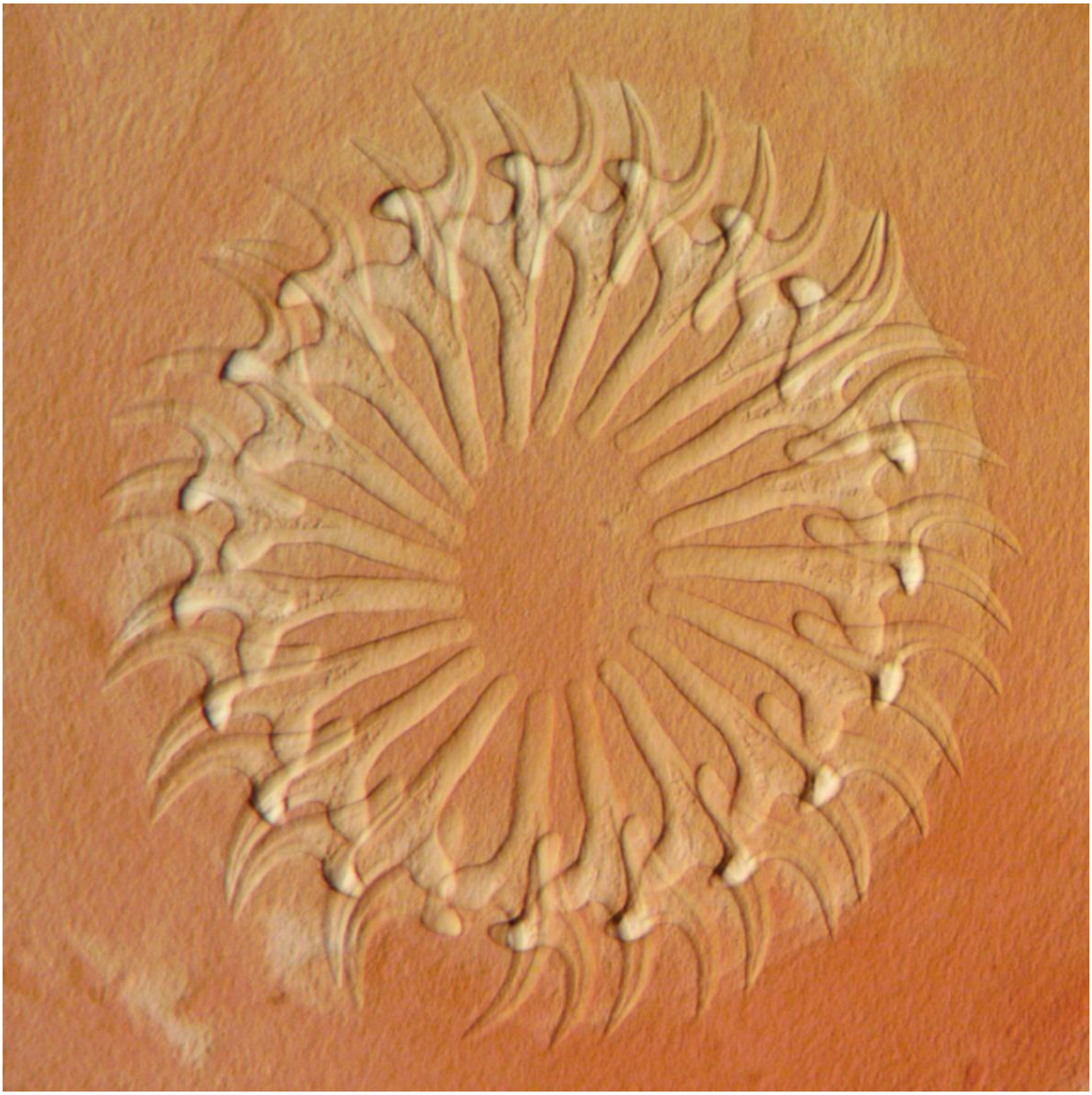
Tapeworms

Interesting little hermaphrodites



Ed Ward MD, Minnesota USA

June 2023

hooks on the scolex of *Taenia pisiformis,* the rabbit tapeworm
Antique microscope slide by Joseph Bourgogne, Paris, 1860
10X objective, oblique lighting
(whole circle ~ 0.2 mm across)

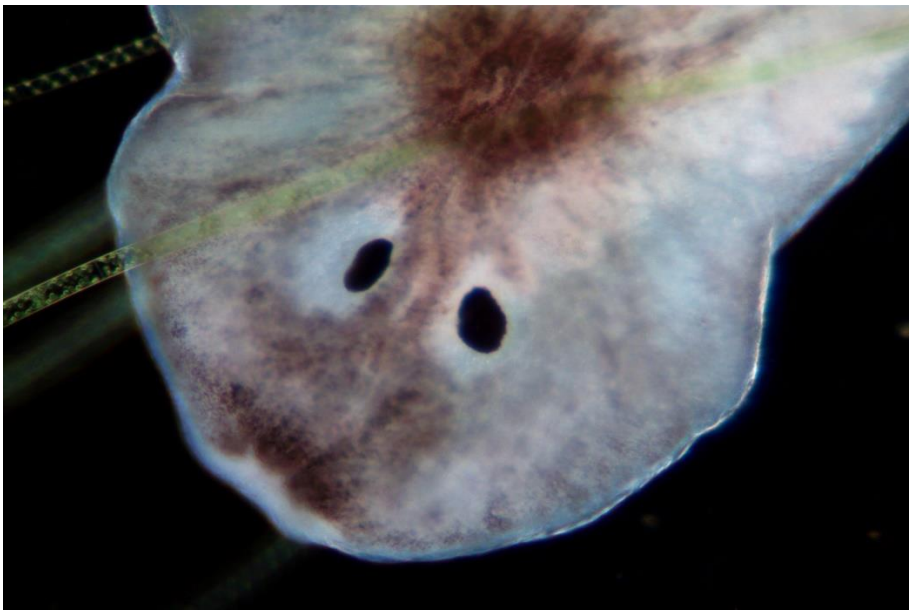
Tapeworms

Text and micrographs by Ed Ward, 2023

Pity the parasites of the world. Just because you live in a host without paying rent, people hate you.

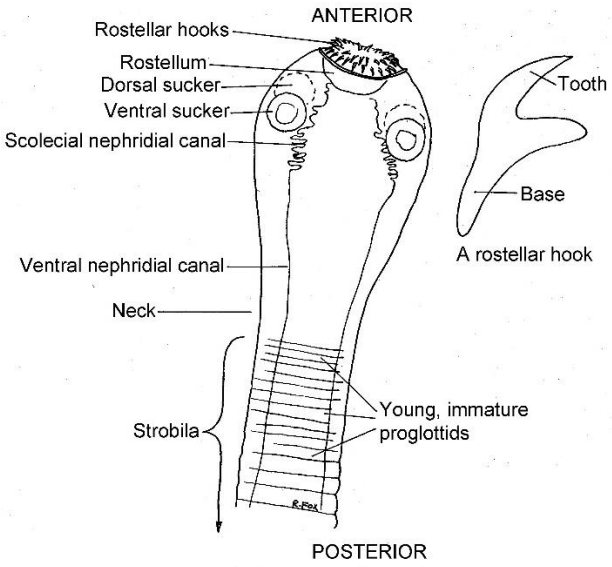
People often feel revulsion when they consider the anatomy of a tapeworm. But considering the design of parasites makes me think about how all life is linked together. Tapeworms are strange little wormish creatures with hook-like teeth, but no mouth. But like other living things a tapeworm is not intrinsically bad or good. It is just an animal that is well adapted to its place in nature. To find food and a home, the tapeworm shares yours. An adult tapeworm lives in the dark, protected by its host's body, washed over by a sluggish current of digested food. Its rather odd body doesn't have unneeded eyes, mouth or stomach. Tapeworms are very successful at what they do, and can live up to 30 years inside their host. Tapeworms usually go undetected. Killing you, their grocery store and house, would be dumb. So they are generally well behaved house guests, but rarely a few errant tapeworm teenagers (larva) really mess up your brain or other internal organs (neurocysticercosis and hydatid disease). Like all life, a tapeworm's ultimate job is to copy itself, and it is good at doing so while living inside another animal.

Tapeworms, also called cestodes, constitute a class of over 5000 species of endoparasitic flatworms in Phylum Platyhelminthes (the other major classical classes of flatworms were trematodes- the parasitic flukes, and turbellarians- the free living flatworms, like friendly little freshwater Planarians). Thapworms lack an intestine, absorbing nutrients straight from the host's gut. An adult tapeworm consists of little more than a tiny head with hooks and suckers to hang on, and a long string of hundreds of egg factories. A simple excretory system rids the body of wastes. They are blind, but a simple nervous system enables them to smell, and to coordinate a few muscles. Many tapeworms have very complex live cycles with the larvae (cysticercoids or "bladder worms") living in different organs or host animals than the adult.

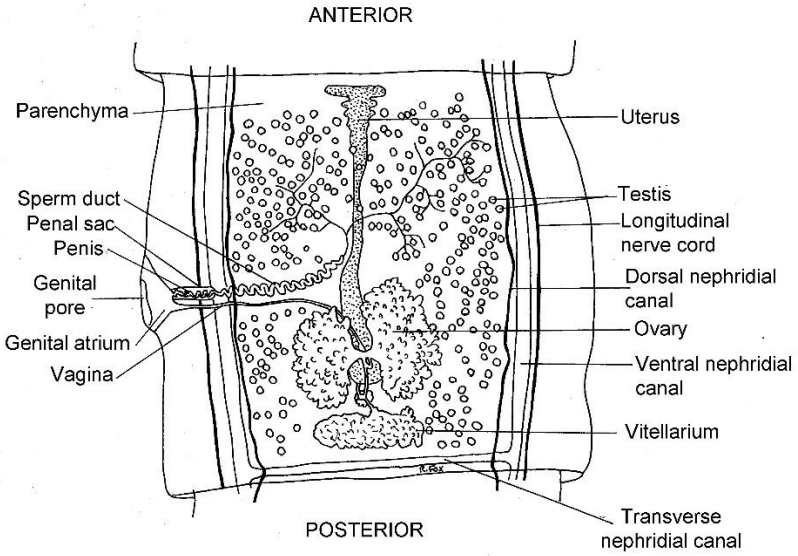


Photomicrographs by author using AO Reichert Microstar 410 or Diaster 420 microscopes with a 3 Mp USB microscope camera with or without a 0.5X reduction lens

Tapeworms have more respectable cousins, such as this *Dugesia sp* planarian 4X objective, dark field



Anatomy of scolex ('head end') of *T psiformis*, rabbit tapeworm Oklahoma Biological Survey



Anatomy of a maturing proglottid of *T psiformis*, rabbit tapeworm Oklahoma Biological Survey

Tapeworms are internal parasites, living in the guts of us vertebrates for at least 270 million years (just before the earliest dinosaurs). Investigation of four tapeworm genomes finds they are drastically simplified, having jettisoned unneeded baggage such as instructions for synthesizing nutrients and even many homeobox genes (which lay down body plans during early development). Having abandoned the usual body plan instructions, they look odd. They look surprisingly like *Plexus ricei*, a Ediacaran Period fossil from about 570 million years ago, (just before the Cambrian Explosion of animal body plans) recently found in Australia. *Plexus* was 80 cm long, and had a worm-like, flattened body divided into short segments. It had a body cavity and a separate hollow tube running its full length. That body plan could possibly lead to both the chordates (sea squirts and vertebrates) and to most invertebrates. *Plexus* is a candidate for being the first bilaterally symmetric animal. This hypothetical "urbilaterian" gave rise to all mollusks, arthropods, echinoderms and vertebrates, including us. It's possible that by throwing away so many body plan genes, tapeworms reverted back to something akin to the common ancestor of bilateralian animals. You may have right and left hands, a segmented backbone and a head because most animals descended from a tapeworm-like late Precambrian common ancestor. This is just my own crazy theory, but it fits recent fossil and genomic evidence.

Geologic time is deep beyond everyday human understanding. The earliest physical evidence of tapeworms is of their eggs in a shark coprolite (fossilized poop) from the Permian period in Brazil. With tiny slow changes, a lot happened in the next 270 million years. In that time the continents, creeping about an inch a year (5 feet in a human lifetime) smashed together then split apart again. Tapeworms moving blindly though millions of hosts somehow adapted from living in fish into occupying big land animals and learned to use muscle tissues or little arthropods for housing their young. The dinosaurs (which may have harbored tapeworms)

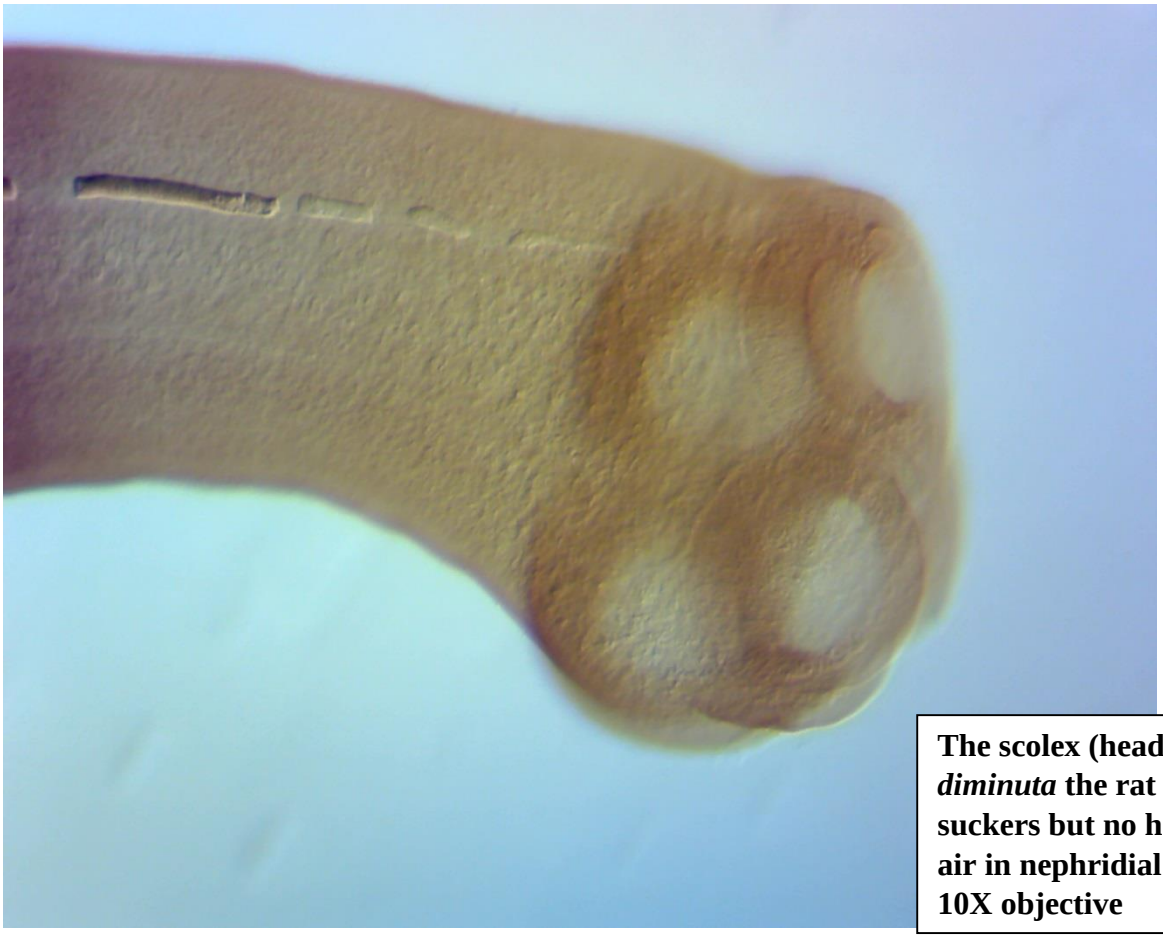
became extinct, and the worms adapted to living in many new kinds of vertebrates, eventually including dogs that were attracted to the garbage of our human ancestors. (Or maybe dogs got tapeworms from their masters after domestication about 10,000 years ago, according to one theory). So today many animals, including some of our beloved pets and children, have worms clinging to their insides stealing tiny bits of their food.

And as if throwing away perfectly good genes and stealing food isn't bad enough, over time tapeworms also became sexual degenerates. Sex has such strong benefits that even bacteria, the simplest of living things, sometimes practice it. And humans, who fancy ourselves to be the apex of living things, are downright obsessed with it. If we just budded babies off our sides like hydra do, we'd be giving parasites a free ride. Reducing our offspring down to microscopic egg and sperm for part of the reproductive process gives most parasites the slip (leaving them in the old body). And probably more importantly, sex reshuffles the genes we got from mom and dad into new and unique combinations. This creates small variations that nature can work with to slowly refine species over time. But tapeworms are deviants. They have sex, but are oversexed hermaphrodites, with each individual animal having hundreds of both male and female parts. Snails are also hermaphrodites, but they have the good sense to seek out partners to have sex with, mixing up the gene pool like good animals do. But tapeworms have sex with themselves all the time, reducing the chance to stir up the genes. So tapeworms are basically mutant, inbred, masturbating, ugly little thieves.

The strange bodies and parasitic lifestyles of tapeworms prompted me to lapse into moral judgement, but I should not have. To human sensibilities it seems the parasite is a sort of devious criminal, but of course it is not. Objectively tapeworms are physically degenerate, having lost previous anatomical structures and abilities, but they are not morally degenerate, having no willful behaviors. Losing eyes and mouth and other body parts reduces the metabolic drain of those parts, allowing all energy to go into making offspring. Being able to self-fertilize makes sense when you have very limited mobility and might never meet others of your own kind. Other than self-sufficient sex, they just need to hold on and turn your food into eggs. As my title photomicrograph of the hook circle of a rabbit tapeworm shows, they have evolved very good holdfasts. As is often taught, tapeworms are "perfect parasites", having reduced their bodies to "a bag of reproductive organs bathed in a sea of predigested food." Tapeworms are just another unthinking part of vast ecological webs that move bits of energy and mass across the earth's surface. The tapeworm seems perfectly designed for the strange life it lives, because slowly adapting to over 270 million years of being passed through millions of animal's guts make today's tapeworm perfectly matched to that niche. It's no wonder that people attribute intelligence to worms and think there must be a designer for such strange and perfect little creatures. But tapeworms make no choices; they simply follow occasional programmed responses to smells. People make moral judgments about things in nature, but nature doesn't judge us, even though she does have intricate order and rules.

Recall the tale of Moby Dick. The ocean and the whale are mute, uncaring and powerful forces compared to puny man. They neither bear him ill will nor will they show him mercy. Nature has

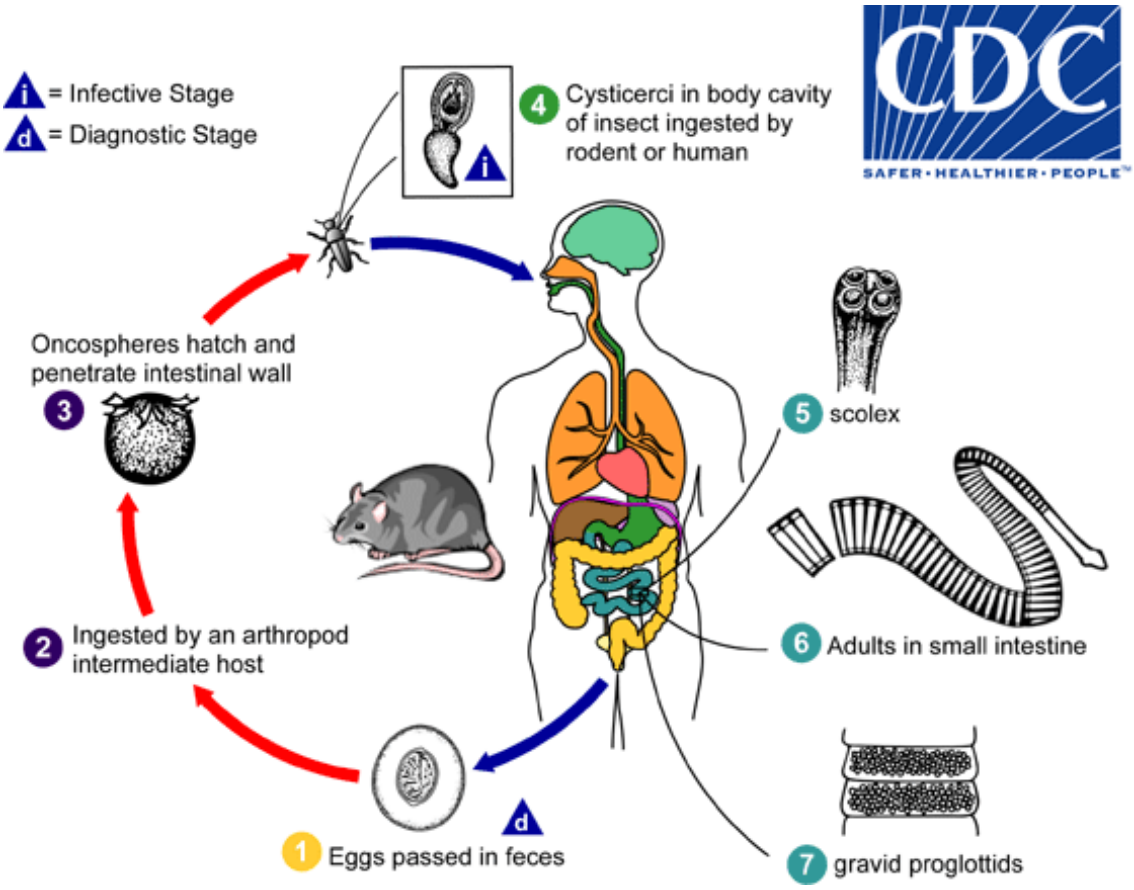
rules that sailors can learn to make seafaring possible, enjoyable at times, dangerous at others. Man is a unique part of nature that can understand, and make choices. The apparent grand design of nature is an illusion created by the laws of physics which begat the laws of chemistry and of life. On every level from the quark to the whole universe, nature has order and rules which seem beautiful to most scientists. Life is more than just red in tooth and claw, a never ending struggle for survival: it also seems to me gorgeously beautiful and is intricate and full of amazing surprises like complex parasite life cycles. 10,000 years ago man learned enough of nature's rules to cultivate tasty plants and animals, leading to settled life and civilization, and recently man learned enough physics to make flying and thinking machines. Getting out in nature and learning her patterns is awe inspiring, if you just open either your scientific or spiritual mind.



The scolex (head) of *Hymenolepis diminuta* the rat tapeworm. Note 4 suckers but no hooks, and bits of air in nephridial (excretory ducts) 10X objective

But I digress; let's move on to one of the species of tapeworm I have many slides of. The specific perverted little parasite in question today is *Hymenolepis diminuta*, the rat tapeworm. The worms are widely available, as rats live everywhere man does. Rats and other rodents are the worm's definitive host. Adult worms are 20 to 60 cm long (far longer than a rat but intestines and worms are bothgood at coiling up). Eggs are passed in rat poop and are eaten by flour beetles, where oncospheres released from eggs become cysticercoid larvae. When infested beetles are eaten by rats the tapeworms can grow up in their intestines and complete their lifecycle. Rat tapeworms are common worldwide, especially in wild rats.

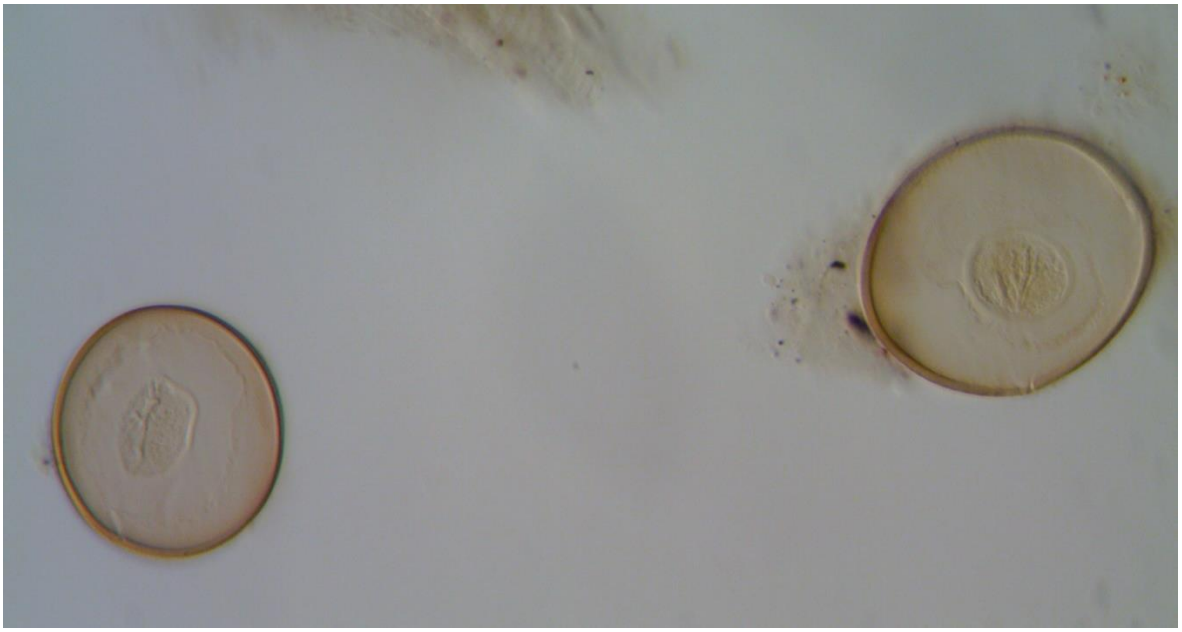
Rarely humans (usually children) eat infested beetles and develop human hymenolepiasis. The infections are most often asymptomatic. Infested humans can shed eggs, so this isn't a dead end for the tapeworms (as it is with several other tapeworm species). On rare occasion the human child host feels weak or abdominal pain. Tapeworm infections are diagnosed mostly by examining stool specimens under a microscope. If required, infestation can be treated with a single dose of the de-wormer drug praziquantel.



***H. diminuta* life cycle**

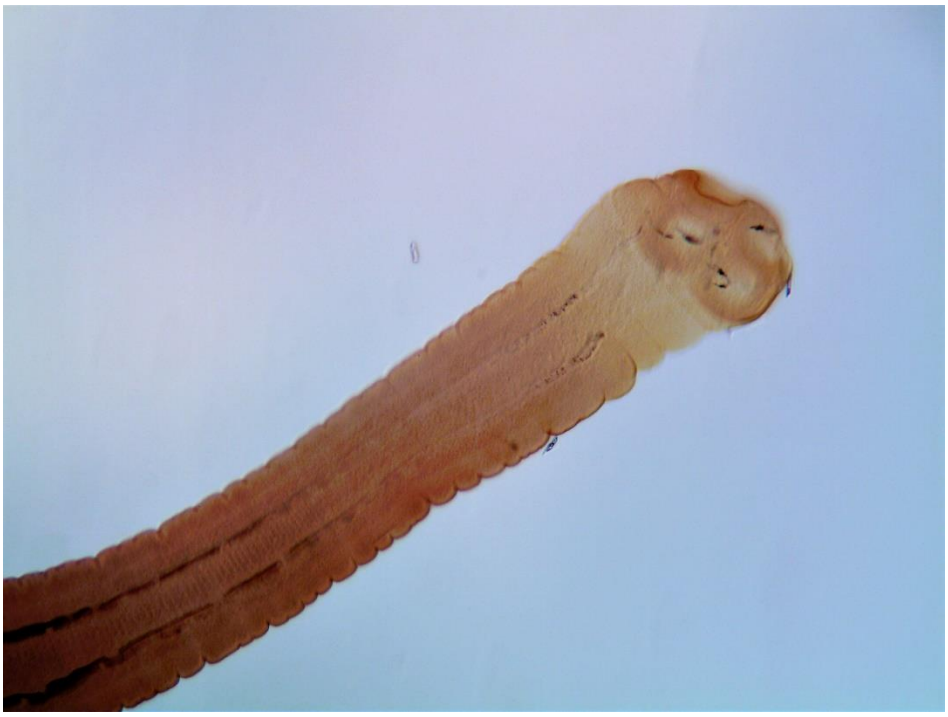
Eggs of *Hymenolepis diminuta* are passed out in the feces of the infected definitive host 1. The mature eggs are ingested by an intermediate host (various arthropods) 2, and oncospheres are released from the eggs and penetrate the intestinal wall of the host 3, which develop into cysticercoid larvae. *Tribolium* species are common intermediate hosts for *H. diminuta*. The cysticercoid larvae persist through the arthropod's morphogenesis to adulthood. *H. diminuta* infection is acquired by the mammalian host after ingestion of an intermediate host carrying the larvae 4. Humans can be accidentally infected through the ingestion of insects in precooked cereals, or other food items, and directly from the environment (e.g., oral exploration of the environment by children). After ingestion, the tissue of the infected arthropod is digested releasing the cysticercoid larvae in the stomach and small intestine. Eversion of the scoleces 5 occurs shortly after the cysticercoid larvae are released. Using the four suckers on the scolex, the parasite attaches to the small intestine wall. Maturation of the parasites occurs within 20 days and the adult worms can reach an average of 30 cm in length 6. Eggs are released in the small intestine from gravid proglottids 7 that disintegrate after breaking off from the adult worms. The eggs are passed in feces.

Some *Hymenolepis diminuta* photomicrographs showing life stages (slides from collection of late parasitologist, Professor Harley Jones Van Cleave)



Eggs. 40X objective, oblique lighting. This is rat poop fixed in alcohol, formalin, and acetic acid (AFA) then mounted in glycerol. The abundant *H. diminuta* eggs are round or almost so, about 70-80 microns across. The eggs sometimes show hooks, which are later lost.

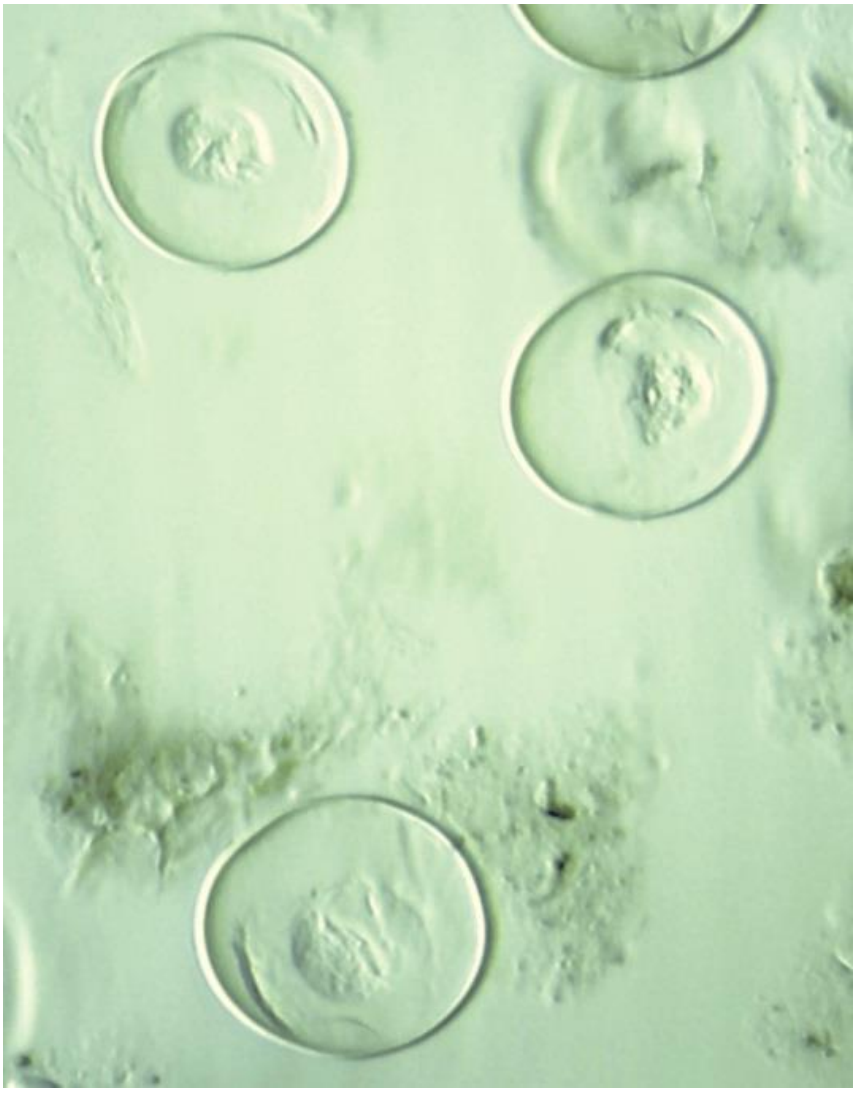
Cysticercoid. 20X objective, oblique illumination. Cysticercoid is about 150 microns across. This is the larval stage, which develops from the central oncosphere of the egg, and matures in flour beetles. Either a beetle larva or adult may ingest the tapeworm eggs. To become adult worms, the cysticercoids must pass into a rat when it eats an infested beetle.



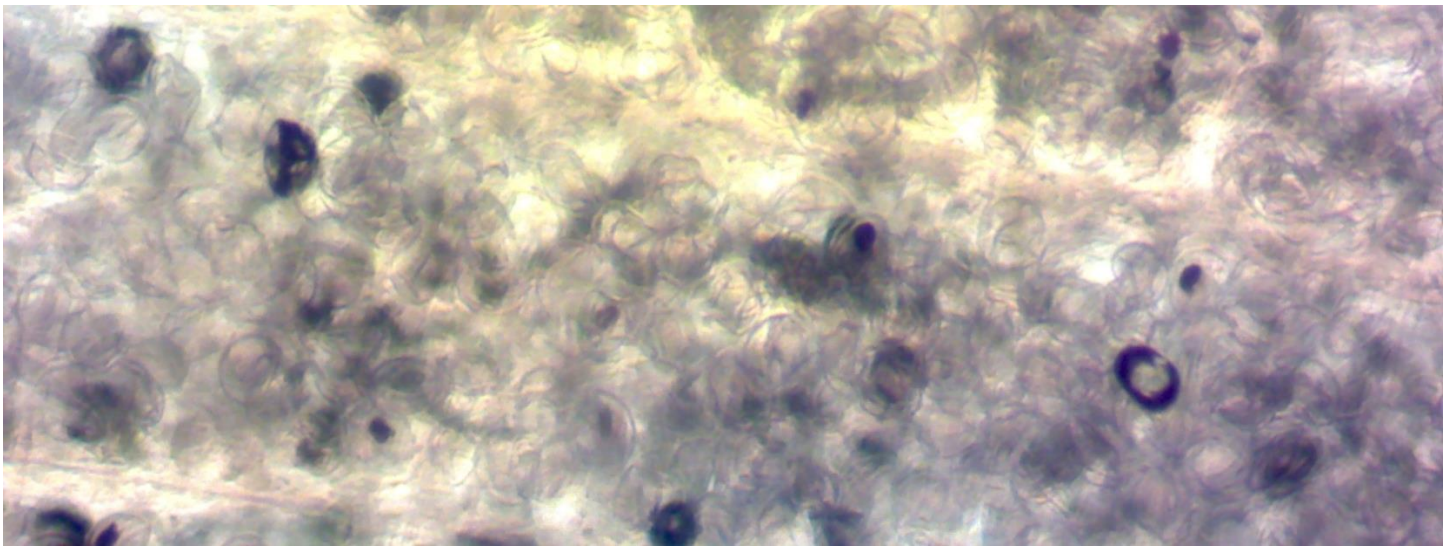
Adult. 10X objective. The tapeworms live and grow in a rat's intestine. Another view of a scolex, which in *H diminuta* has suckers only; no hooks. Distally, the segments grow bigger, as the gonads are growing and maturing, with much of the proglottid becoming occupied by the uteri, which will fill with eggs. When the gonads mature, sex can begin. Eventually the proglottids are stuffed with eggs and little else. Mature proglottids break off the posterior end of the animal and/or eggs are released into the colon and soon pass into the rat's poop.

The vintage *H. diminuta* tapeworm slides were made at the University of Illinois, likely between 1920 and the 1950. They were part a teaching collection of the famous parasitologist Professor Van Cleave. Harley Jones Van Cleave (1886-1953) was by all descriptions a remarkable man. In addition to his career at the University of Illinois he had worked at the US Bureau of Fisheries and Cold Springs Harbor Laboratory. He became president of the American Microscopical Society (apparently a very tiny society) and the American Society of Parasitologists. "Dr. Van" researched parasites of fish and other organisms, and his students loved him. He was chairman of the Department of Zoology at the University of Illinois, which now has a Harley Jones Van Cleave Professorship of Host-Parasite Interactions.

I was very fortunate to find two boxes of Dr. Van Cleave's teahing slides on eBay in 2014, listed by one of his previous graduate students, who used them in her own teaching. Most slides were made at the University of Illinois, and others were made by biological supply houses. Ward's Natural Science (and Carolina Biological Supply) still exist but Turtox/General Biological Supply House in Chicago, Triarch, Ann Arbor Biological Center and others are out of business. Too bad; they made some good slides.

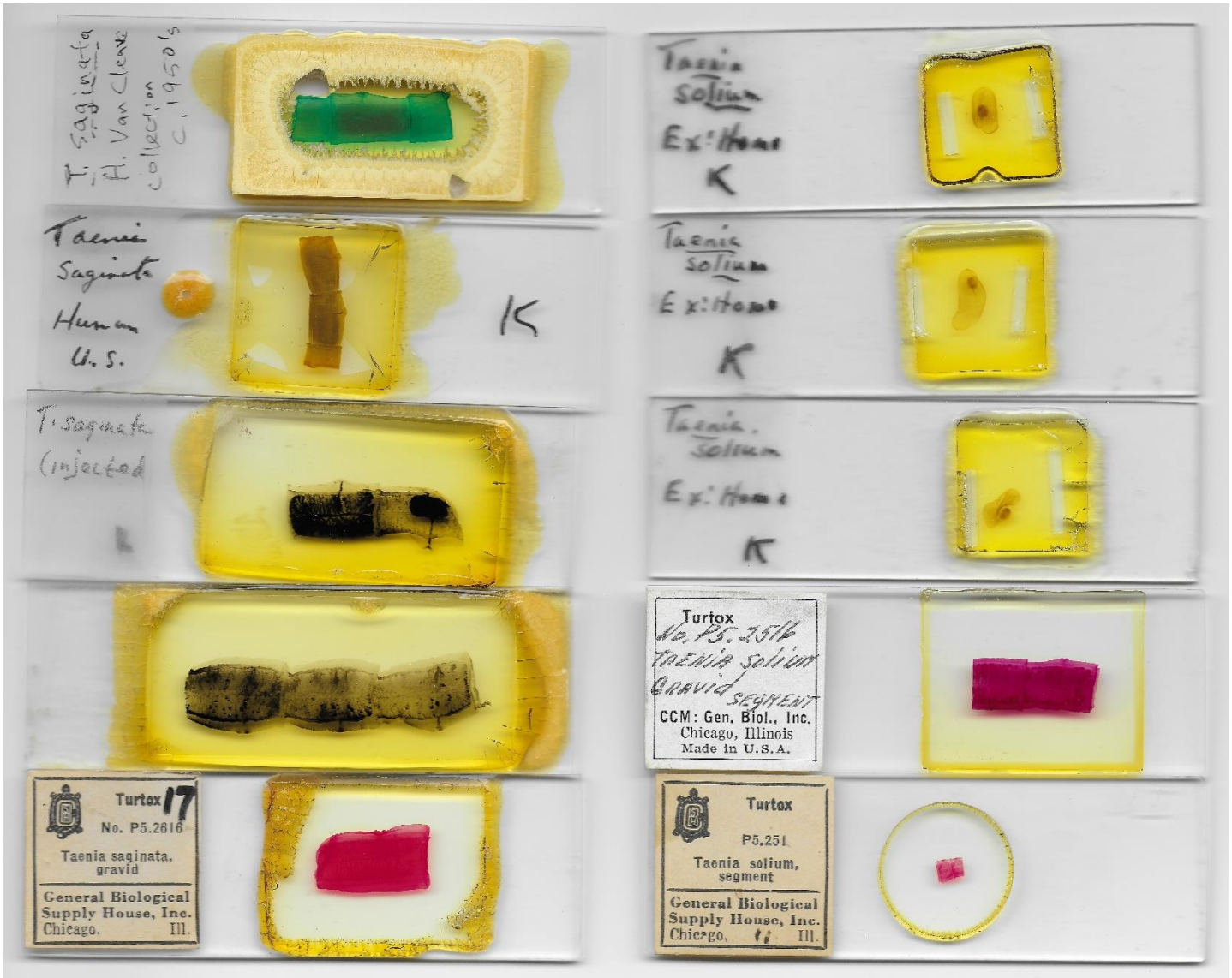


Left: more *H. diminuta* eggs "*ex Rattus*" (from rat feces) 40X objective



Above: maturing *H. diminuta* proglottid, packed with eggs, 10x

Text and photomicrographs by Ed Ward
lifecycle charts from CDC (The US Centers of Disease Control)
vintage ad above is from thequackdoctor.com



Some mid 20th century microscope slides of tapeworms in the genus *Taenia* that can cause disease in humans, from the teaching collection of Dr. Van Cleave at the University of Illinois.
(Ex:Homo on some labels does not refer to a change in sexual preference, but means specimen came from a human)

"Common" Human Tapeworm Diseases

Parasites are animals that live in the body of another animal, taking resources the host would otherwise use for itself (or living attached to the outside in the case of ectoparasites such as ticks). We find this so repulsive we give it a special name, "infestation" refers to parasitic diseases caused by animals such as tapeworms, flukes, roundworms, arthropods (i.e. mites, ticks, and lice) and some protozoa (malaria, amoeba, etc.) and excluding illness caused fungi, bacteria, and viruses, which we call infections. Although called "disease" in most cases worm parasites cause few or no symptoms. You may or might not get a bellyache or some diarrhea. If the parasite eats enough of your digested food, you'll lose weight. If there is a high risk of complications or you feel sick, then we doctors will treat you with anti-parasitic drugs. In the case of tapeworms, we might give you a dewormer, mostly similar to veterinary drugs.

Most US doctors don't need to know much about parasites. They'll never see patients with them. Lice and pinworms minor infestations and are less common than decades ago. Apart from a year in Africa, I've seen far more panic about parasites than actual parasites. Every few years a patient would come to my office convinced they have parasites. They can feel them moving, making them sick to their stomach. Patients have brought me proof; they caught some worms. In most cases it turned out to be tiny curled bit of toilet paper. These poor souls have become so anxious they can't tell what's real. I always consider the possibility that the patient could be right and do what I can to rule that out. Negative tests won't dissuade some people with delusional parasitism (that is the official diagnostic label) and some will find an alternative practitioner to give them arsenic, mercury or similar risky treatments.

Let's focus on some real medical aspects of tapeworms. You need not worry much about tapeworms if you have lived in a developed nation your whole life. The CDC (Centers for Disease Control) estimates less than 1000 people in the US get tapeworm infestation per year and most of those are migrant workers. But worldwide the food supply is not as secure and about 50-70 million humans are infected with *Taenia saginata* or *T. solium* (cattle or pig tapeworms) globally. And about 50,000 unfortunate souls die of cysticercosis annually mostly in the developing world. In the US, regulation of livestock feeding practices and inspection of food animals have largely eliminated human tapeworm infestations.

Tapeworms have a simple anatomy, but have evolved very complex life cycles. Most have a definitive host, the animal where adult tapeworms live and produce eggs, and a different intermediate host which harbors juvenile stages of tapeworm. Adult tapeworms invariably live in a vertebrate host's intestines, but tapeworm larva target one or more tissues throughout the bodies of an invertebrate or vertebrate, and may pass through more than one intermediate host.

Three tapeworms are medically important because humans are the usual definitive host (*Taenia saginata, T. solium, Hymenolepsis nana*). Less commonly, man is an accidental host (*H. diminuta, Dipylidium caninum, Diphyllobothrium latum, Bertiella*) or dead end host (*Echinococcus, Spirometra*). Most tapeworm infestations are harmless, but two species have larvae that can invade vital organs, resulting in potentially serious disease (cysticercosis caused by *T solium* and hydatid disease from *Echinococcus*). Before you get too worried, remember that tapeworm disease is very rare in the United States. I have practiced medicine for years, and have seen fewer cases than I have fingers. Most cases are intestinal, and the tapeworm has no interest in harming or being noticed by you, so many cases they cause no symptoms or problems at all.

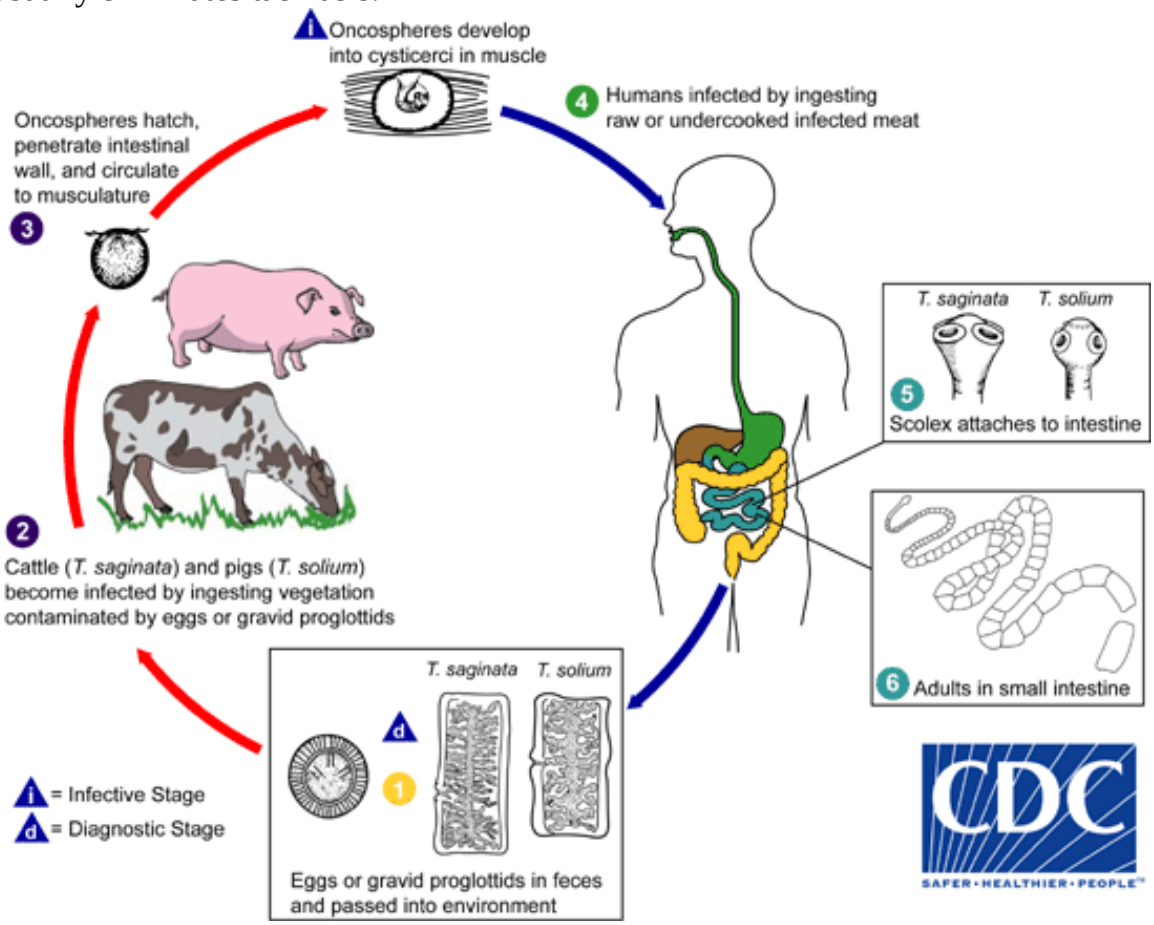
Dipylidium caninum can be passed from dogs to children who eat their fleas. Similarly, bertielliasis is a rare disease of children that eat mites infested by *Bertiella mucronata* or *B. studeri,* tapeworms of nonhuman primates, rodents or marsupials. Sparganosis is a rare disease that occurs when a person acquires the *Spirometra erinaceieuropaei* dog tapeworm by eating an infested frog or snake second intermediate host, bringing a complex life cycle to a dead-end.

Taeniasis

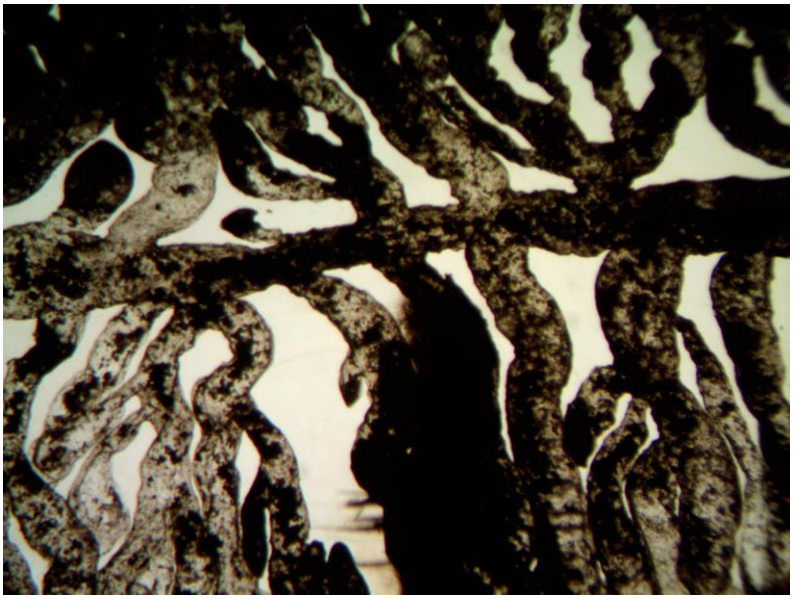
Taenia species tapeworms can cause intestinal infestation (taeniasis) or tissue invasion by cysts (cysticercosis). Taeniasis is acquired by eating infected, undercooked beef or pork. An old US government source estimated about 60 million people around the world were infested with *Taenia saginata* (the beef tapeworm) and about four million are infected with *T. solium* (pork tapeworm). *T. asiatica*, the Asian pork tapeworm, was named in 1993. Tapeworms are rare in the US thanks to public health and meat industry efforts, but migrants may harbor them.

Taenia cysticerci ingested in food attach to the intestine and grow to adulthood in about 3 months. Full size *Taenia* are big tapeworms, often about 4 to 8 meters (12 to 25 feet) long (some *T. saginata* have reached 25 meters), with up to 2000 proglottid segments with up to 100,000 eggs in each segment (a lot of eggs!). Taeniasis symptoms are usually mild, perhaps stomach discomfort, diarrhea, accompanied by the sight of proglottids in feces. Very rarely, proglottids may lodge in bile ducts or the appendix.

Diagnosis is by identification of eggs or proglottids from stool specimens examined under a microscope. Either of the dewormer drugs praziquantel or niclosamide, given orally in a single dose, usually eliminates taeniasis.



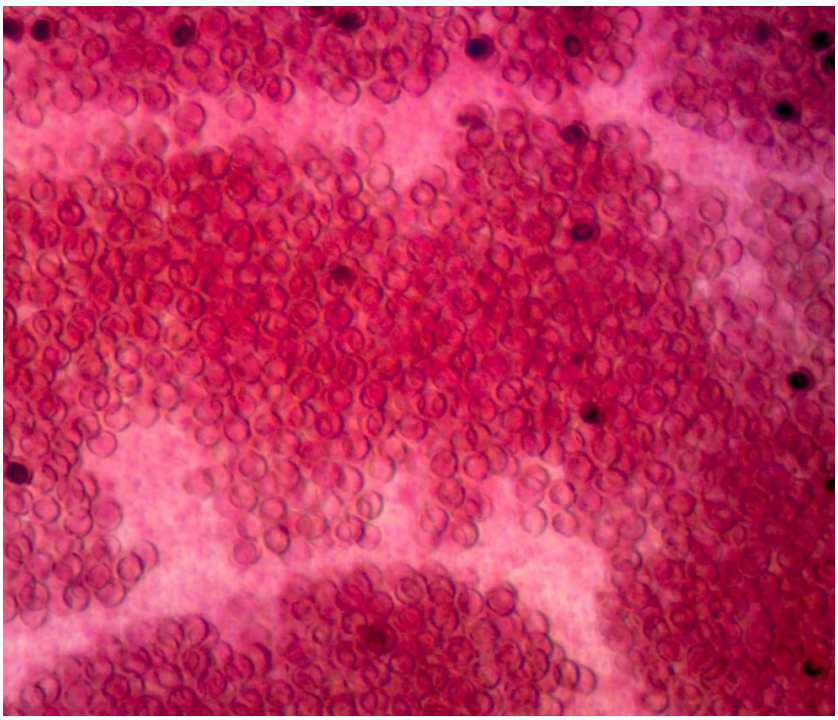
Taeniasis is the infection of humans with the adult tapeworm of *Taenia saginata* or *Taenia solium*. Humans are the only definitive hosts for *T. saginata* and *T. solium*. Eggs or gravid proglottids are passed with feces 1; the eggs can survive for days to months in the environment. Cattle (*T. saginata*) and pigs (*T. solium*) become infected by ingesting vegetation contaminated with eggs or gravid proglottids 2. In the animal's intestine, the oncospheres hatch 3, invade the intestinal wall, and migrate to the striated muscles, where they develop into cysticerci. A cysticercus can survive for several years in the animal. Humans become infected by ingesting raw or undercooked infected meat 4. In the human intestine, the cysticercus develops over 2 months into an adult tapeworm, which can survive for years. The adult tapeworms attach to the small intestine by their scolex 5 and reside in the small intestine 6. Length of adult worms is usually 5 m or less for *T. saginata* (however it may reach up to 25 m) and 2 to 7 m for *T. solium*. The adults produce proglottids which mature, become gravid, detach from the tapeworm, and migrate to the anus or are passed in the stool (approximately 6 per day). *T. saginata* adults usually have 1,000 to 2,000 proglottids, while *T. solium* adults have an average of 1,000 proglottids. The eggs contained in the gravid proglottids are released after the proglottids are passed with the feces. *T. saginata* may produce up to 100,000 and *T. solium* may produce 50,000 eggs per proglottid respectively. (from CDC/DPDx))



Proglottid of *Taenia saginata* (beef tapeworm) injected to show genital ducts, 2.5X objective

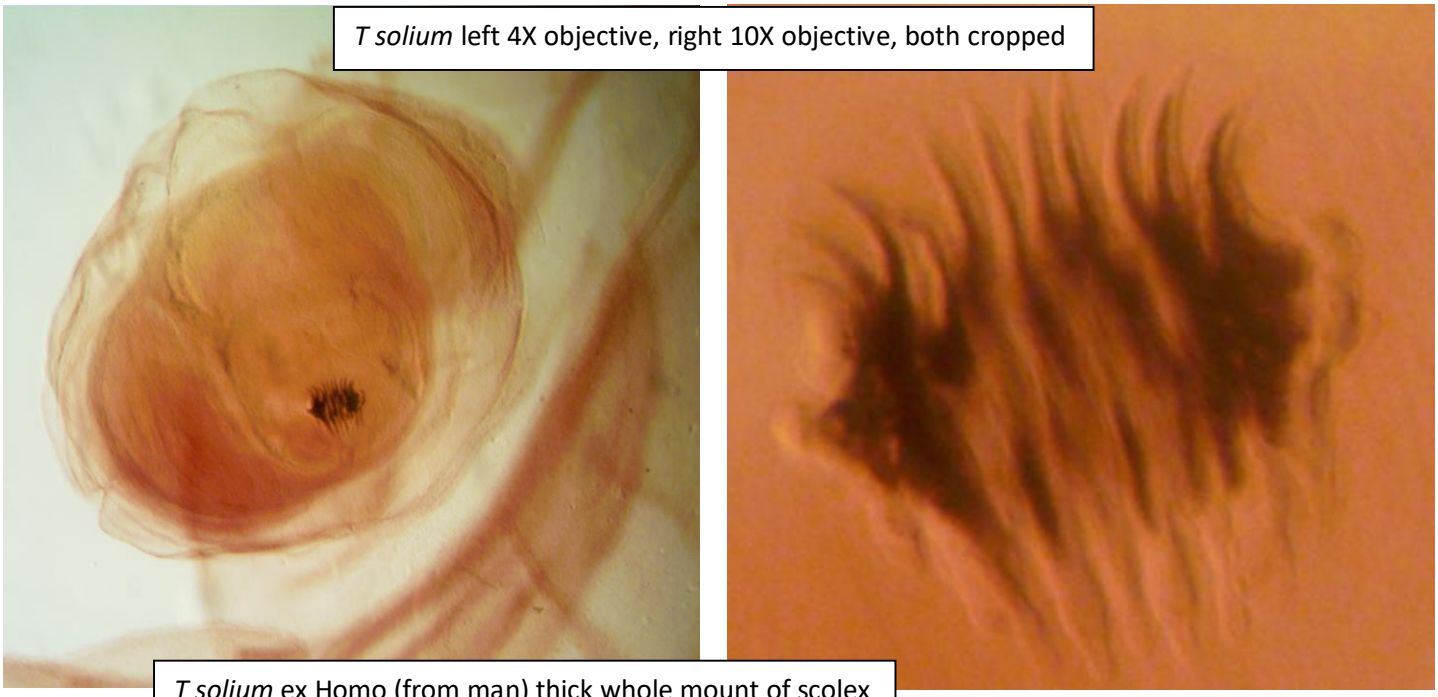
Cysticercosis

If *Taenia solium* eggs from an infested person are ingested, they can burrow across the intestinal wall and release cysticerci (larvae) into the circulation. The larvae travel in the bloodstream to brain, muscle and other tissues where the larvae (also called "bladder worms") then create cysts. Neurocysticerosis (tapeworm brain cysts) can cause seizures and occurs in parts of Mexico, Africa and Asia. *T solium* lives where pigs have access to human feces, and if food or water is then contaminated with human sewage cysticercosis can occur. Anti-worm drugs like albendazole can kill larvae in cysts, but the dead worm may provoke inflammation that makes the patient sicker. Treatment sometimes includes adding steroids or surgery, but sometimes just leaving the cysts alone (with anti-seizure drugs if needed) is the best approach.



Gravid proglottid of *Taenia solium* (pork tapeworm) packed with eggs, 2.5X objective

T solium left 4X objective, right 10X objective, both cropped

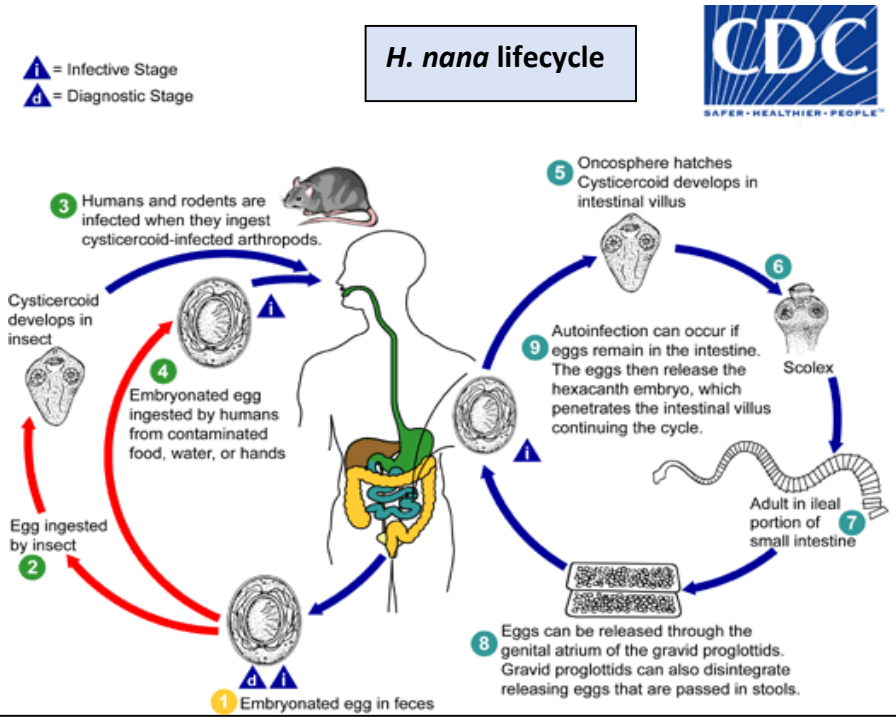


T solium ex Homo (from man) thick whole mount of scolex

Scolex (head) of *Hymenolepis nana* the dwarf human tapeworm, 10X obj

Hymenolepiasis

Hymenolepiasis is intestinal infection by *Hymenolepsis nana*, the dwarf human tapeworm (or very rarely *H. diminuta*, the rat tapeworm). *H. nana* is the most common human tapeworm worldwide, infesting hundreds of millions (particularly children in developing counties). The worm really is very tiny, only up to about 40 mm (4 cm) long, and symptoms are often mild or absent. Rodents and flour beetles can be infected by *H. nana.* Although the complete life cycle involves an arthropod intermediate host, *H. nana* eggs are directly infective to humans, and most transmission is through human to human fecal contamination of food or water. *H. nana* is also the only human tapeworm capable of autoinfection; it can reproduce itself to adulthood inside a host body, boosting parasite load. When I worked in Africa we didn't treat tapeworms, figuring they were unlikely to hurt the patient and likely to be quickly picked up again anyway. If treatment is indicated, one dose of praziquantel or two of niclosamide will do the trick.



Eggs of *Hymenolepis nana* are immediately infective when passed with the stool and cannot survive more than 10 days in the external environment 1. When eggs are ingested by an arthropod intermediate host 2 (various species of beetles and fleas may serve as intermediate hosts), they develop into cysticercoids, which can infect humans or rodents upon ingestion 3 and develop into adults in the small intestine. A morphologically identical variant, *H. nana* var. *fraterna*, infects rodents and uses arthropods as intermediate hosts. When eggs are ingested 4 (in contaminated food or water or from hands contaminated with feces), the oncospheres contained in the eggs are released. The oncospheres (hexacanth larvae) penetrate the intestinal villus and develop into cysticercoid larvae 5. Upon rupture of the villus, the cysticercoids return to the intestinal lumen, evaginate their scoleces 6, attach to the intestinal mucosa and develop into adults that reside in the ileal portion of the small intestine producing gravid proglottids 7. Eggs are passed in the stool when released from proglottids through its genital atrium or when proglottids disintegrate in the small intestine 8. An alternate mode of infection consists of internal autoinfection, where the eggs release their hexacanth embryo, which penetrates the villus continuing the infective cycle without passage through the external environment 9. The life span of adult worms is 4 to 6 weeks, but internal autoinfection allows the infection to persist for years. (from CDC/DPDx)

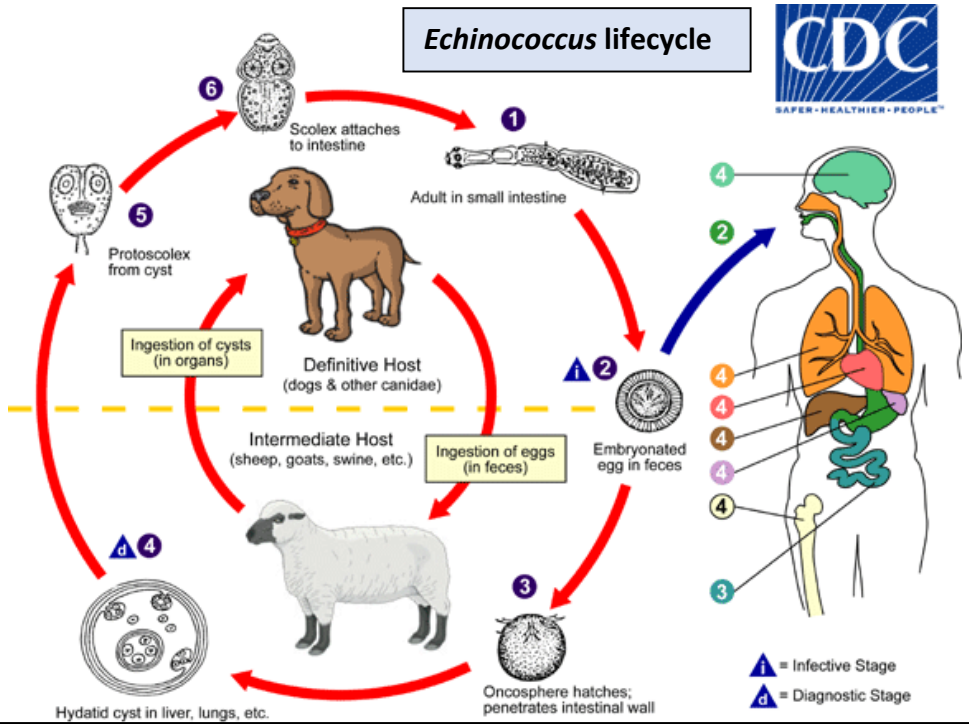
Hymenolepis diminuta is the rat tapeworm. Although smaller than most tapeworms it is 20 to 60 centimeters long, much bigger than *H. nana*. Rats are the definitive hast and fleas harbor cysticerci. Human children can rarely become accidental hosts if they eat an infected flea. Illness is usually mild or absent, and the same dewormer drugs can be used if needed.

Echinococcosis

Echinococcosis is a rare disease caused by dead-end infection by *Echinococcus granulosus* or *E. multilocularis* cysticercoid larvae in liver, lungs or other organs. Both species are tiny worms (6 mm adult) that use canines as definitive hosts; humans get sick by ingesting eggs.

Echinococcus granulosus causes hydatid disease (aka cystic echinococcosis), which is characterized by slowly growing cysts in the liver, lungs, or other tissues. The masses usually show up on CT scan, and blood tests can confirm the presence of *E. granulosus*. Surgery can remove hydatid cysts, but needle drainage with chemical injection or no treatment are options.

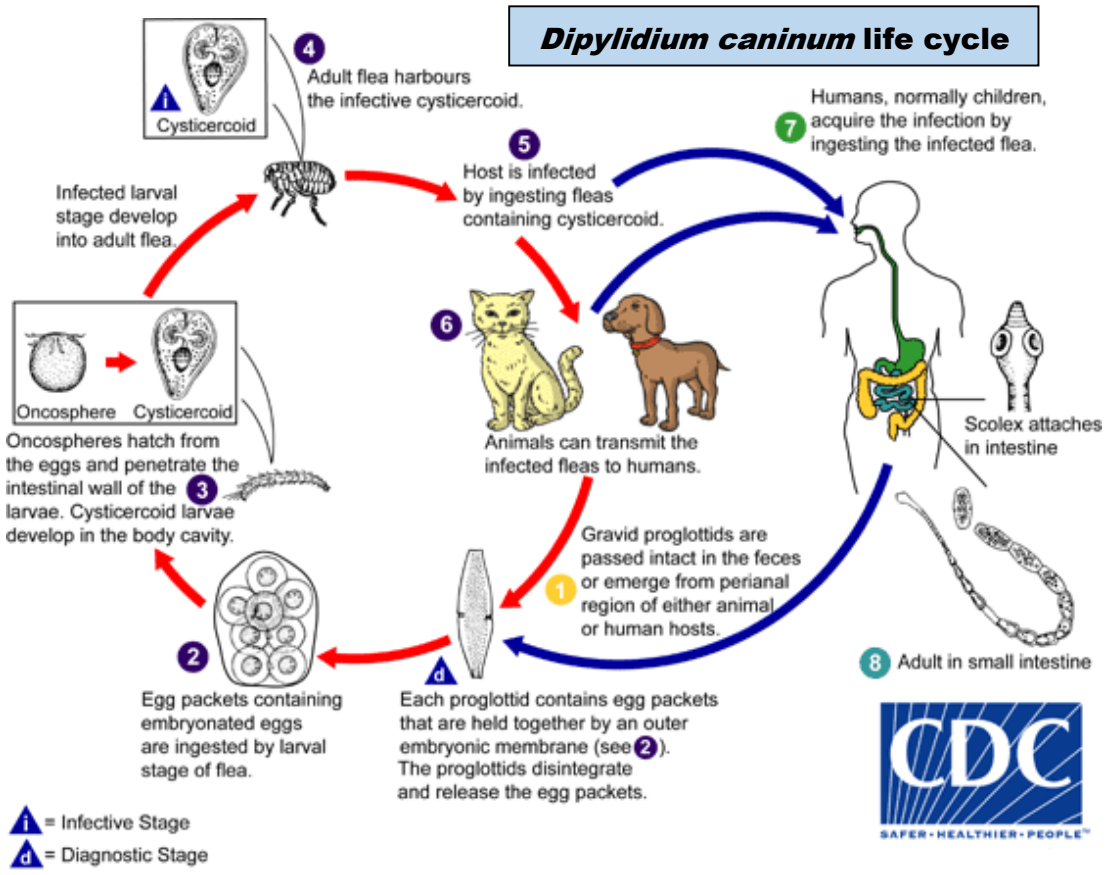
Echinococcus multilocularis causes alveolar echinococcosis, a rare disease of older men that presents with liver failure and masses mimicking liver cancer. X-rays show tiny 2-4mm calcified rings. Blood tests may not be positive at first, and the disease is often fatal, even with treatment (2 years of albendazole). The masses often "metastasize" to lung or brain.



The adult *Echinococcus granulosus* (3 to 6 mm long) (1) resides in the small bowel of the definitive hosts, dogs or other canids. Gravid proglottids release eggs (2) that are passed in the feces. After ingestion by a suitable intermediate host (under natural conditions: sheep, goat, swine, cattle, horses, camel), the egg hatches in the small bowel and releases an oncosphere (3) that penetrates the intestinal wall and migrates through the circulatory system into various organs, especially the liver and lungs. In these organs, the oncosphere develops into a cyst (4) that enlarges gradually, producing protoscolices and daughter cysts that fill the cyst interior. The definitive host becomes infected by ingesting the cyst-containing organs of the infected intermediate host. After ingestion, the protoscolices (5) evaginate, attach to the intestinal mucosa (6), and develop into adult stages (1) in 32- 80 days. The same life cycle occurs with *E. multilocularis* (1.2 to 3.7 mm), with the following differences: the definitive hosts are foxes, and to a lesser extent dogs, cats, coyotes and wolves; the intermediate host are small rodents; and larval growth (in the liver) remains indefinitely in the proliferative stage, resulting in invasion of the surrounding tissues. With *E. vogeli* (up to 5.6 mm long), the definitive hosts are bush dogs and dogs; the intermediate hosts are rodents; and the larval stage (in the liver, lungs and other organs) develops both externally and internally, resulting in multiple vesicles. *E. oligarthrus* (up to 2.9 mm long) has a life cycle that involves wild felids as definitive hosts and rodents as intermediate hosts. Humans become infected by ingesting eggs (2), with resulting release of oncospheres (3) in the intestine and the development of cysts (4), (4), (4), (4), (4), (4) in various organs. (CDC/DPDx)

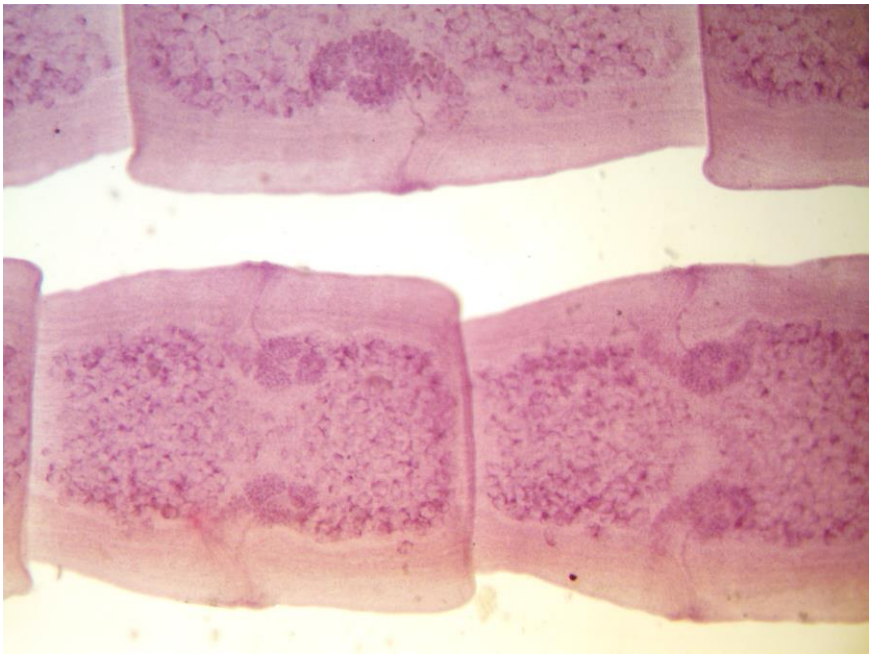
Dipylidium caninum is the two pored dog tapeworm (as its Latin name translates) also called the dog or flea tapeworm, or cucumber tapeworm, because of its usual hosts, and because of the seed-like shape and size of its segments. The definitive host (harbors adult worms) is dogs, but *D. caninum* occasionally infests cats, and on rare occasion flea eating human children. The worm requires a flea (or sometimes a biting louse) as an intermediate host to complete its life cycle.

When mature, segments (proglottids) break off the end of the adult worm and either pass out in the dog's feces or crawl out of the dog's anus. The proglottids release many thousands of eggs, most of which will perish on the ground. But a lucky few eggs are eaten by small fleas (in their larval stage). The eggs hatch into oncospheres which burrow across the intestinal wall of the flea and become cysticercoids (tapeworm larva, also called "bladder worms") in the body cavity of the adult flea. When a dog eats the bloodsucking insect ectoparasite flea, it is infected by the endoparasite hidden within. The cysticercoid grows into an adult worm, living in the dog's intestine. Then a cycle that started over 270 million years ago with the first tapeworm can repeat itself yet again.



Full size adult *D. caninum* are about 18 inches (45 cm) long. The host may be asymptomatic, or get a little diarrhea or but may notice passing what look like seeds in the stool. Mature, egg stuffed proglottids break off to be passed in the feces, or to crawl out the anus. Isolated *D. caninum* proglottids have been called "crawling cucumber seeds". At first I was surprised by tiny blind, headless segments of worm being mobile. But nature has accomplished far harder tasks. Millennia ago, some worms that by chance mutation had proglottids which could move a little bit probably succeeded in getting more eggs outside its host's body where they were eaten by fleas, and the two pored dog tapeworms of today are those egg's descendants.

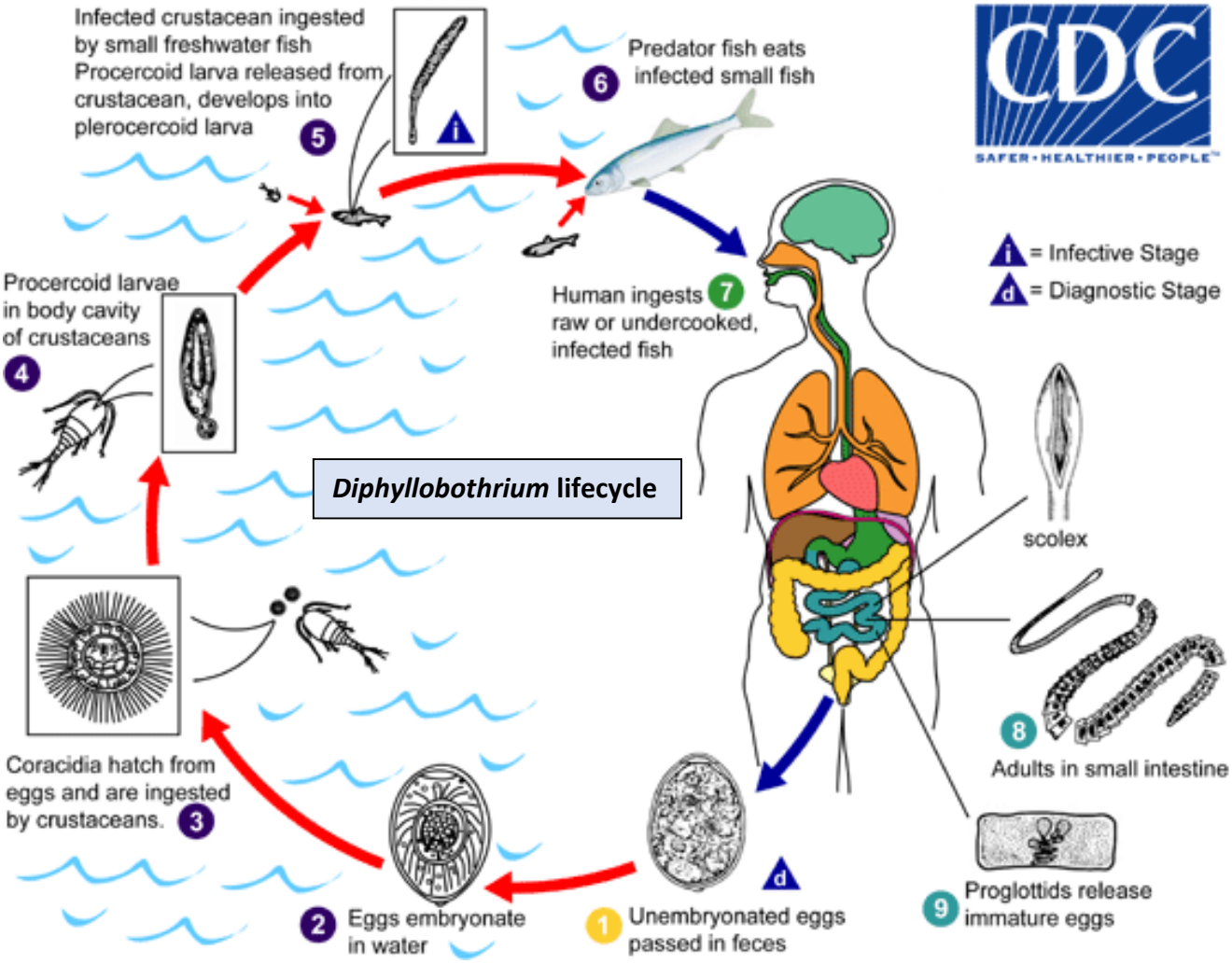
Scolex (head) of *Dipylidium caninum*
the two pored dog tapeworm
20X objective (direct, no reducer)



Proglottids of *Dipylidium caninum*
two pored dog tapeworm
4X objective (with 0.5X reducer)

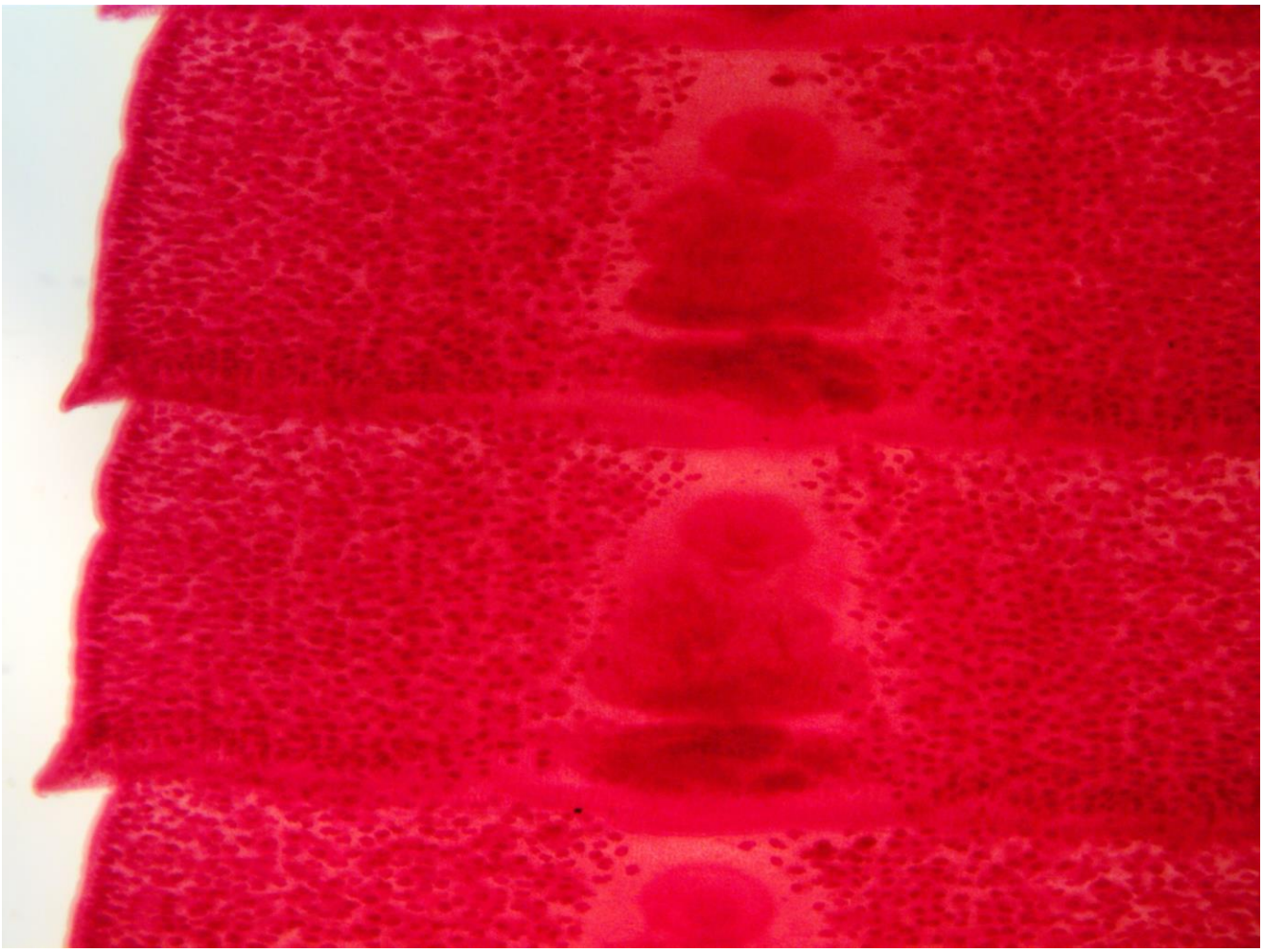
Diphyllobothriasis

Diphyllobothrium latum, aka the broad or fish tapeworm, can infect people near the Baltic Sea or in Asia (rarely North Amercia) who eat infested, undercooked freshwater fish. The resulting intestinal infection is often asymptomatic, but B12 deciency anemia, eosinophilia, and bile duct blockage (by proglottids) may occur. If needed, diphyllobothriasis is easily treated with drugs. The adult tapeworm is up to 10 meters long with wide, dosoventrally flattened proglottids.

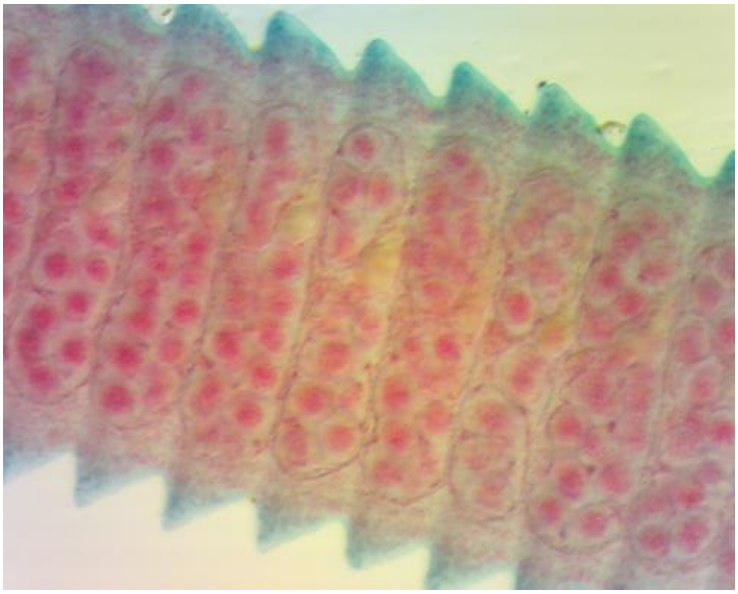


Immature eggs are passed in feces 1. Under appropriate conditions, the eggs mature (approximately 18 to 20 days) 2 and yield oncospheres which develop into a coracidia 3. After ingestion by a suitable freshwater crustacean (the copepod first intermediate host) the coracidia develop into procercoid larvae 4. Following ingestion of the copepod by a suitable second intermediate host, typically minnows and other small freshwater fish, the procercoid larvae are released from the crustacean and migrate into the fish flesh where they develop into a plerocercoid larvae (sparganum) 5. The plerocercoid larvae are the infective stage for humans. Because humans do not generally eat undercooked minnows and similar small freshwater fish, these do not represent an important source of infection. Nevertheless, these small second intermediate hosts can be eaten by larger predator species, e.g., trout, perch, walleyed pike 6. In this case, the sparganum can migrate to the musculature of the larger predator fish and humans can acquire the disease by eating these later intermediate infected host fish raw or undercooked 7. After ingestion of the infected fish, the plerocercoid develop into immature adults and then into mature adult tapeworms which will reside in the small intestine. The adults of *D. latum* attach to the intestinal mucosa by means of the two bilateral groves (bothria) of their scolex 8. The adults can reach more than 10 m in length, with more than 3,000 proglottids. Immature eggs are discharged from the proglottids (up to 1,000,000 eggs per day per worm) 9 and are passed in the feces 1. Eggs appear in the feces 5 to 6 weeks after infection. In addition to humans, many other fish eating mammals can also serve as definitive hosts for *D. latum*. (CDC/DPDx)

The elaborate multi-stage, multi-host lifecycle of fish tapeworm *Diphyllobothrium* is a wonder to behold. Long before DNA sequencing, over many years old fashion biologists with simple microscopes pieced together that the very different parasites they found in copepods, small fish, big fish, seals, sea gulls and people were not different species, but actually the life stages of a large tapeworm. The tapeworm is like Moby Dick, uncaring and in this case literally blind as it is passed from animal to animal. The worm is not out to get us, nor will it show us mercy. If we have the misfortune to eat some under-smoked herring, and years later have the bad luck that one of thousands of shed proglottids gets lodged in our bile duct, we'll get sick with pain and jaundice and likely go under the knife for a "gallstone". The surgeon will get a big surprise when he checks out the bile duct: that's no stone, that's a piece of some strange parasite. Man is a part of those vast ecological webs that move bits of flesh and energy around the surface of the earth. Man fancies himself as above all that, supreme ruler of the planet and subject to no rules. But although highly evolved man is unique in being sentient and technological, to the blind worm we are just another fish eating mammal in which to complete its programming to make more worms. Truly everything in the universe is connected to everything else.



***Diphyllobothrium latum*, broad fish tapeworm by Turtox, in Van Cleave slide collection**
Ovaries are in middle of proglottid, the small dots are each a testes. A lot of gonads.
4X obiective



Above: some parasite slides from collection of Professor Van Cleave

Left: proglottids of *Hymenolepis nana* dwarf human tapeworm, with maturing ovaries, 10X objective

hooks on scolex of *Taenia pisiformis* the rabbit tapeworm
Antique microscope slide by Joseph Bourgogne, Paris, 1860
20X objective, phase contrast, stitch of 2 images
(image about 0.2 mm across)

As always, Micscape has lots of good information for amateur microscopists wanting to learn more about how to do it yourself.

I was inspired to think more about the patterns in nature by reading the essays of Richard Hovey over the years. He references tapeworms a few times in his wide ranging essays.

Ed Ward, comments welcomed, email – eward1897 AT gmail DOT com

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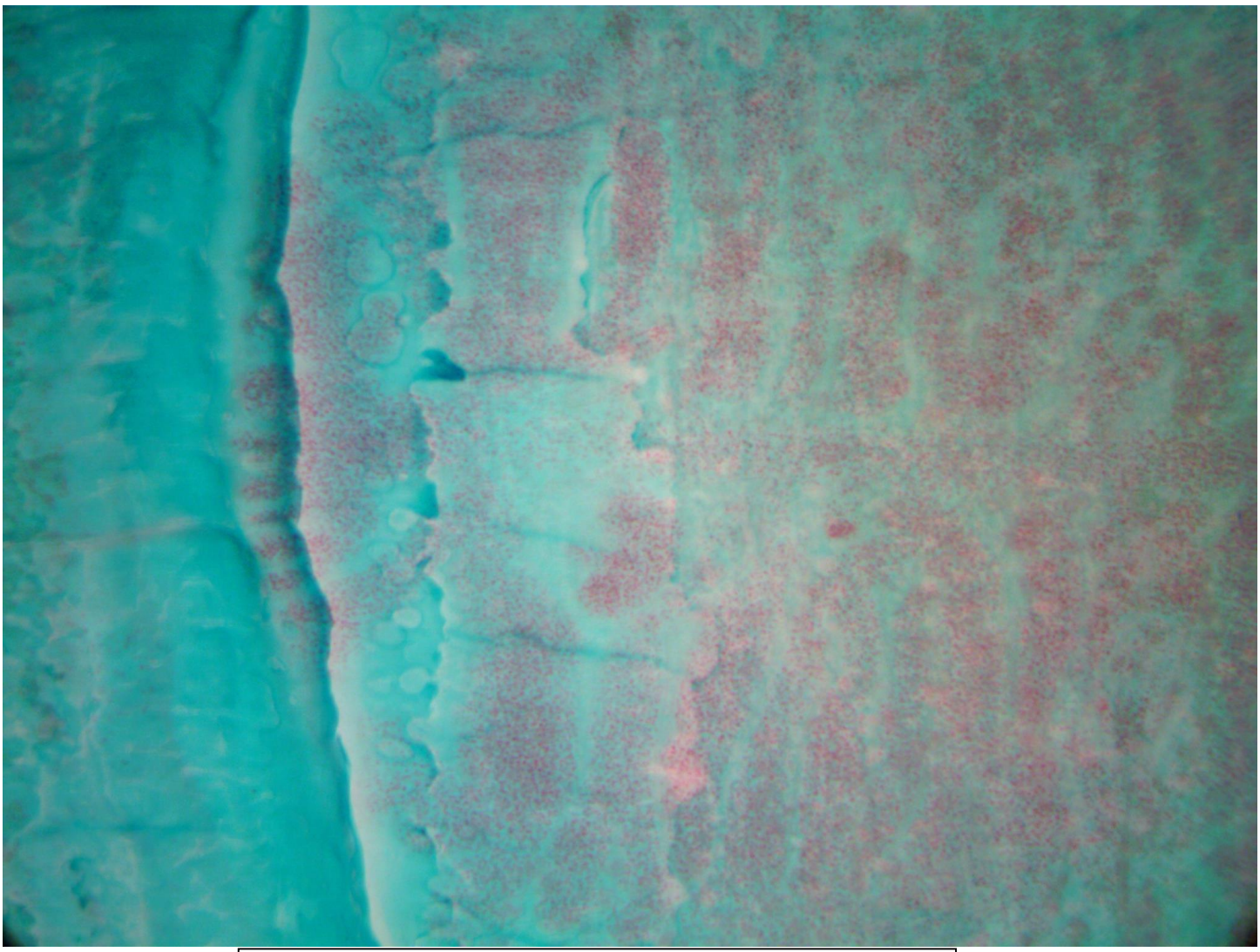

Part of a big proglottid of *Taenia saginata,* the beef tapeworm
Nice stains by Professor Van Cleave
2.5X objective, image is about 5 mm across