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Learning Programs for Biology Education

Branches on the Tree of Life: Flatworms
Study Guide

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Supplement to Video Program

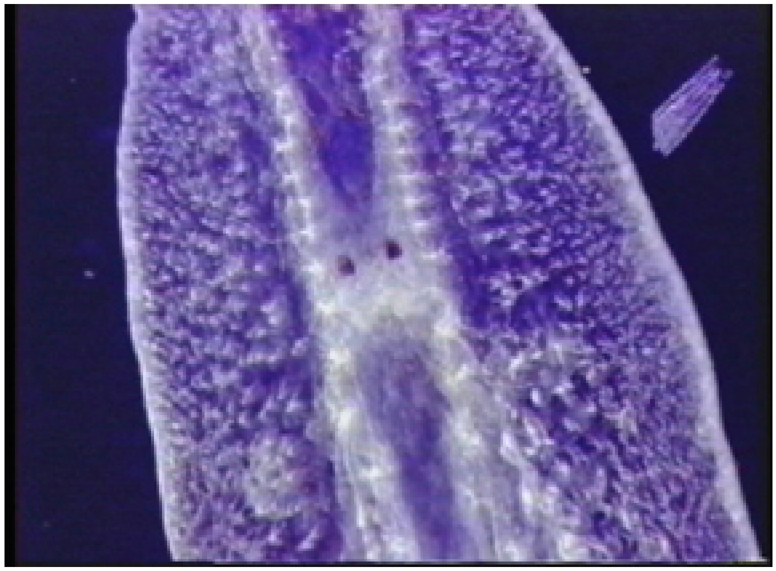
The earliest motile animals were probably small squishy creatures drifting about, feeding on the single cells that had, until that time, been the dominant forms of life on planet Earth. Their bodies, made from two cell-layers were radially symmetrical, like today's jellyfish. This configuration works quite well for drifters, but radial symmetry has severe limitations for any form of directional swimming.

Some time around 600 million years ago multicellular animal having three cell layers and bilateral symmetry appeared. In other words, they had a right and left side and a head end. These "bilateral animals" coexisted in a world of complex single cells – competing with them, and eating them just as their descendents do today.

Stenostomum (right) and *Stentor*, a single cell

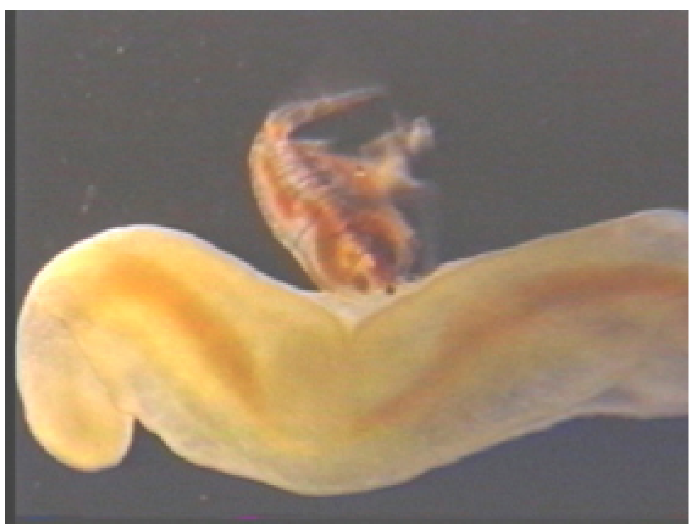
From such a bilateral ancestor evolved the major branches of animal life, molluscs, annelids, arthropods, echinoderms, chordates and a large phylum of animals that have maintained the characteristics of that bilateral ancestor – the flatworms, phylum platyhelminthes – "platy" means flat, like a plate – "helminth" means worm. Platyhelminths are three-cell layer, bilateral animals.

Locomotion: As flatworms glide over surfaces using their coat of cilia, their course is set by information processed by a brain and communicated through nerves that extend both forward from the brain and back, through the worm's body. This hard-wiring makes possible the worm’s behavior.

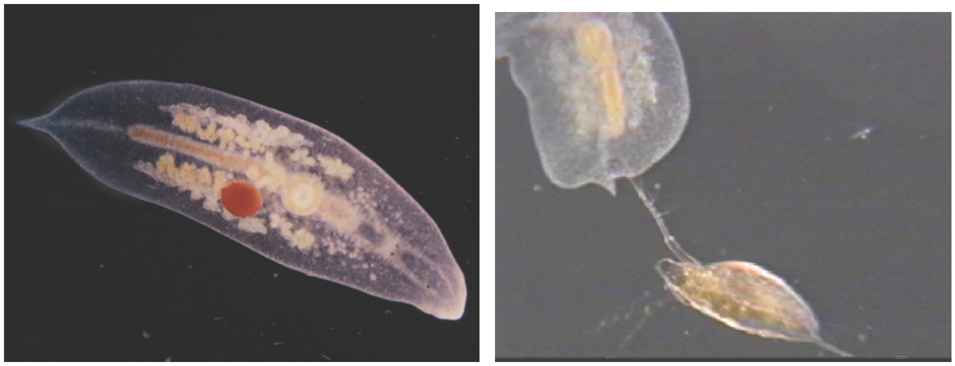


Mesostoma (fresh water) showing eye spots, brain, and two nerve trunks.

Microscopic and primitive, these flatworms may mimic the bilateral ancestor in their **reproduction.** They are without sex, but effectively increase their numbers by developing chains of individuals that will separate and continue the process.



Feeding on single cells is fine for microscopic worms, but larger worms need more substantial meals. This one has captured a copepod. Closing in, the worm smears the crustacean with slime, binding its appendages, preventing escape. Now the flatworm maneuvers the prey until its mouth is firmly in contact—and begins sucking out the copepod's organs.



This flatworm uses slime in a different way. It lays out a slime trap-line, and in a few minutes traps a daphnia.

The feeding process involves a sequence of behaviors. First the worm inserts its feeding tube between the waterflea's shells, pumping in digestive enzymes. After a few minutes, the enzymes begin breaking down the prey's tissues and its heart stops. Now the worm changes its position, preparing for the actual feast.

With suction applied, Daphnia's tissues are quickly transferred into the worms stomach.

These high-protein meals make possible the production of **eggs**. Flatworms living in ponds that freeze or dry produce two kinds of eggs depending on conditions: Eggs that produce new baby flatworms, a strategy that allows the population to build up when living conditions are favorable—

– and eggs that develop thick outer walls. These thick walled eggs result from sexual reproduction, a process often stimulated by deteriorating conditions. Most flatworms are **parthenogenetic** – both sexes in the same individual, so one mating produces two sets of eggs.

When ponds dry, the adult worms perish, but they leave behind their resistant eggs, ready to start a new flatworm population when water returns.

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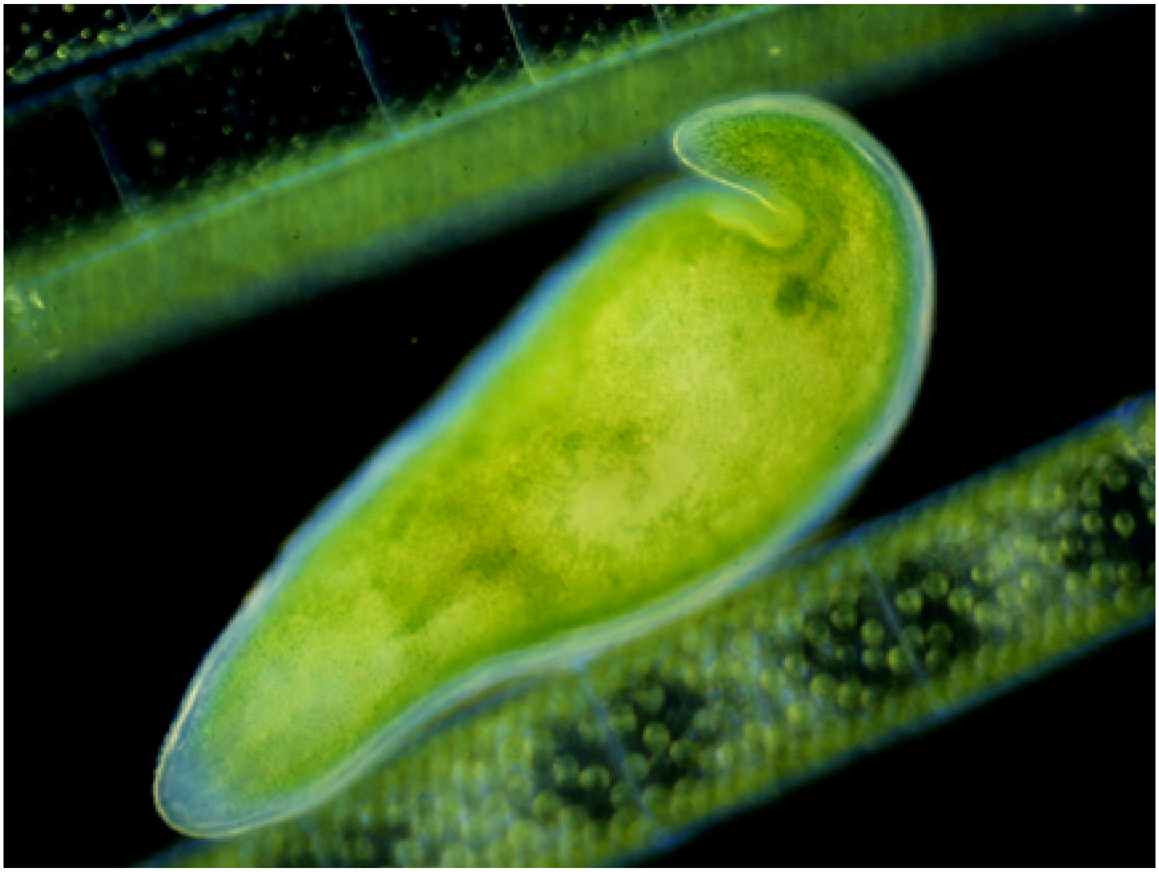

The green color of this worm is due to a garden of symbiotic **algae** growing in its tissues. The algae contribute products made by photosynthesis to their host. In turn the flatworm sunbathes, giving its helpers light needed for **photosynthesis**.

Green worms with embryos. Embryos prior to infection with symbiotic algae.

The babies are born without green guests and must "infect themselves" by ingesting algae cells.

This unforgettable face belongs to a planarian, a type of flatworm often studied in biology classes.

The "eyes" are light receptors that help the worms avoid bright sunlight, lessening exposure to harmful ultra violet radiation.

The ear-like flaps are loaded with chemical receptors, capable of picking up the weak chemical signals that mean food.

Turning its head from side to side, a planarian can home in on the smells diffusing out from food, in this case, a bit of earthworm placed in their aquarium.

Approaching their snack, the worms' feeding tubes extend and start pumping in food.

The worm's branched **digestive system** extends throughout its body, assuring that all of its tissues are in close contact with digesting food.

Although they are sexual organisms, planarians build up their numbers by simply pulling in two. In a few days each half will regenerate its missing parts. The ability to regenerate new body parts is so highly developed in planarians that if one's head is split, each half will regenerate a complete new head.

Planarians and most other free-living flatworms belong to **Class Turbellaria** – named for the turbulence their cilia create as they move through the water. Turbellarian-like ancestral flatworms probably preceded many of the other lines of animal life. Then, as animal life diversified, the worms took advantage of parasitic opportunities, evolving into **ectoparasites** of fish, flukes, and tapeworms.


Turbellarian flatworms from a vernal pool, one with drought-resistant eggs.

Class Monogenea

Flatworms were around for a long time before the appearance of the first primitive fish. However, once fish evolved, they opened up a whole new food source for flatworms – "fish scum."

Today these ectoparasites make up a distinct, but little known branch of flatworms living on fish and amphibians – the flatworm class monogenea.

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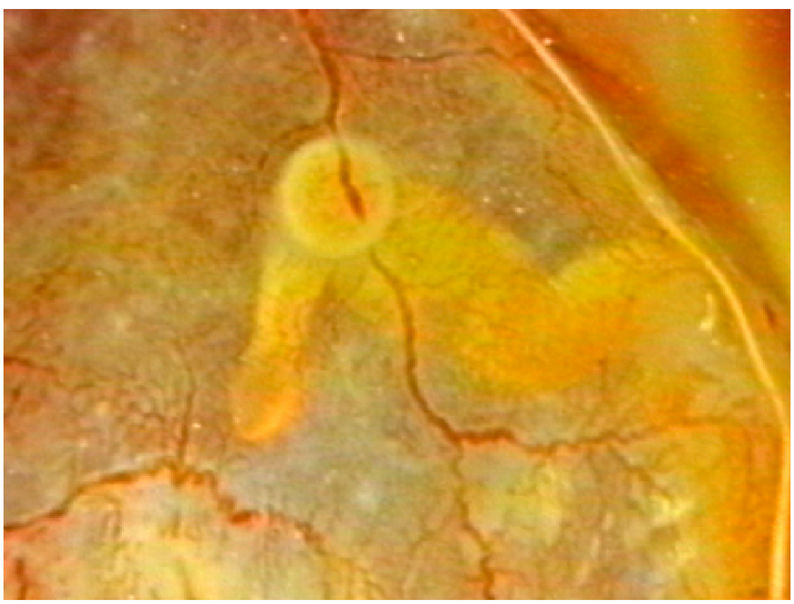
The next time you go fishing, look closely at the fins of your catch. You may see a **monogenetic** flatworm hanging on with its powerful tail hooks.

Flukes (Class Trematoda)

In earlier times, when brain-destroyed frogs were dissected in biology classes, students were often surprised to discover flukes living in their subject's organs.



Here, a large bladder fluke can be seen holding on to the frog's bladder wall.
Its oversized sucker prevents loss when the frog empties its bladder.

Lung flukes feed upon the linings of the lungs, breaking down the lung tissue and gorging on blood. The mature lung flukes are little more than sacks of reproductive organs manufacturing thousands of eggs.

The eggs are coughed up by the frog, swallowed and shed into the pond with the frog's feces.

Within each egg develops a ciliated larva that goes off in search of the first host in the lung fluke's life cycle – a pond snail.

Burrowing into the snail, the larva initiates an amazing reproductive multiplication. Living on the snail tissue, the larva develops into a sac of germinal cells. Each of these hundreds of germinal cells produces a new sac. Inside of these secondary sacs develop masses of larvae called cercaria, a staggering multiplication of parasites that leaves the snail in rather poor health.

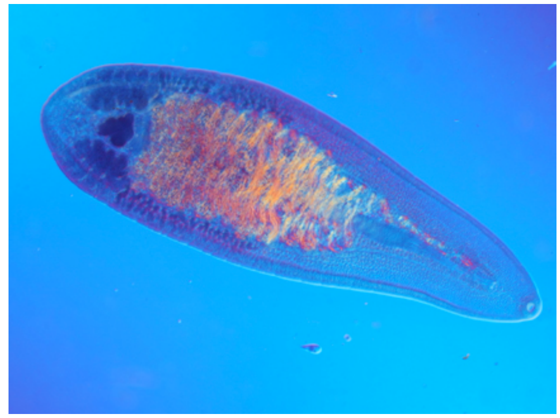
A forked-tail cercarium

Vast numbers of Cercaria burrow out of the snail and swim away to find their next host. In the case of the frog lung fluke, the next host is an aquatic insect larva.

When they reach the insect the tail will be discarded and the worm will burrow in and form a cyst. Now it waits for the insect to emerge and be eaten by a frog.

Breaking out in the frog's stomach, the flukes crawl up the esophagus and enter the air tubes leading to the lungs where they eventually mate and start egg-production all over again.


Chinese liver fluke

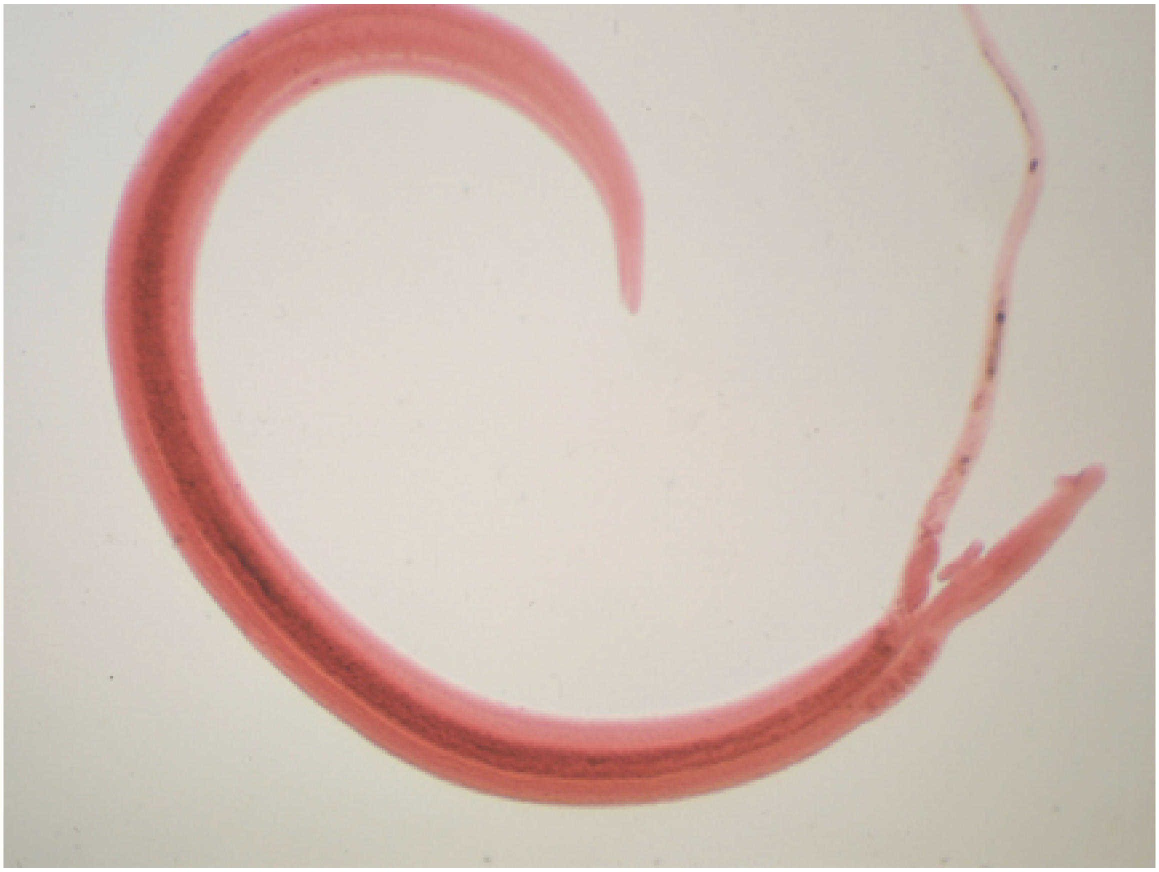

Unidentified fluke from gull intestine

Frogs are not alone in having fluke problems. Every kind of animal has them, and all of these parasites have complex lifecycles involving snails or clams, suggesting that the flukes first evolved as parasites of molluscs.

The sexually mature flukes come in all sizes, each adapted by its shape and behavior for life in a particular organ of its host.


Sheep live fluke

This species, reaching two centimeters in length, occupies the livers of sheep and deer, often jamming their host's bile ducts. Sheep get the parasite by eating water plants on which the cercaria have formed cysts



A schistosome blood fluke male holds the female in his copulatory fold. These flukes live in blood vessels of warm-blooded animals (including humans), impeding circulation.

Title: Tape worms (Class Cestoda)

Monogenetic flatworms live mostly on outer surfaces of fish. Fluke species inhabit the organs of every kind of vertebrate animals. A third branch of flatworm parasites has become adapted to living in a concentrated source of predigested nutrients—the vertebrate intestine.

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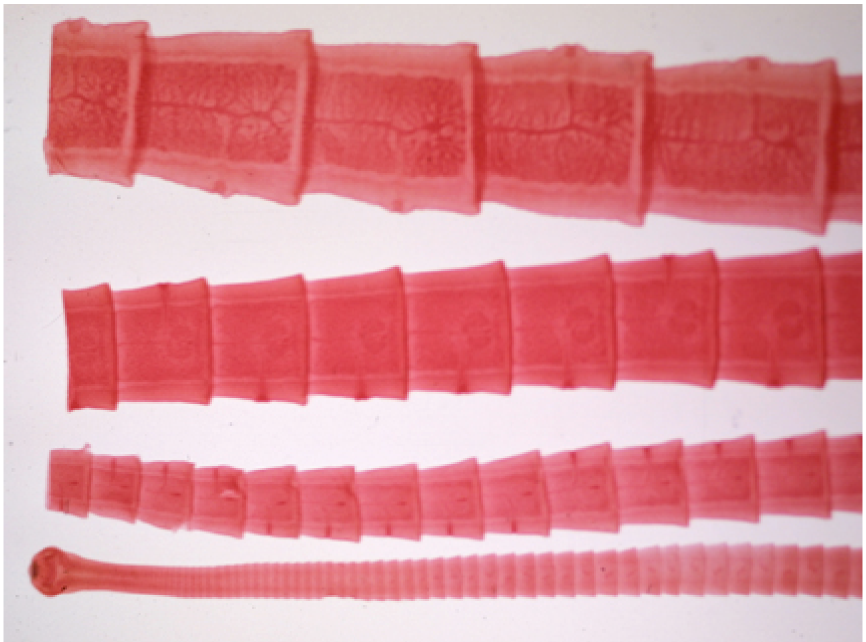
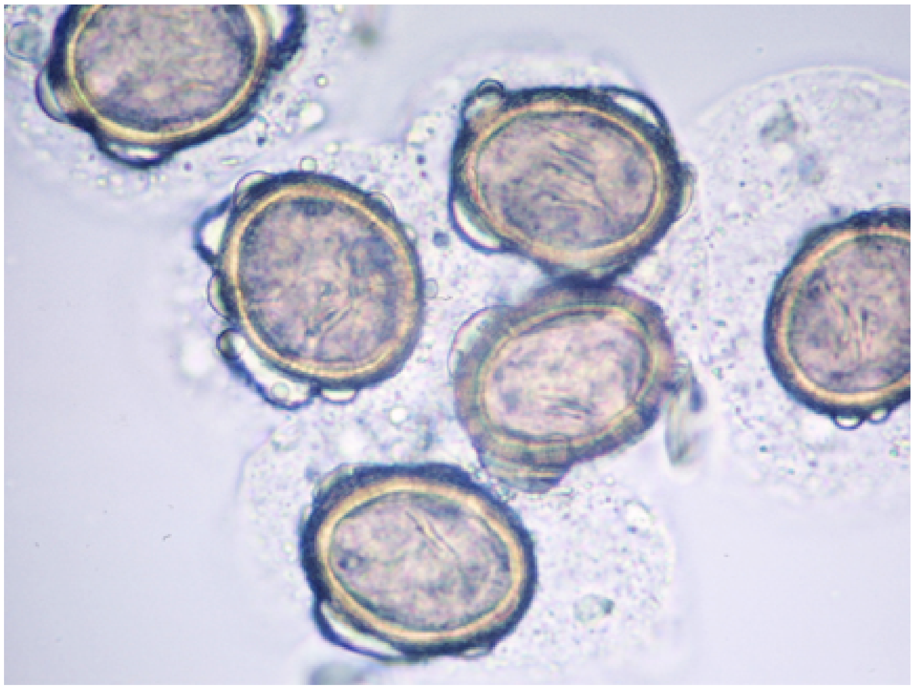


Tapeworms are distinguished by having bodies made up of chains of reproductive individuals called **proglottids**. At times, you may have seen these **egg-loaded** proglottids emerging from a pet. The chain of proglottids that make up a tapeworm are kept within the intestine by one specialized individual at the head of the chain – the **scolex**

Scolex of *Tanea solium*, the pork tapeworm.

In this human infesting species, the scolex is equipped with both hooks and suckers – allowing it to hang on to the intestinal lining, where the proglottids can absorb the soup of digested nutrients.

Tapeworm matings must occur in the unromantic surroundings of the their host's small intestine, where each hermaphroditic proglottid mates with a proglottid from a neighboring worm. Following mating, the fertilized proglottids become sacs of eggs, ready to escape and be eaten by an intermediate host.



Tapeworm eggs

In *Tanea solium*, a tapeworm of humans, the intermediate host is a pig that has ingested human feces containing the tapeworm eggs, still a possibility in many areas of the world.

The tapeworm embryos hook their way through the pig's intestinal wall, where they are carried by the blood stream to the muscles. Here they form small, encapsulated tapeworm embryos.

Preparing a pig pit-roast.

When the pork is eaten without sufficient cooking the embryos digests out and grow into a mature intestinal parasites.

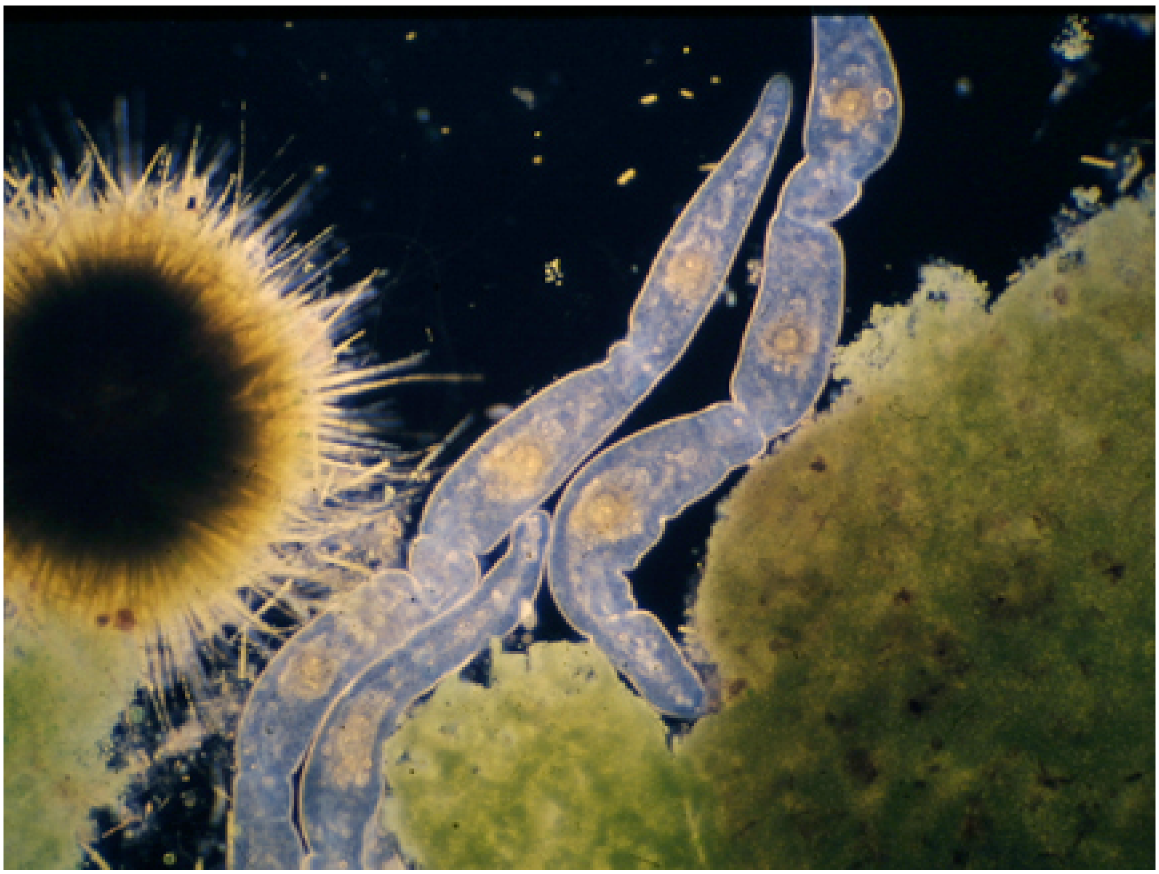
A large tapeworm is an unwelcome guest, but the situation becomes much worse if the human, instead of the pig, ingests the tapeworm eggs. In this case the larvae burrow through the human's intestinal wall and form cysts in muscles and organs.

This old autopsy photo shows a human brain riddled with tapeworm cysts – the cause of death.

Conclusion

Flatworms are an ancient line of animal life with four surviving branches: Class Turbellaria, the free-living flatworms, Class Monogenea- ectoparasites of fish and amphibians, Class Trematoda, the flukes, and Class Cestoda, the tapeworms.

Even before these lines began their evolutionary divergence, flatworm-like ancestors with three-cell layers and bilateral symmetry opened the door for the great evolutionary experiments that produced the diversity of animals living today.



Primitive flatworms from a pond water sample.

Research Tips

To find planarians in ponds, rinse water plants in a white pan where the brown worms are easily seen crawling over the white surface. In streams, carefully lift rocks and look for planarians on the under side. Planarians can be kept in aquariums, or individually, in plastic cups where you can investigate their feeding behavior and their regenerative abilities. In regeneration studies, worms are cut using an ice cube as an operating table. The ice slows the worm, and presumably acts as an anesthetic.

Microscopic flatworms are often found in cultures of decaying plant vegetation where they are easily spotted using a stereo dissecting microscope. However, some are in the same size range as larger protozoans, such as *Spirostomum*. How to tell worms from cells? Look for the eyes, suckers and mouths. Observing the behavior of these tiny worms may be as close as we can come to visualizing life on Earth 600 million years ago, a time when animal life was just getting started.

Flukes and fish go together like lichen on rock. If a fish is caught for the table, remove its intestine, carefully tease it open and look for flukes. For purposes of identification, flukes can be killed in alcohol (starting with 30% and going through a series of increasing concentrations up to 90%). Following dehydration in alcohol, they can then be stained using a variety of stains that differentiate the fluke's organs. Then you may be able to identify the fluke using a **parasitology reference book**, or possibly from a search of the internet. Also, if flukes are found, return to the fishing hole and collect **water snails**. Keep a dozen or so snails in a glass jar changing the water daily. Watch for rapidly wiggling **cercaria** in the water. Give the cercaria access to possible host organisms in order to determine more about the fluke's lifecycle. A word of warning: If you find forked tail cercaria, be careful about giving them access to your skin as they are likely to be blood flukes. In North America, blood flukes are hosted by aquatic birds and mammals, but usually not by humans. As they burrow in your arm they will soon discover they have entered a very unfriendly host. Although your immune response will kill the cercaria, their dead bodies in combination with a strong immune response will leave a big red welt. People who wade or swim where animal-infesting blood flukes live, often come out of the water covered with red welts, a condition known as "swimmer's itch." In some tropical regions there are related blood flukes (Schistosomes) that get by human resistance and make their homes in blood vessels, creating a serious health risk for their human host.

Also examine the fins of fresh caught fish with a magnifying glass to locate the curious monogenetic flatworms, once thought to be a kind of fluke. When opening the fish's intestine look for slowly undulating white ribbons – tapeworms. Many fish tapeworms rely on their eggs being eaten by copepods and other small water animals, so finding a tapeworm brings up the possibility of running an experimental lifecycle in order to learn how the particular tapeworm gets into the fish. Recreating lifecycles in the laboratory has given biologists the understanding needed to stop parasitic diseases in animals, wild, domestic, or human.

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