adults of all 3,000 cestode species are internal parasites. Cestodes have no mouths or guts, and the syncytial skin absorbs nutrients, mainly carbohydrates and amino acids, from the host, and also disguises it chemically to avoid attacks by the host's immune system. Shortage of carbohydrates in the host's diet stunts the growth of the parasites and kills some. Their metabolisms generally use simple but inefficient chemical processes, and they compensate by consuming large amounts of food relative to their size.

In the majority of species, known as eucestodes ("true tapeworms"), the neck produces a chain of segments called proglottids by a process known as strobilation. Hence, the most mature proglottids are furthest from the scolex. Adults of *Taenia saginata*, which infests humans, can form proglottid chains over 20 metres (66 ft) long, although 4 metres (13 ft) is more typical. Each proglottid has both male and female reproductive organs. If the host's gut contains two or more adults of the same cestode species, they generally fertilize each other, but proglottids of the same worm can fertilize each other and even fertilize themselves. When the eggs are fully developed, the proglottids separate and are excreted by the host. The eucestode life cycle is less complex than that of digeneans, but varies depending on the species. For example:

Adults of *Diphyllbothrium* infest fish, and the juveniles use copepod crustaceans as intermediate hosts. Excreted proglottids release their eggs into the water, and the eggs hatch into ciliated, swimming larvae. If a larva is swallowed by a copepod, it sheds the cilia and the skin becomes a syncytium and the larva makes its way into the copepod's hemocoel (internal cavity that is the main part of the circulatory system) and attached itself with three small hooks. If the copepod is eaten by a fish, the larva metamorphoses into a small, unsegmented tapeworm, drills through to the gut and becomes an adult.

Various species of *Taenia* infest the guts of humans, cats and dogs. The juveniles use herbivores, for example pigs, cattle and rabbits, as intermediate hosts. Excreted proglottids release eggs that stick to grass leaves and hatch after being swallowed by a herbivore. The larva makes its way to the herbivore's muscles and metamorphoses into an oval worm about 10 millimetres (0.39 in) long, with a scolex that is kept inside. When the definitive host eats infested and raw or undercooked meat from an intermediate host, the worm's scolex pops out and attaches itself to the gut, and the adult tapeworm develops.

A members of the smaller group known as Cestodaria have no scolex, do not produce proglottids, and have body shapes like those of digeneans. Cestodarians parasitize fish and turtles.

== Classification and evolutionary relationships ==

The oldest confidentially identified parasitic flatworm fossils are cestode eggs found in a Permian shark coprolite, but helminth hooks still attached to Devonian acanthodians and placoderms might also represent parasitic flatworms with simple life cycles. The oldest known free-living platyhelminth specimen is a fossil preserved in Eocene age Baltic amber and placed in the monotypic species *Micropalaeosoma balticus*, while the oldest subfossil specimens are schistosome eggs discovered in ancient Egyptian mummies. The Platyhelminthes have very few synapomorphies, distinguishing features that all Platyhelminthes and no other animals have. This makes it difficult to work out both their relationships with other groups of animals and the relationships between different groups that are described as members of the Platyhelminthes.

The "traditional" view before the 1990s was that Platyhelminthes formed the sister group to all the other bilaterians, which include, for example, arthropods, molluscs, annelids and chordates. Since then molecular phylogenetics, which aims to work out evolutionary "family trees" by comparing different organisms' biochemicals such as DNA, RNA and proteins, has radically changed scientists' view of evolutionary relationships between animals. Detailed morphological analyses of anatomical features in the mid-1980s and molecular phylogenetics analyses since 2000 using different sections of DNA agree that Acoelomorpha, consisting of Acoela (traditionally regarded as very simple "turbellarians") and Nemertodermatida (another small group previously

classified as " turbellarians ") are the sister group to all other bilaterians , including the rest of the Platyhelminthes . However , a 2007 study concluded that Acoela and Nemertodermatida were two distinct groups of bilaterians , although it agreed that both are more closely related to cnidarians (jellyfish , etc .) than other bilaterians are .

Xenoturbella , a bilaterian whose only well @-@ defined organ is a statocyst , was originally classified as a " primitive turbellarian " . However , it has recently been reclassified as a deuterostome .

The Platyhelminthes excluding Acoelomorpha contain two main groups , Catenulida and Rhabditophora , both of which are generally agreed to be monophyletic (each contains all and only the descendants of an ancestor that is a member of the same group) . Early molecular phylogenetics analyses of the Catenulida and Rhabditophora left uncertainties about whether these could be combined in a single monophyletic group , but a study in 2008 concluded they could , therefore Platyhelminthes could be redefined as Catenulida plus Rhabditophora , excluding the Acoelomorpha .

Other molecular phylogenetics analyses agree the redefined Platyhelminthes are most closely related to Gastrotricha , and both are part of a grouping known as Platyzoa . Platyzoa are generally agreed to be at least closely related to the Lophotrochozoa , a superphylum that includes molluscs and annelid worms . The majority view is that Platyzoa are part of Lophotrochozoa , but a significant minority of researchers regard Platyzoa as a sister group of Lophotrochozoa .

It has been agreed since 1985 that each of the wholly parasitic platyhelminth groups (Cestoda , Monogenea and Trematoda) is monophyletic , and that together these form a larger monophyletic grouping , the Neodermata , in which the adults of all members have syncitial skins . However , there is debate about whether the Cestoda and Monogenea can be combined as an intermediate monophyletic group , the Cercomeromorpha , within the Neodermata . It is generally agreed that the Neodermata are a sub @-@ group a few levels down in the " family tree " of the Rhabditophora . Hence the traditional sub @-@ phylum " Turbellaria " is paraphyletic , since it does not include the Neodermata although these are descendants of a sub @-@ group of " turbellarians " .

= = Evolution = =

An outline of the origins of the parasitic life style has been proposed . Epithelial feeding monopisthocotyleans on fish hosts are basal in the Neodermata and were the first shift to parasitism from free living ancestors . The next evolutionary step was a dietary change from epithelium to blood . The last common ancestor of Digenea + Cestoda was monogenean and most likely sanguinivorous .

The earliest known fossils of tapeworms have been dated to 270 million years ago . They were found in coprolites (fossilised faeces) from an elasmobranch .

= = Interaction with humans = =

= = = Parasitism = = =

Cestodes (tapeworms) and digeneans (flukes) cause important diseases in humans and their livestock , and monogeneans can cause serious losses of stocks in fish farms . Schistosomiasis , also known as bilharzia or snail fever , is the second @-@ most devastating parasitic disease in tropical countries , behind malaria . The Carter Center estimated 200 million people in 74 countries are infected with the disease , and half the victims live in Africa . The condition has a low mortality rate , but often is a chronic illness that can damage internal organs . It can impair the growth and cognitive development of children , and increase the risk of bladder cancer in adults . The disease is caused by several flukes of the genus Schistosoma , which can bore through human skin . The people most at risk are those who use infected bodies of water for recreation or laundry .

In 2000 , an estimated 45 million people were infected with the beef tapeworm Taenia saginata and

3 million with the pork tapeworm *Taenia solium* . Infection of the digestive system by adult tapeworms causes abdominal symptoms that are unpleasant but not disabling or life threatening . However , neurocysticercosis resulting from penetration of *T. solium* larvae into the central nervous system is the major cause of acquired epilepsy worldwide . In 2000 , about 39 million people were infected with trematodes (flukes) that naturally parasitize fish and crustaceans , but can pass to humans who eat raw or lightly cooked seafood . Infection of humans by the broad fish tapeworm *Diphyllobothrium latum* occasionally causes vitamin B12 deficiency and , in severe cases , megaloblastic anemia .

The threat to humans in developed countries is rising as a result of social trends : the increase in organic farming , which uses manure and sewage sludge rather than artificial fertilizers , and spreads parasites both directly and via the droppings of seagulls which feed on manure and sludge ; the increasing popularity of raw or lightly cooked foods ; imports of meat , seafood and salad vegetables from high risk areas ; and , as an underlying cause , reduced awareness of parasites compared with other public health issues such as pollution . In less developed countries , inadequate sanitation and the use of human feces (night soil) as fertilizer and to enrich fish farm ponds continues to spread parasitic platyhelminths , and poorly designed water supply and irrigation projects have provided additional channels for their spread . People in these countries often cannot afford the cost of fuel required to cook food thoroughly enough to kill parasites . Controlling parasites that infect humans and livestock has become more difficult , as many species have become resistant to drugs that used to be effective , mainly for killing juveniles in meat . While poorer countries still struggle with unintentional infection , cases have been reported of intentional infection in the US by dieters desperate for rapid weight loss .

== Pests ==

There is concern about the proliferation in northwest Europe , including the British Isles , of the New Zealand planarian *Arthurdendyus triangulatus* and the Australian flatworm *Australoplana sanguinea* , both of which prey on earthworms . *A. triangulatus* is thought to have reached Europe in containers of plants imported by botanical gardens .

== Benefits ==

In Hawaii , the planarian *Endeavouria septemlineata* has been used to control the imported giant African snail *Achatina fulica* , which was displacing native snails , and *Platydemus manokwari* , another planarian , has been used for the same purpose in Philippines , Indonesia , New Guinea and Guam . Although *A. fulica* has declined sharply in Hawaii , there are doubts about how much *E. septemlineata* contributed to this . However , *P. manokwari* is given credit for severely reducing , and in places exterminating , *A. fulica* ? achieving much greater success than most biological pest control programs , which generally aim for a low , stable population of the pest species . The ability of planarians to take different kinds of prey and to resist starvation may account for their ability to decimate *A. fulica* . However , these abilities have raised concerns that planarians may themselves become a serious threat to native snails .

A study in La Plata , Argentina shows the potential for planarians such as *Girardia anceps* , *Mesostoma ehrenbergii* , and *Bothrosomostoma evelinae* to reduce populations of the mosquito species *Aedes aegypti* and *Culex pipiens* . The experiment showed that *G. anceps* in particular can prey on all instars of both mosquito species and maintain a steady predation rate over time . The ability for these flatworms to live in artificial containers showed the potential of placing these species in popular mosquito breeding sites , which would ideally reduce the amount of mosquito borne diseases .