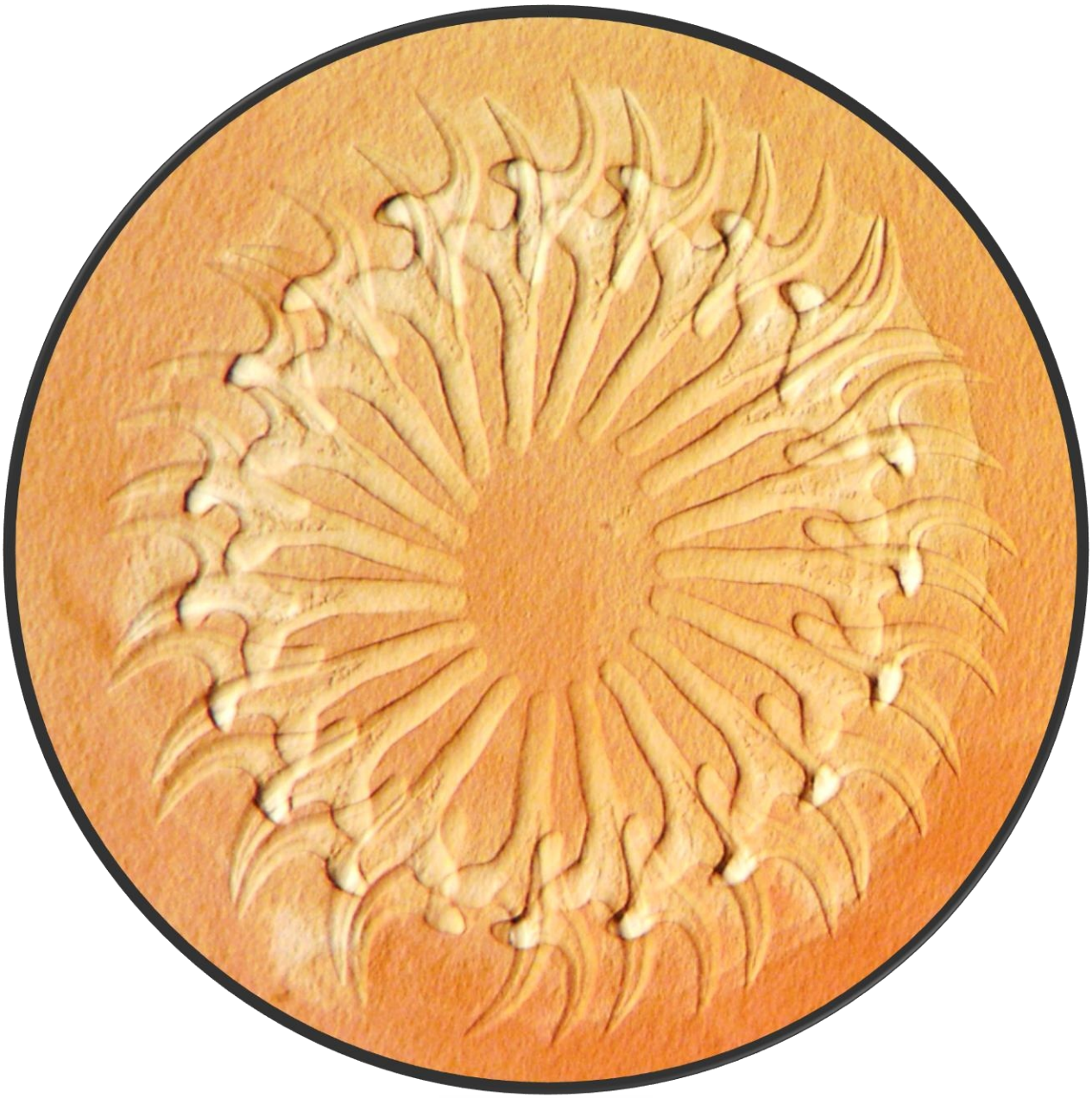
Parasites part 5 some parasites that are flatworms



Ed Ward MD, Minnesota USA

April 2024

Origins of this article

I have long been fascinated by strange organisms. In my training I gave talks about spotted fevers and the ticks that spread them. I volunteered in West Africa in 2004, treating parasites and other neglected tropical diseases. About a decade ago I started using old microscopes as a hobby, and now I contribute to *Micscape* magazine.

My curiosity makes for a long article divided into parts. Flatworms are discussed now, and eventually I'll relate my own and other true stories about patients with parasites. I collect vintage slides of parasites, allowing me to illustrate some kinds. I focus mostly on human parasites, but many of my images show parasites of animals

Disclaimers

I started out as a little boy and have not fully matured, still thinking creepy crawly things are interesting.

I am a medical doctor (general internal medicine) but nothing in this article should be used to diagnose or treat medical conditions. Medical Parasitology is a subspecialty full of rare cases and exceptions. The few times I encountered parasites locally, I consulted the US CDC website and the state health department.

If you think you have parasites, consult your doctor. If you live in the USA or Europe having serious parasites is very unlikely, so the doctor will likely dismiss your self diagnosis without testing and offer you $100 of anxiety pills. An alternative healer might happily order $200 of parasite tests and sell you a $200 parasite cleanse you don't need. Serious human parasites are now rare in wealthy nations. Soap, clean water, well cooked meat, shoes and flush toilets are your best bets against parasites.

Cover page illustration

The job of an adult tapeworm is to hang on to your intestinal wall. These hooks on the scolex of *Taenia pisiformis*, the rabbit tapeworm, certainly appear up to the task. Tapeworms have no mouth.
Antique microscope slide by Joseph Bourgogne, Paris, 1860
10X objective, oblique lighting
(hook circle is about 0.2 mm across)

Other illustrations

If not noted otherwise, photomicrographs are mine, taken with AO/Reichert microscopes with USB camera. With a 0.5X reducer (added late 2017) my 2.5X objective images are about 5 mm across, the 4X about 3 mm, 10X about 1.2 mm, 40X about 0.3 mm (300 microns), and 100X about 125 microns. Some images adjusted for brightness and contrast. Some patient photos of mine from West Africa are also included.

Contents

Abstract **(pertains to parasites in general)**

Life spreads and adapts everywhere it can survive, including inside and outside the bodies of animals. The bodies of animals turned out to be comfy and tasty. Evolution therefore produces many endoparasites (like intestinal worms) and ectoparasites (such as lice). Most wild animals have parasites, as did most humans in the past. Although most individuals are not harmed, parasites can injure by heavy infestation or by complications. In poor and tropical areas many people are still harmed and even killed, including about 600,000 annual deaths from malaria. Some parasites can also act as vectors to spread bacteria and viruses that cause Lyme disease, encephalitis, plague and other disease. Nearly half of humans still have parasites, most commonly helminths (worms) and hidden toxoplasmosis, but they don't make most of us sick. Members of many different branches of life have sometimes become parasitic: especially protozoans, flatworms, roundworms, and arthropods (including ticks, crustaceans, insects). I will discuss three main kinds of parasites of humans: protozoan parasites, worms, and ectoparasites.

Parasites are most harmful in the tropical and poor areas of the world. We need to continue life saving efforts to control malaria, worms, and other neglected tropical diseases. Still, most of you reading this need not fear parasites. Anxiety about parasites is far more common than parasitic disease in the developed world. Parasites may be the majority of animal species. The balance of nature might be hurt if we continue to extinct parasite species faster than we can discover them.

Proteocephalus tapeworm from large mouth bass, slide H Van Cleave, 10X objective, image ~ 1 mm wide

Haematopinus suis pig louse, antique slide by Edward Ward, Manchester, stereomicroscope

Chapter 3, part A, Flatworm parasites

Outline

Many different groups of animals have settled on a long cylindrical body shape, and we call them **worms**. Those that are parasites are called **helminths**. Most of those parasites are flatworms (tapeworms and flukes) or roundworms.

Taxonomy schemes for Phylum Platyhelminthes

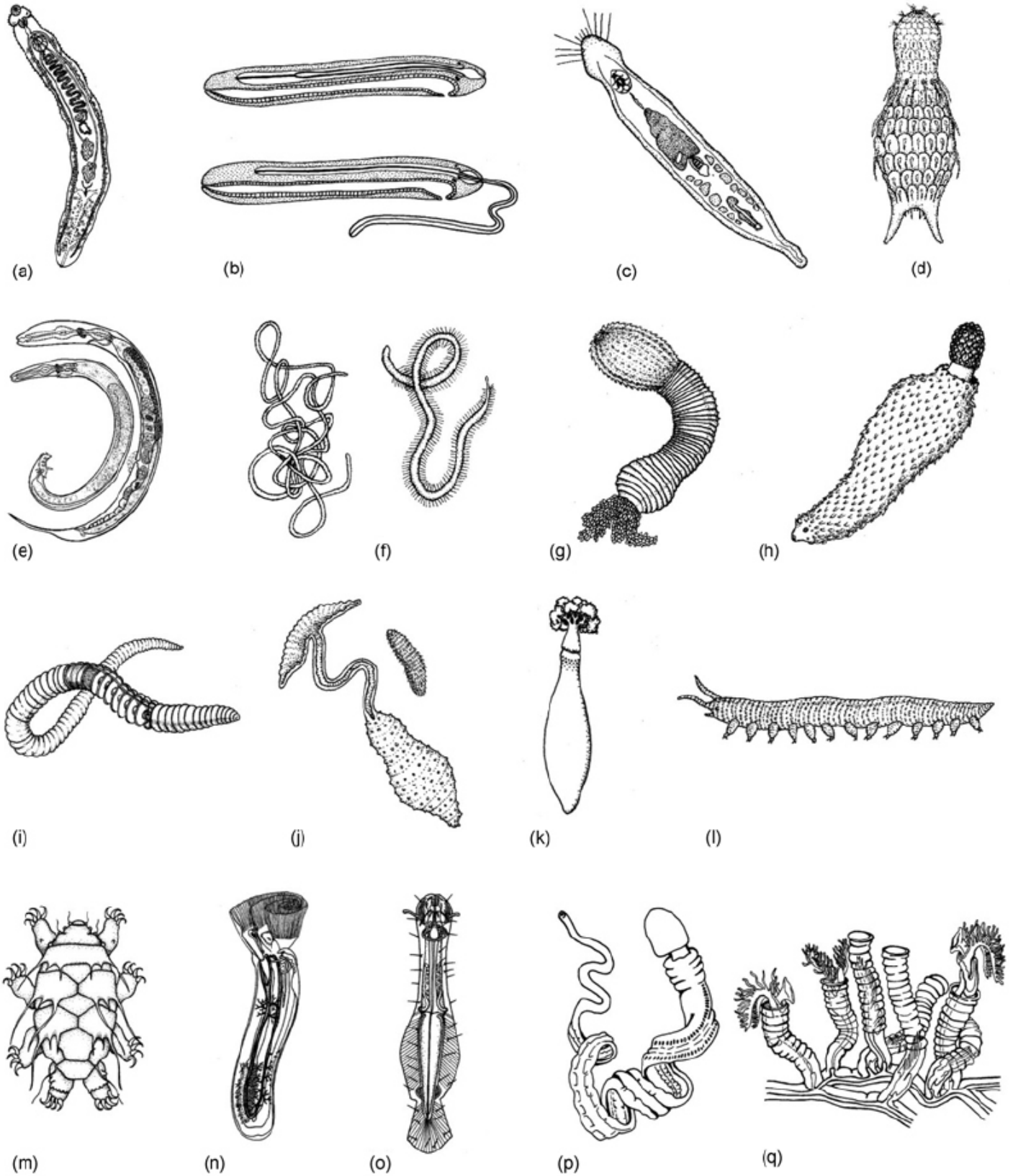
Traditional classification (based on anatomy and lifestyle)

- Class Turbellaria (free living flatworms)
- parasitic:
  - Class Cestoda (tapeworms)
  - Class Trematoda (flukes)
  - Class Monogenea (ectoparasites of fish)

Newer phylogenetic classification (based on relatedness; genomic)

- Class Catenulida (only 100 species, small free living)
- Subphylum Rhabditophora
  - Classes Turbellaria, Cestoda, Trematoda, Monogenea, others
  - "dangling" orders include Rhabdocoela, Polycladida, Tricladida (planaria), others

Not discussed this month are other worm groups with parasites: Nematoda, Acanthocephala, etc.



16 extant vermiform phyla (a) Platyhelminthes; (b) Nemertea; (c) Gnathostomulida; (d) Gastrotricha; (e) Nematoda; (f) Nematomorpha; (g) Priapulida; (h) Acanthocephala; (i) Annelida; (j) Echiura; (k) Sipuncula; (l) Onychophora; (m) Tardigrada; (n) Phoronida; (o) Chaetognatha; (p) and (q) Hemichordata: (p) acorn worm; (q) pterobranchia. not to scale. from Ma, Hou, Baines. (2010). Phylogeny and evolutionary significance of vermiform animals from the Early Cambrian Chengjiang Lagerstätte. **Science China Earth Science** 2010

Nonparasitic Flatworms Gone Wild

One free living flatworm in the news is the **hammerhead worm**. These toxic worms are native to Asia, and now there are 5 invasive species in the Eastern US and Canada.

Hammerhead planaria poss. *Diversibipalium sp*, Dairy Farm Nature Park, Singapore, Feb 2024, Bird Ecology Study group website

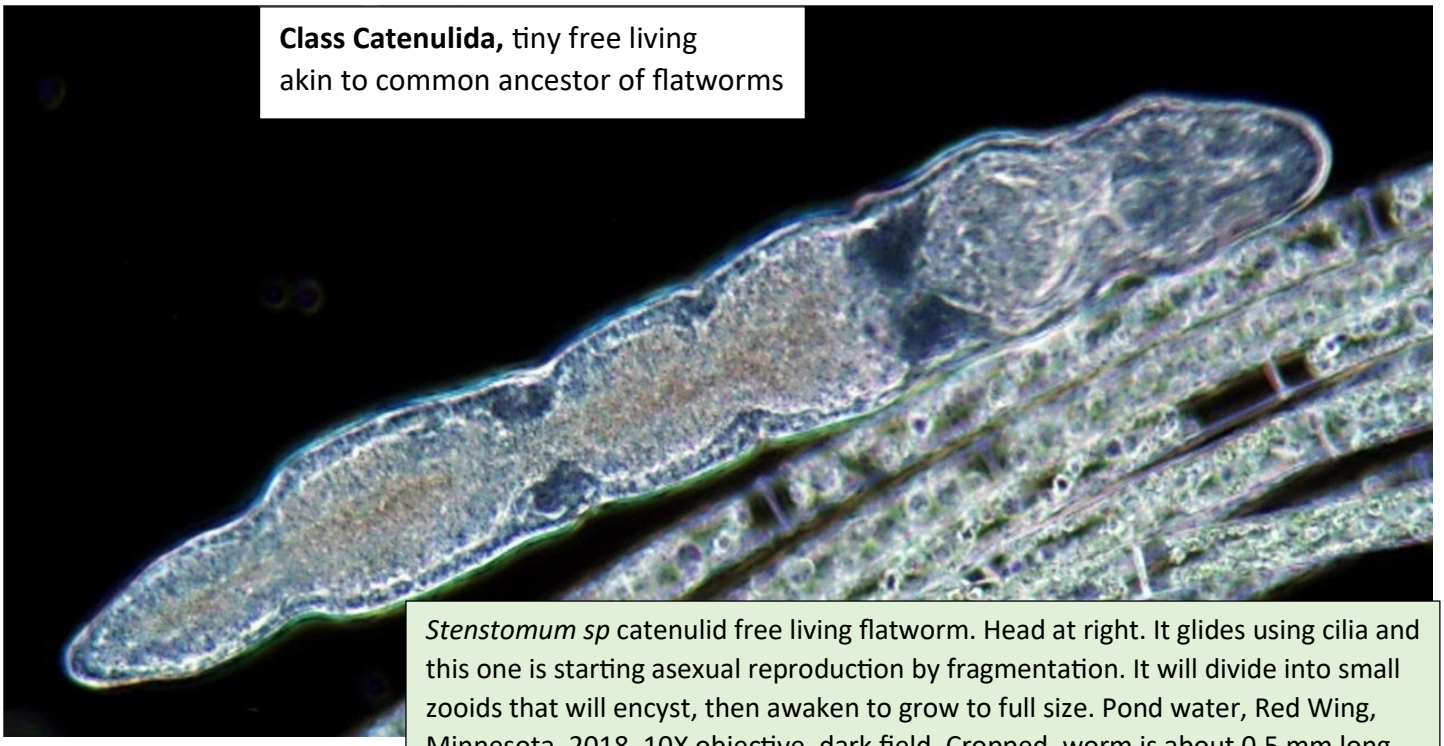
These big, beautiful creatures are land planaria (order Tricladida, 3 main intestinal branches) that can reach 25 cm (10 inches) long. They can be confused with slugs or snakes but have a large version of the simple flatworm body plan. No heart, lungs or gills; oxygen is absorbed through moist skin. *Bipalium sp* contain deadly tetrodotoxin, so don't eat them and minimize handling. Tetrodotoxin is the same sodium channel nerve poison that can kill you if the chef doesn't properly fillet your pufferfish (the toxin is secreted by symbiotic bacteria embedded in the fish). Perfectly cooked pufferfish is said to make your tongue pleasantly tingle from just a touch of poison. Hammerhead land planaria are voracious predators of earthworms and other small invertebrates.

More free living flatworms Gone Wild

Marine flatworms can be so beautiful as to defy imagination. Many are poisonous and evolved bright colors as a warning to potential predators. Some swim with undulating movements. These flatworms look much like sea slugs, but the two are not closely related. Sea slugs are gastropod mollusks with a body cavity, anus, heart, gills and other good bodily inventions not developed by humble, simpler flatworms. These bright marine flatworms are in Order Polycladida ("many branched" referring to intestinal shape).

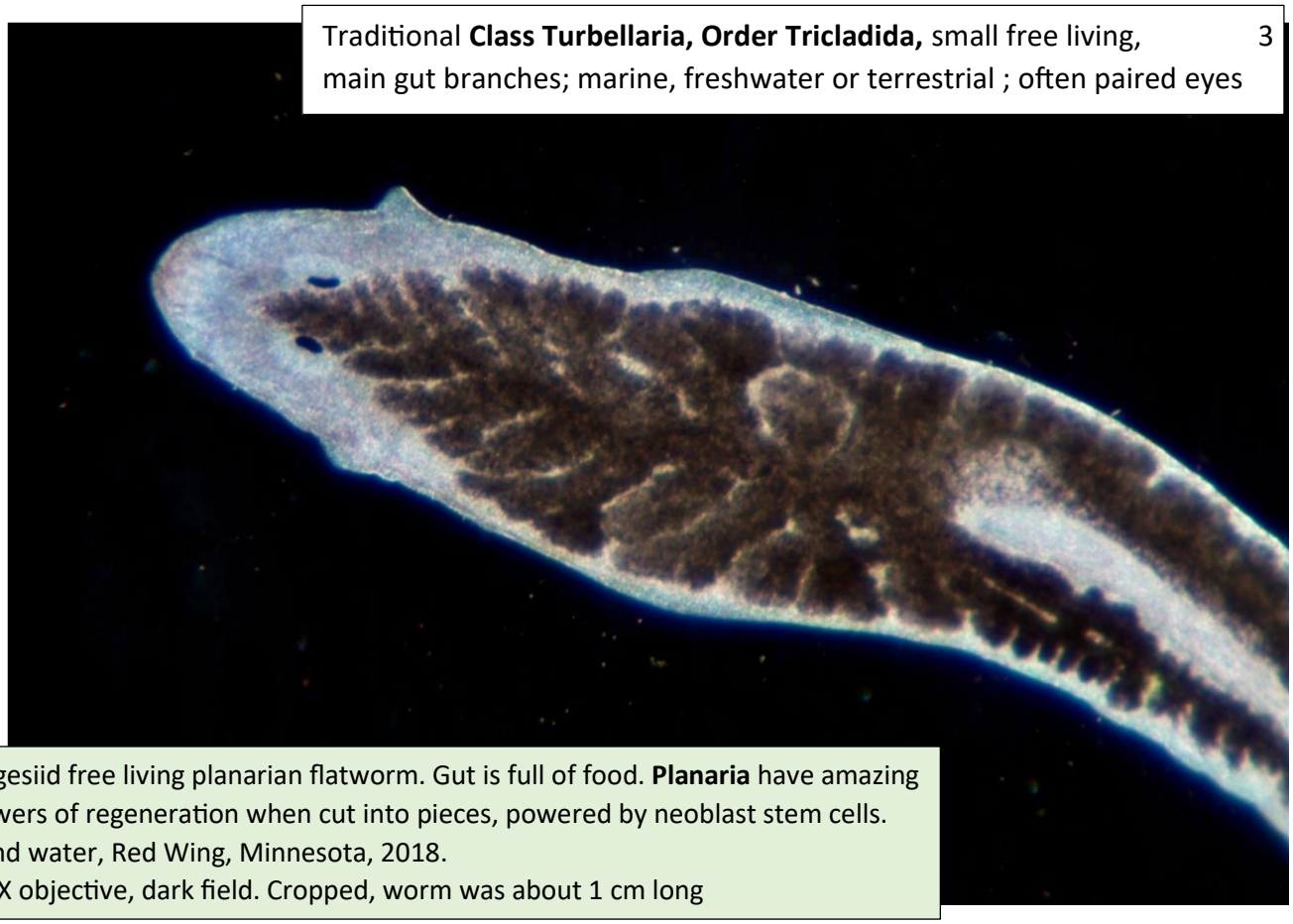
In addition to flamboyant colors, marine flatworms have swagger too. The lower right photo shows two worms "**penis fencing**". One or both hermaphrodites (each has male and female organs) may be punctured by a stylet penis and injected with sperm from their rival/lover. (photos wildsingapore.com, except lower right reed.edu/biology/AmeliaMegana)

Some examples of major flatworm groups



Class Catenulida, tiny free living
akin to common ancestor of flatworms

Stenstomum sp catenulid free living flatworm. Head at right. It glides using cilia and this one is starting asexual reproduction by fragmentation. It will divide into small zooids that will encyst, then awaken to grow to full size. Pond water, Red Wing, Minnesota, 2018. 10X objective, dark field. Cropped, worm is about 0.5 mm long

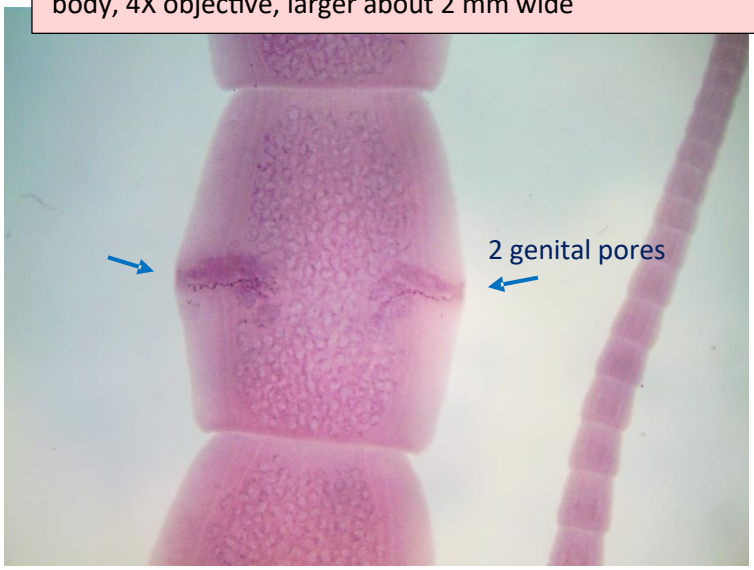


Traditional **Class Turbellaria, Order Tricladida,** small free living, 3
main gut branches; marine, freshwater or terrestrial ; often paired eyes

Dugesiid free living planarian flatworm. Gut is full of food. **Planaria** have amazing powers of regeneration when cut into pieces, powered by neoblast stem cells. Pond water, Red Wing, Minnesota, 2018.
2.5X objective, dark field. Cropped, worm was about 1 cm long

Class Cestoda, intestinal parasites, head modified for attachment, body segmented, i.e**. tapeworms**

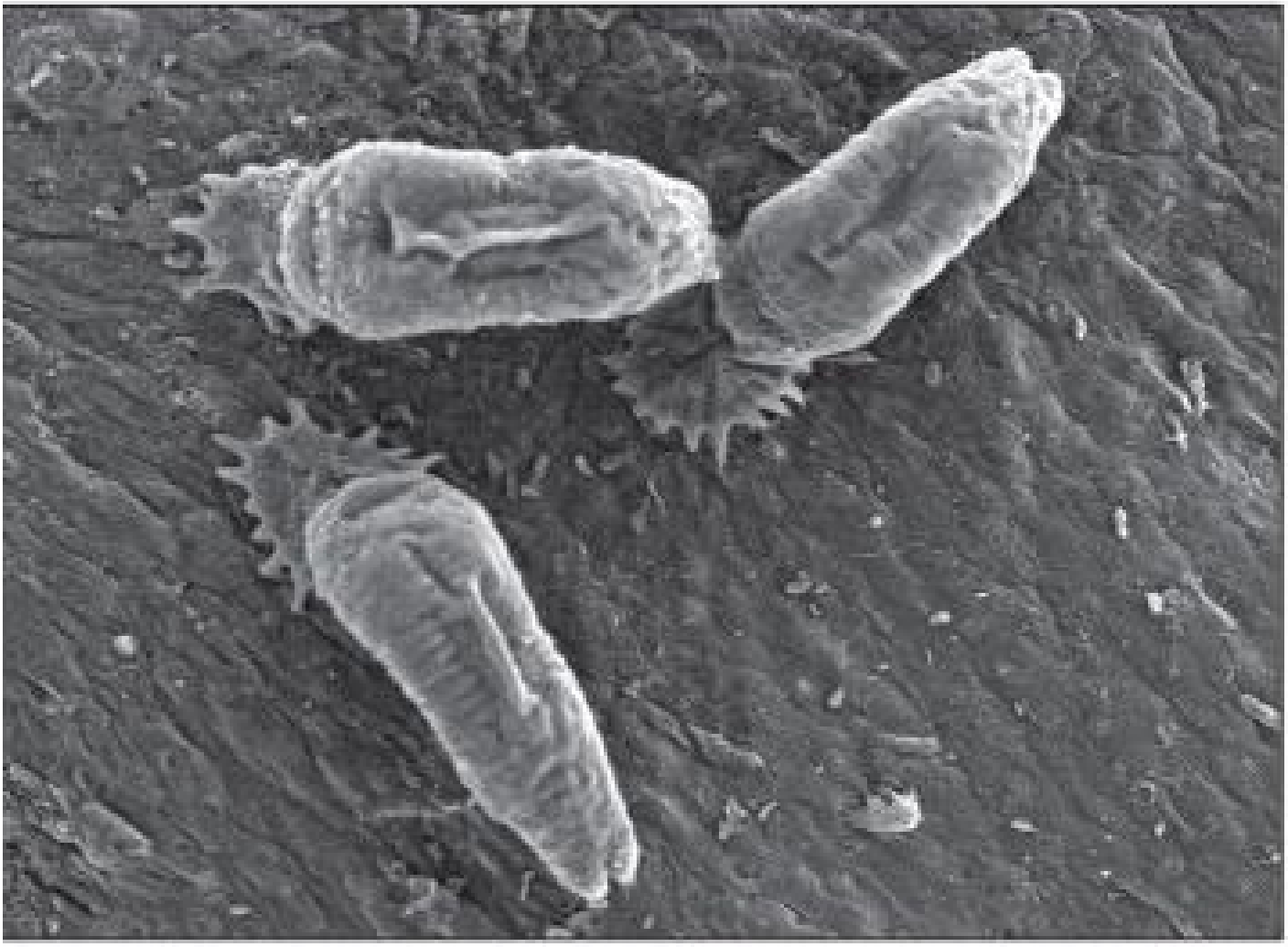
Dipyllidium caninum aka the two pored dog tapeworm, has a life cycle in fleas and dogs, but human children sometimes eat infected fleas. Adults live in the intestine and pass wriggling "cucumber seed" proglottids in feces. At left: scolex with hooks and 4 suckers, 20X objective, phase contrast, ~0.3 mm wide. Below: two portions of body, 4X objective, larger about 2 mm wide



Class Trematoda, internal parasites with complex life cycles that may involve blood, liver or lungs, i.e. **flukes**

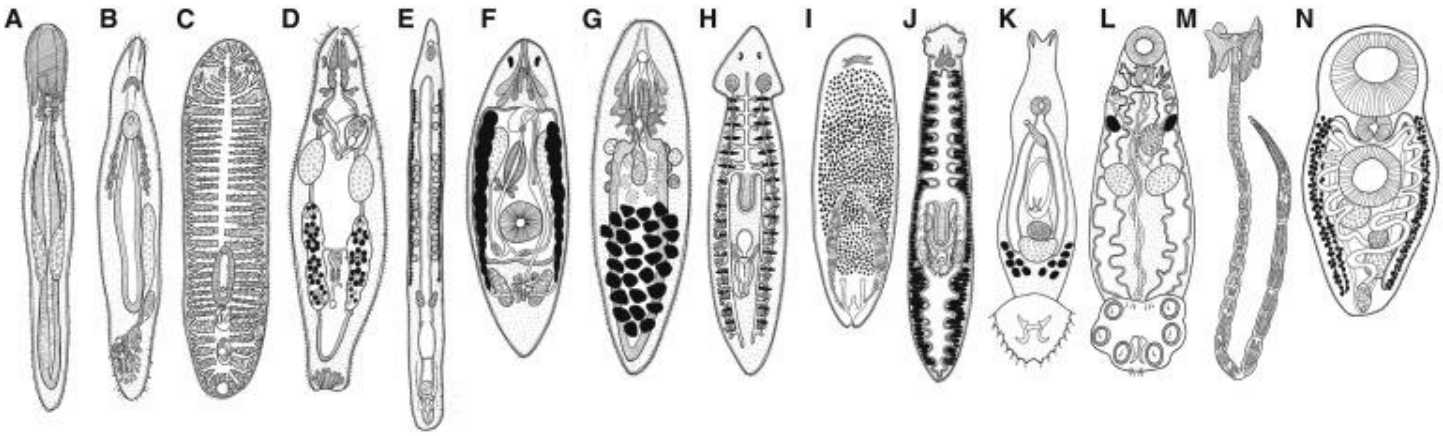
Clonorchis sinensis aka the Chinese liver fluke, from the vintage Ward's slide, stained. Fluke about 12 mm long. Enlarged image is stitched with 4X objective

Class Monogenea, tiny ectoparasites on fish skin or gills, most with large hooks or suckers

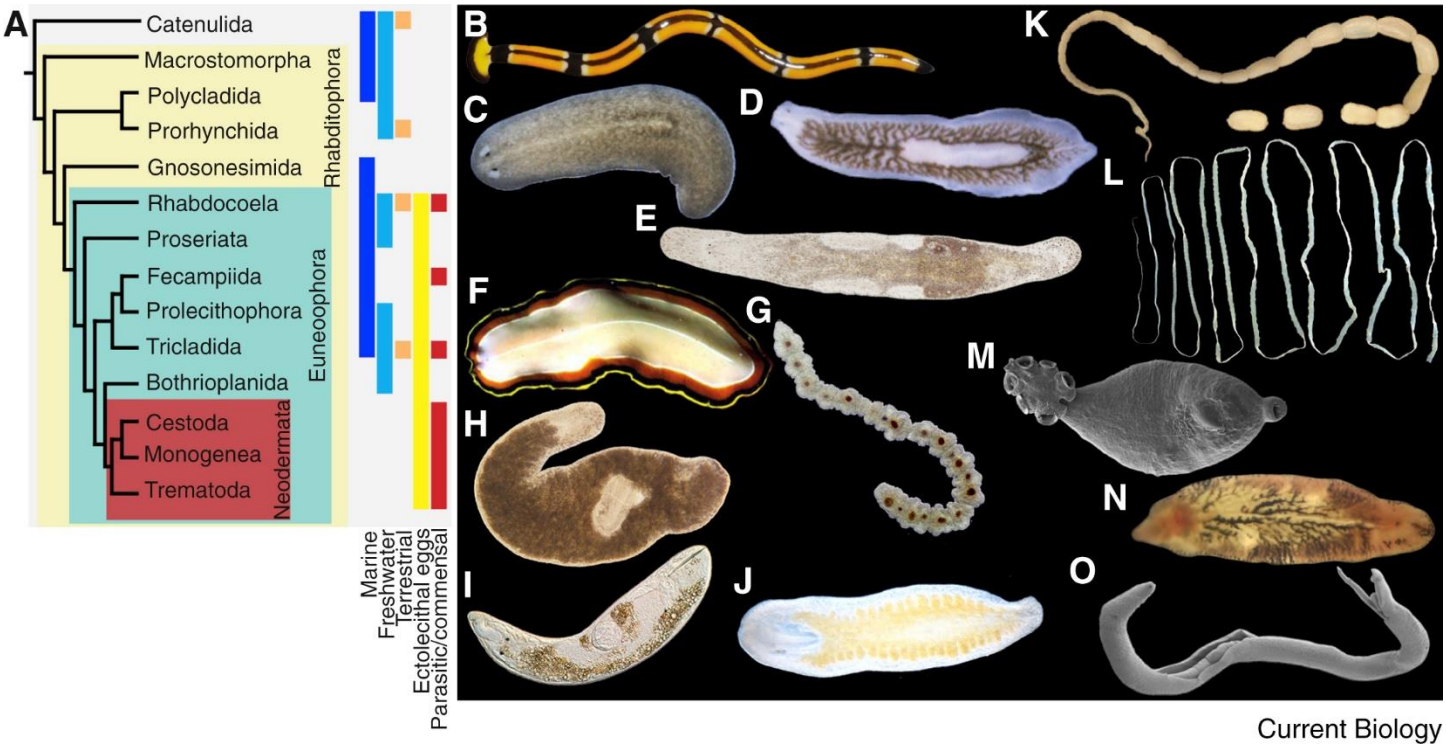


Gyrodactylus salaris infection on skin of Atlantic salmon (*Salmo salar*), important pest in Norway. Scanning Electron micrograph, each worm about 0.5 mm long image Stentiford er al Policy, phylogeny, and the parasite **Trends in parasitology.** 2014

Flatworm Diversity



Selected flatworms (A) Catenulida, (B) Macrostomorpha, (C) Polycladida, (D) Gnosonemisida (Lecithoepitheliata), (E) Proseriata, (F) Rhabdocoela, (G) Prolecithophora, (H) Tricladida, (I) Fecampiida, (J) Bothrioplanida, (K) Monopisthocotylea (Monogenea), (L) Polyopisthocotylea (Monogenea), (M) Cestoda, (N) Trematoda; not to scale, images from J Caira in Littlewood, Waeschenbach, Evolution: A Turn Up for the Worms **Current Biology** 2015



(A) left, modern family tree of the Platyhelminthes. Orders are shown except in Neodermata, for which Classes shown. (B) Land planarian, Tricladida *Bipalium sp*. (C) Freshwater planarian, Tricladida *Schimidtea mediterranea*. (D) Freshwater planarian, Tricladida *Procotyla fluviatilis* (E) Macrostomorpha *Macrostomum ligano* (F) Polycladida *Pseudoceros bimarginatus* (G) Catenulida *Catenula lemnae* (H) Bothrioplanida *Bothrioplana semperi* (I) Rhabdocoela *Gyratrix hermaphroditus* (J) Prorhynchida *Geocentrophora applanata* (K) Dog tapeworm, Cestoda *Dipylidium caninum* (L) Beef tapeworm, Cestoda *Taenia saginata* (M) Monogenea *Protopolystoma xenopodis* (N) Trematoda *Fasciola hepatica* (O) Trematoda *Schistosoma mansoni.* in Collins, J Platyhelminthes **Current Biology** 2017

Worms

In previous articles I reviewed parasite biology and then described the most common protozoa (single celled, microscopic eukaryotes) that parasitize people. Now I will begin to discuss the most classic of parasites, worms. These are multicellular animals and the adults are usually large enough to be seen without a microscope.

You know what a worm is; it's a wriggly tube shaped animal. Being slender and legless is useful for moving through granular substates like soil and mud. Father of taxonomy Linnaeus lumped all worms together as "Vermes" as they have a similar shape, but there are many rather different kinds of animals that appear worm like. The common earthworm is an annelid or segmented worm. There are many annelid species but just a few (leeches) are parasites.

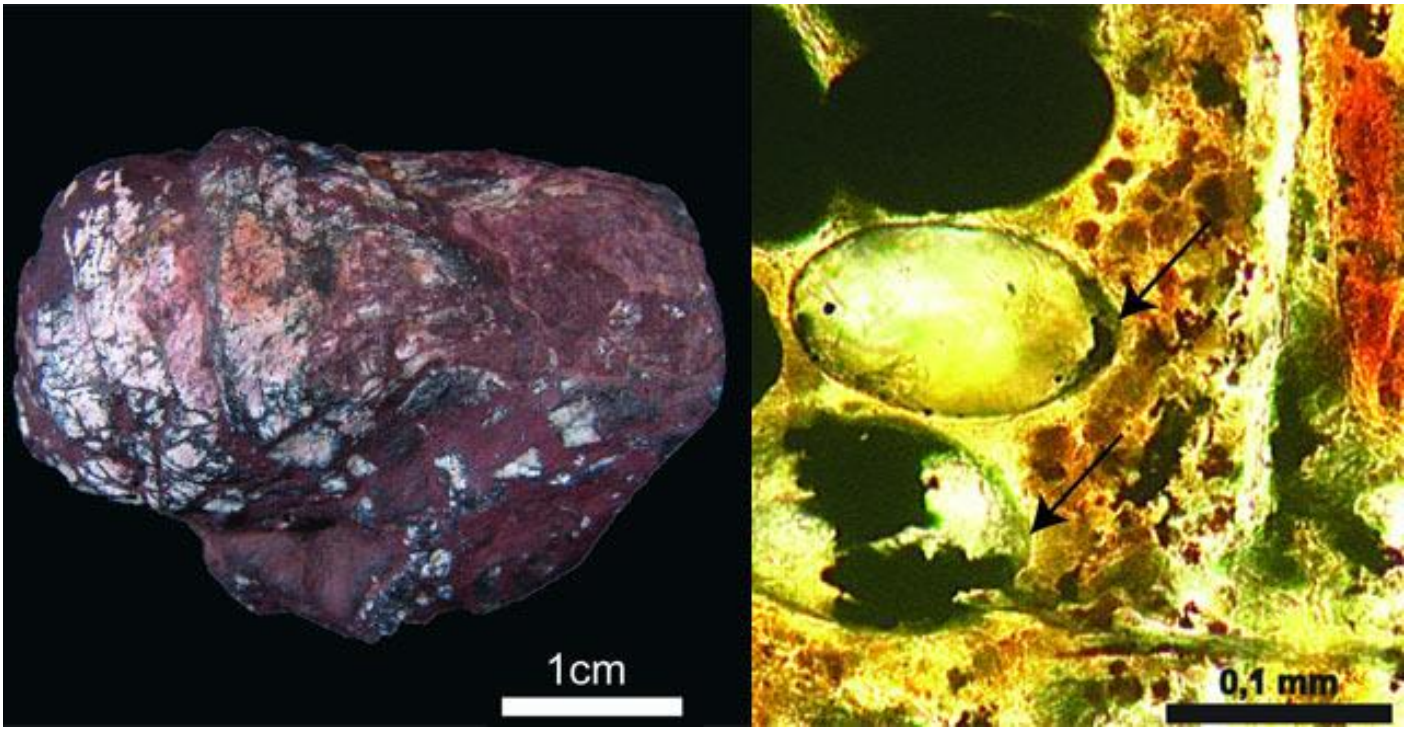
The big 3 phyla of worms are Platyhelminthes, Nematoda and Annelida: flatworms, roundworms and segmented worms. The type of worms that are most commonly parasites are flatworms and roundworms. Flatworms get their own phylum, Platyhelminthes. In the evolution of animals, flatworms were the first "regular animals". Unlike shapeless sponges and radially symmetric corals, flatworms have bilateral symmetry and are mostly mobile. Many have a pair of simple eyes. Flatworms have just two "germ layers" during embryologic development and a simpler body plan without the body cavity possessed by other worms and other animals. Being flat (as most are) confers the advantage of every cell being not too far from the animal's surface. This is important for gas exchange (oxygen and carbon dioxide) in animals that lack circulatory, respiratory and excretory systems. Flatworms have a simple digestive system with a mouth only (it doubles as an anus and is often coupled with a very muscular pharynx) and a branched (to deliver nutrients) gut. The first hunters were flatworms, and flatworms were the first animal group to have many members adopt a parasitic lifestyle.

If you know t any flatworms it might be **planaria** from high school biology class. Although their land relatives are now in the news for being invasive exotics, the ones you likely learned about are ½ to 2 cm long freshwater scavengers. They glide on cilia, have cute little eyes and "ears" (really chemical sensors more akin to noses) on the head and a mouth with extensible pharynx (muscular throat) on the bottom side middle of the body. Famously, if you cut a planaria into 5 pieces each would grow into a small worm. I even split the head (with a slightly T-shaped cut) to create 2 headed planaria. In high school I also recreated an experiment showing planaria can respond to magnetic fields. I recall my experimental techniques were a little fuzzy and I gave some worms the benefit of the doubt when I wasn't sure. I badly wanted a positive answer. I got it, winning a simple stereomicroscope as prize. Planaria were many biologists' favorite worm to research development, before the nematode *C. elegans* usurped that role.

Parasitic worms are also called **helminths**. The most common worms of humans are soil transmitted helminths, and the big three worldwide are all nematode worms: roundworm (*Ascaris lumbricoides*), the whipworm (*Trichuris trichiura*) and hookworms (*Necator americanus* and *Ancylostoma duodenale*). As many as 2 billion humans may still be infected with soil borne helminths, although most infected individuals don't feel ill. I will delve into nematodes next time.

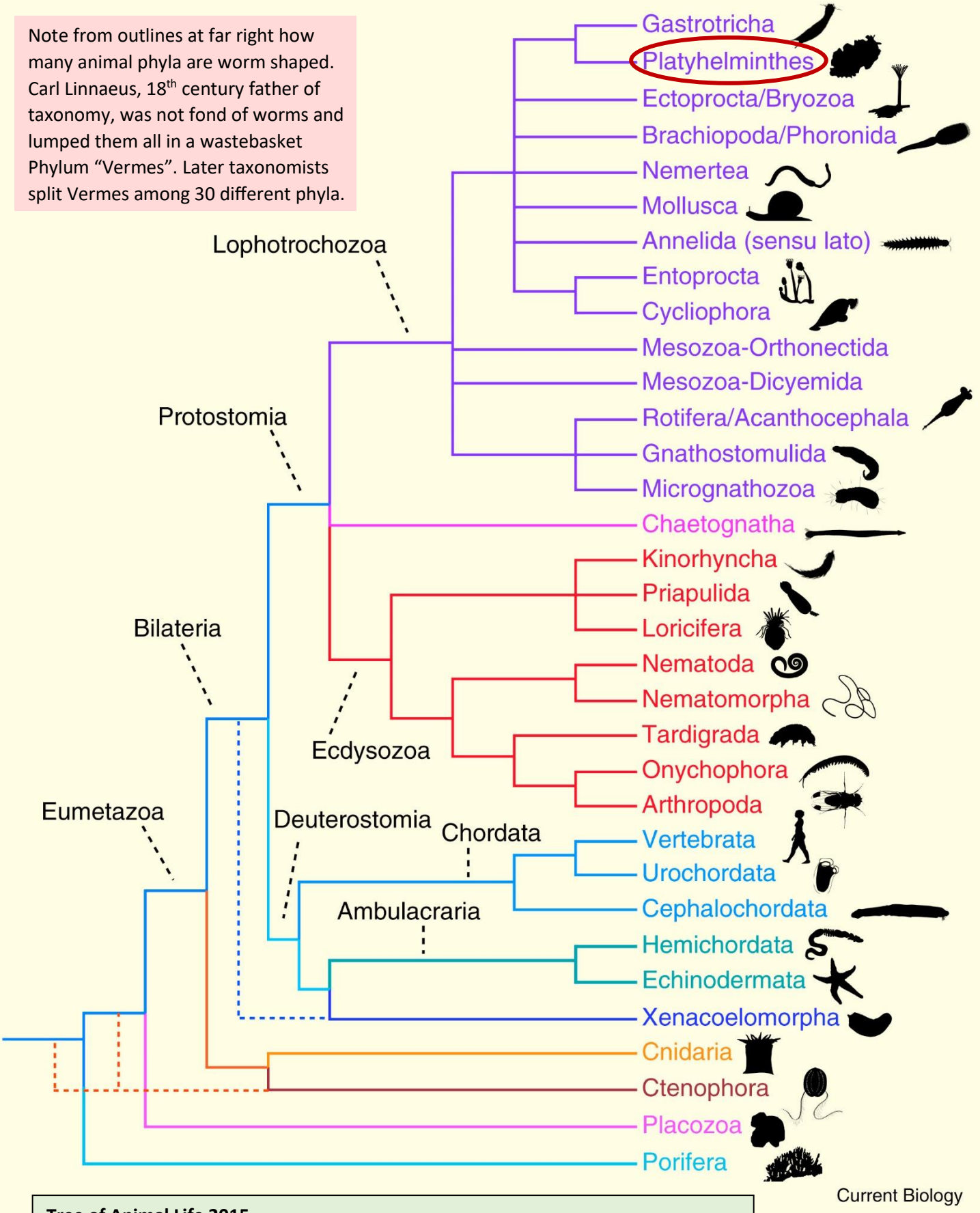
Most flatworm species became parasites

Platyhelminithes is the oldest phyla of fully mobile animals. Flatworms may have split from other animals about 839 million years ago (per genomic clocks), so they have had more time to evolve than other animals, save for corals and sponges. What did they do with all that time? They became parasites. About 80% of the 30,000 described species are parasites; the others are predators or scavengers. Platyhelminthes is the "most parasitic" of the large phyla of animals. (100% of Acanthocephala, "thorny headed" worms evolved from cute little rotifers, are parasitic, but the phylum only has about 1500 species.) In some parts of Africa and Southeast Asia the biggest health burden is caused not by soil acquired nematodes but by parasitic flukes with complex life cycles in fresh water snails and human livers or bladders. Tapeworms are found around the world, being spread by our domesticated livestock. Tapeworms are sometimes seen in feces, have a distinctive shape, and were described in ancient Greece and Rome. 270 million year old tapeworm eggs in fossil shark poop from the Permian Period in Brazil are the oldest known endoparasite fossils.

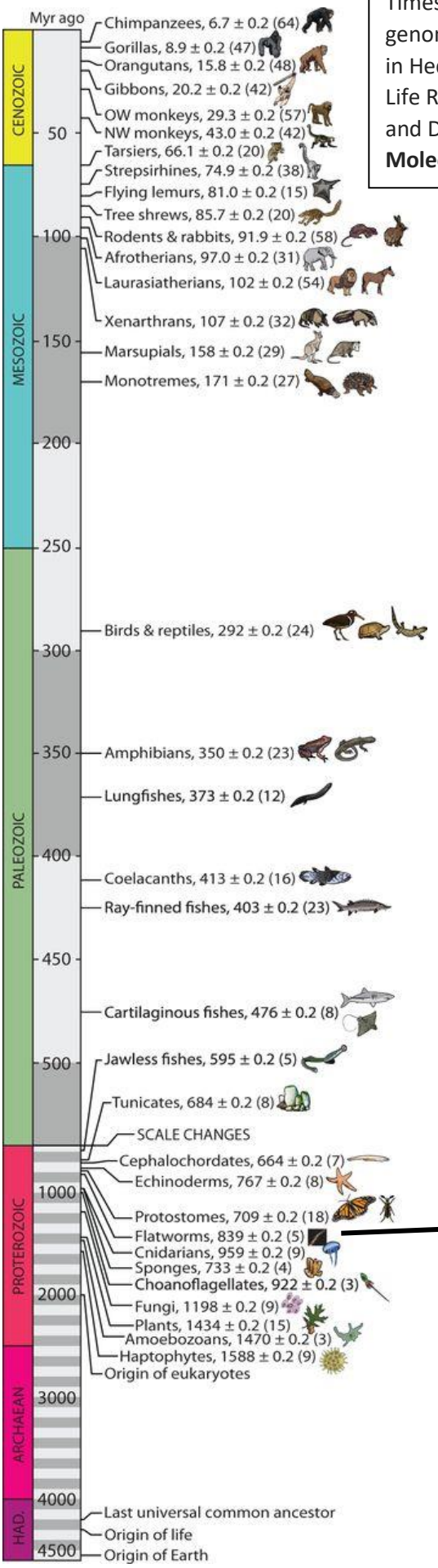


Left, the shark coprolite. Right, thin section under the microscope, showing tapeworm eggs
Dentzien-Dias et al Tapeworm Eggs in a 270 Million-Year-Old Shark Coprolite. 2013 **PLoS ONE**

Note from outlines at far right how many animal phyla are worm shaped. Carl Linnaeus, 18th century father of taxonomy, was not fond of worms and lumped them all in a wastebasket Phylum "Vermes". Later taxonomists split Vermes among 30 different phyla.

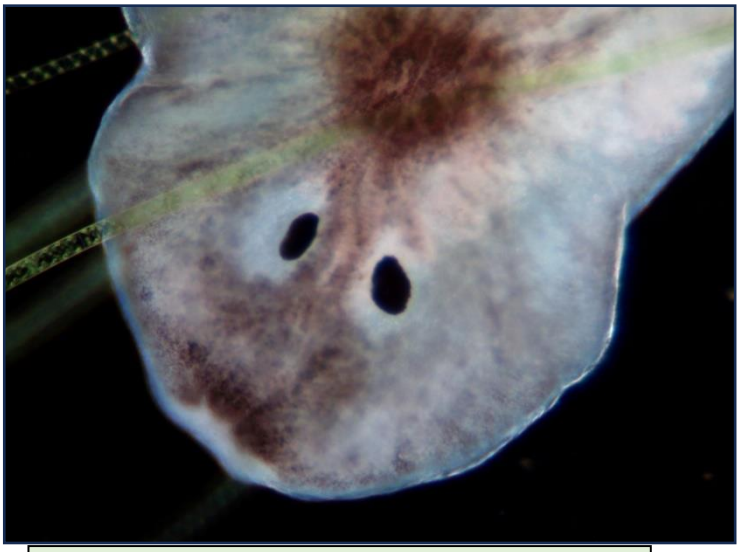


Tree of Animal Life 2015
Best estimate of the phylogenetic relationships of major animal phyla. Major clades are named. Alternative possible positions are indicated by dashed lines. Telford, Budd, Philippe, Phylogenomic Insights into Animal Evolution **Current Biology** 2015



Times of diversification per genomic clocks of select groups, in Hedges, Kumar et al Tree of Life Reveals Clock-Like Speciation and Diversification 2015 **Molecular Biology and Evolution**

Tapeworm and fluke vintage slides
Dipylidium caninum, 2 pored dog tapeworm slide by JD Mizelle, helminth parasitologist U of Illinois and Notre Dame 1930s and 1940s
Fasciolopsis buski, giant intestinal fluke, this one about 5 cm long, slide by Wards Science

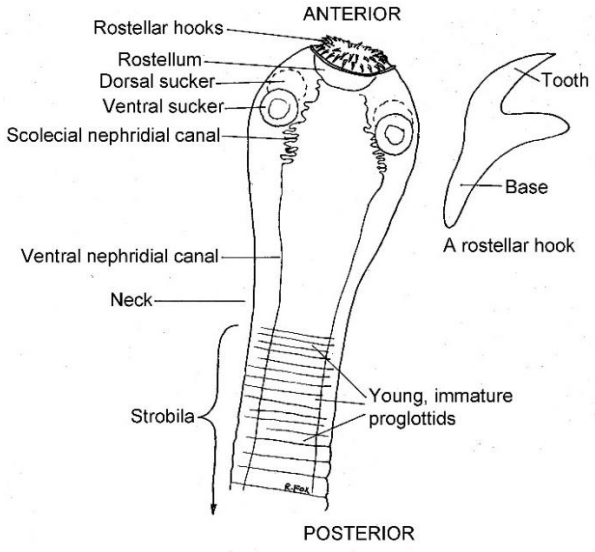


Tapeworms and flukes have free living cousins, such as this friendly little *Dugesia sp* (or related) planaria, Order Tricladida.
from stream, Red Wing, Minnesota USA,
4X objective, dark field, head ~2 mm wide

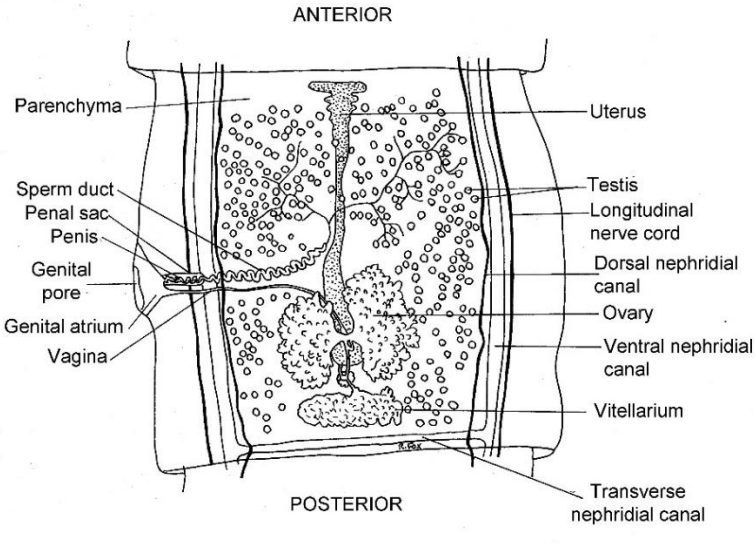
Tapeworms, aka as Class Cestoda

Tapeworms, also called cestodes, constitute a class of about 6000 species of endoparasitic flatworms in Phylum Platyhelminthes (the other major "classical classes" of flatworms are trematodes- the parasitic flukes, and turbellarians- the free living flatworms, like friendly freshwater Planarians). Tapeworms 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.

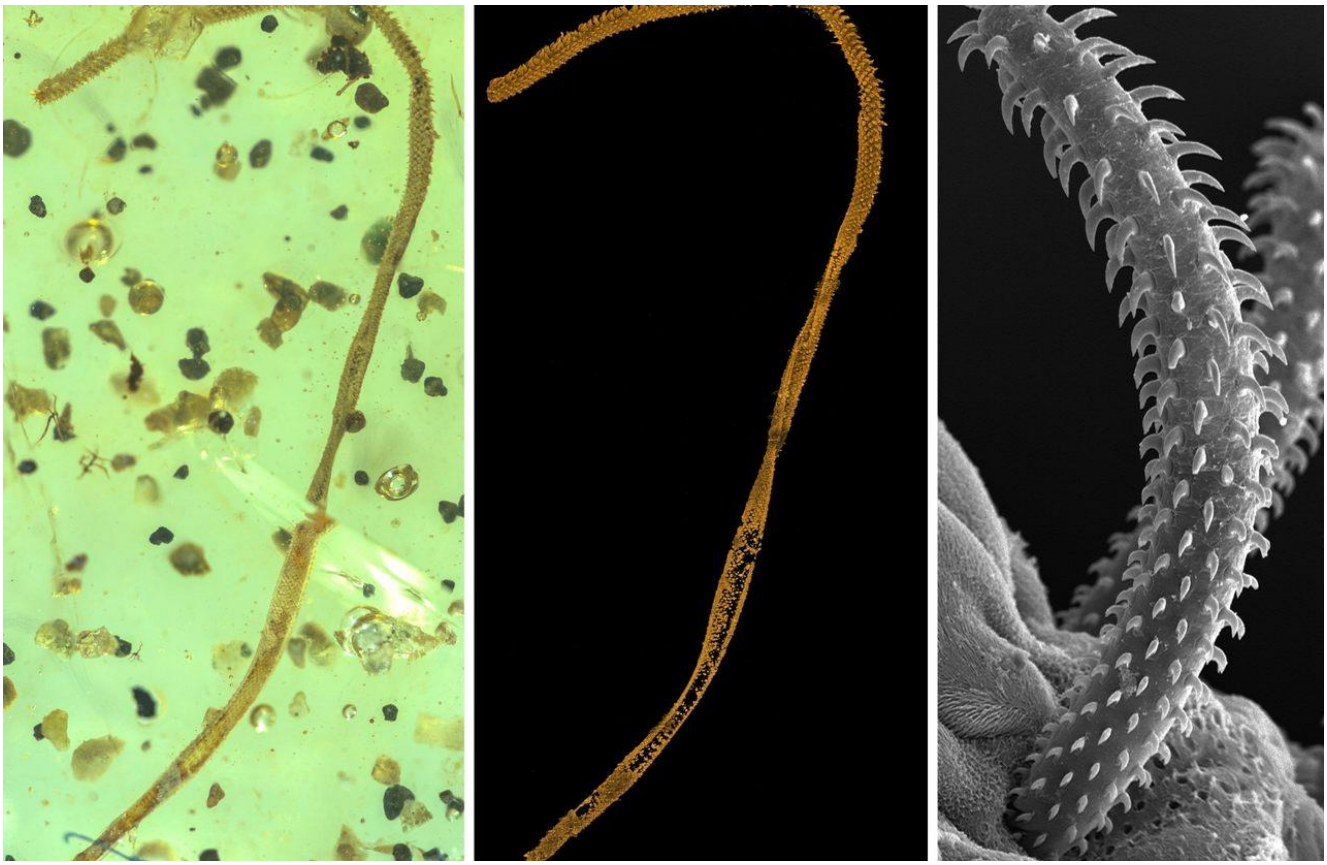
People often feel revulsion when they consider the anatomy of a tapeworm. But evolution has adapted them perfectly for living in vertebrate intestines. Tapeworms are strange looking with flat segmented bodies, hook-like teeth, but no mouth or gut. For food and a home, a tapeworm shares yours. An adult worm 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 counterproductive. So they are generally well behaved house guests, but on rare occasions a few errant tapeworm teenagers (cysticercoid larva) trash 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 quite good at doing so while living inside another animal.

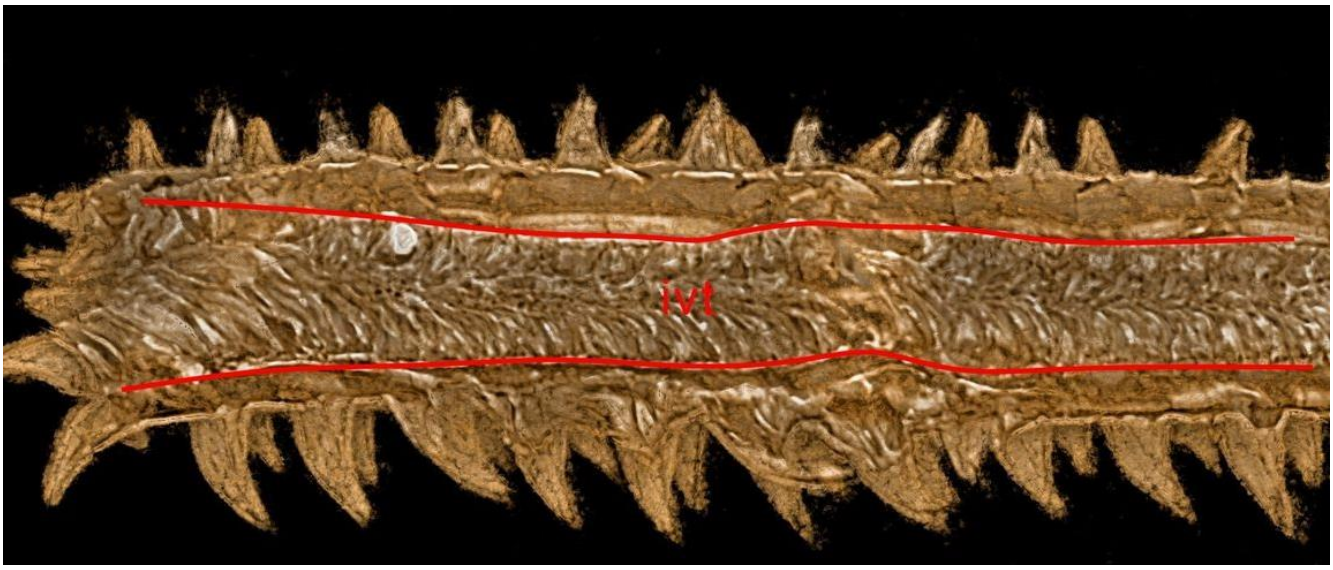


Anatomy of scolex ('head end') of *T psiformis*, rabbit tapeworm
Oklahoma Biological Survey



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





Hot off the press 22 March 2024, another tapeworm fossil, this time from “Burmese” amber, Myanmar, Cretaceous age, about 99 million years old. The fossil is a tentacle of a fish tapeworm. formed when a sloppy dinosaur dropped a bit of fish gut onto tree sap. This ancient amber has amazing fossils, but is ethically tricky (much of the amber trade funds an ethnic civil war). Upper images show optical photomicrograph of fossil left, 3D reconstruction from micro CT middle, and SEM tentacle of modern trypanorhynch tapeworm of sharks right. Bottom micro CT photomicrograph of fossil shows tentacle interior detail.
Luo et al Exceptional preservation of a marine tapeworm tentacle in Cretaceous amber. **Geology** 2024

Tapeworms are internal parasites, living in the guts of vertebrates for at least 270 million years (before the earliest dinosaurs). Investigation of four tapeworm genomes shows they are drastically simplified, having jettisoned unneeded baggage such as instructions for synthesizing nutrients and even many homeobox genes (which lay down basic body plans during early development). Having abandoned the usual body plan instructions, tapeworms look odd. They look surprisingly like *Plexus ricei*, an 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 looking 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.

The time life has been evolving on earth is deep beyond everyday human understanding. Imagine each 1 meter (3.3 feet) step you take represents 1000 years. Slide your foot 10cm and no one you know was yet born, 20cm (8 inches) to the dawn of the industrial revolution, 1 full step to the middle ages, another to the time Of Rome and Christ, 10 steps to beyond civilization and the invention of agriculture, 300 steps to the emergence of *Homo sapiens*, 3200 steps (3.2 km) to Lucy, our first fully erect ancestor. At 7 km (about 1 ½ hours at an average 4.5 km/hour walking speed) you could meet the common ancestor of man and chimps. At 60 km (a 13 hour death march without a break) an asteroid wipes out the dinosaurs (except some birds), allowing some fuzzy little animals (mammals) to come out of their burrows to take their turn ruling the earth. At 252 km (16 days of walking a good 16 km/ 10 miles a day) the end Permian Great Dying kills off 95% of all species. At 550 km = ½ billion years = 34 days with no break, animals become abundant for the first time in Cambrian seas. 2000 km = 2 billion years = 4.2 months with no break, the first eukaryote, protozoa-like (LECA). 3800 km = 3.8 bilion years + about 8 months walking, the first life (prokaryotic, LUCA). 4550 km = 4.6 billions years = 9 ½ months walking, origin of the earth and sun from cosmic dust. 13,700 km = 13.7 billion years = 2 ½ years daily walking = walking 1/3 of the way around the earth, the Big Bang, birth of the Universe.

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 slowly 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 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 wasn't bad enough, over time tapeworms also became sexual degenerates. Sex has such strong benefits that even bacteria, the simplest of living things, often 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 thousands of both male and female sex organs. 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, blind, 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 made today's tapeworms 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

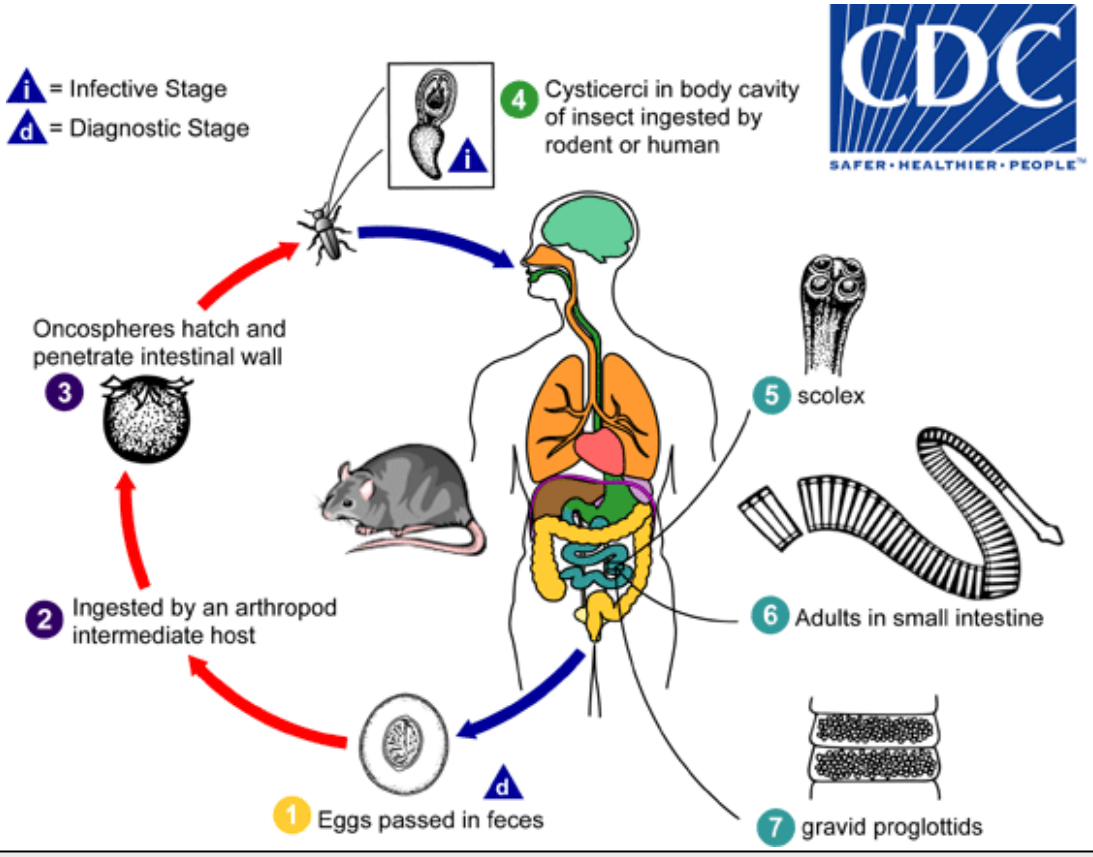
and perfect little creatures. But tapeworms make no choices; they simply follow occasional preprogrammed responses to smells. People make moral judgments about things in nature, but nature doesn't judge us, even though she does have intricate order and inviolate rules.

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, but still 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 and of evolution. 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 complex and full of shocking surprises like simple parasites that turn snails into zombie disco dancers. 10,000 years ago man learned enough of nature's rules to cultivate tasty plants and animals, leading to city life and civilization, and just recently man learned enough physics to make flying and thinking machines. Don't forget you are part of nature. Going outside and learning her beauty is inspiring if you open your scientific or spiritual mind.

Scolex (head) of *Hymenolepis diminuta* the rat tapeworm. Note 4 suckers but no hooks, and bits of air in 1 nephridial (excretory) duct. 10X objective

But I digress; let's move on to one of the species of tapeworm I have slides of. The specific little hermaphroditic 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 both good 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 in rat feces[1]. Eggs ingested by intermediate hosts (*Tribolium* and other arthropods)[2], and oncospheres are released, penetrate the intestinal wall[3], develop into cysticercoid larvae. *H. diminuta* infection is acquired by mammals through ingestion of an intermediate host carrying larvae[4]. Humans can be accidentally infected through the ingestion of insects in precooked cereals or other food, or directly from the environment (oral exploration by children). After ingestion, digestion releases the cysticercoid larvae in the stomach and small intestine. Eversion of the scolex[5] occurs shortly afterwards. Using four suckers the parasite attaches to the small intestine wall. Maturation occurs within 20 days and adult worms can reach an average 30 cm in length[6]. Eggs are released from disintegrating gravid proglottids[7] and eggs are passed in feces.

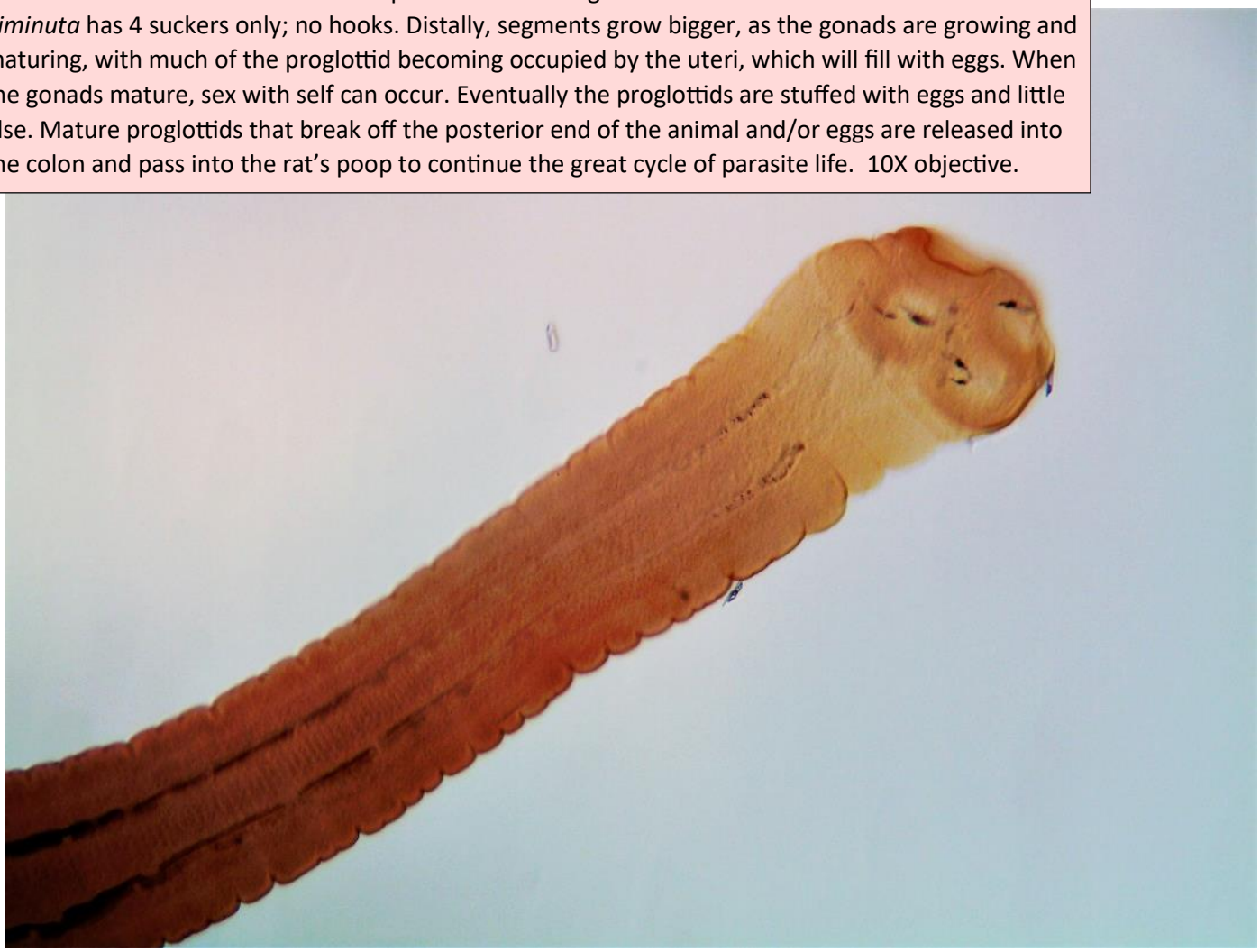
Hymenolepis diminuta photomicrographs showing life stages

Slides from collection of late parasitologist, U of Illinois Professor Harley Jones Van Cleave

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

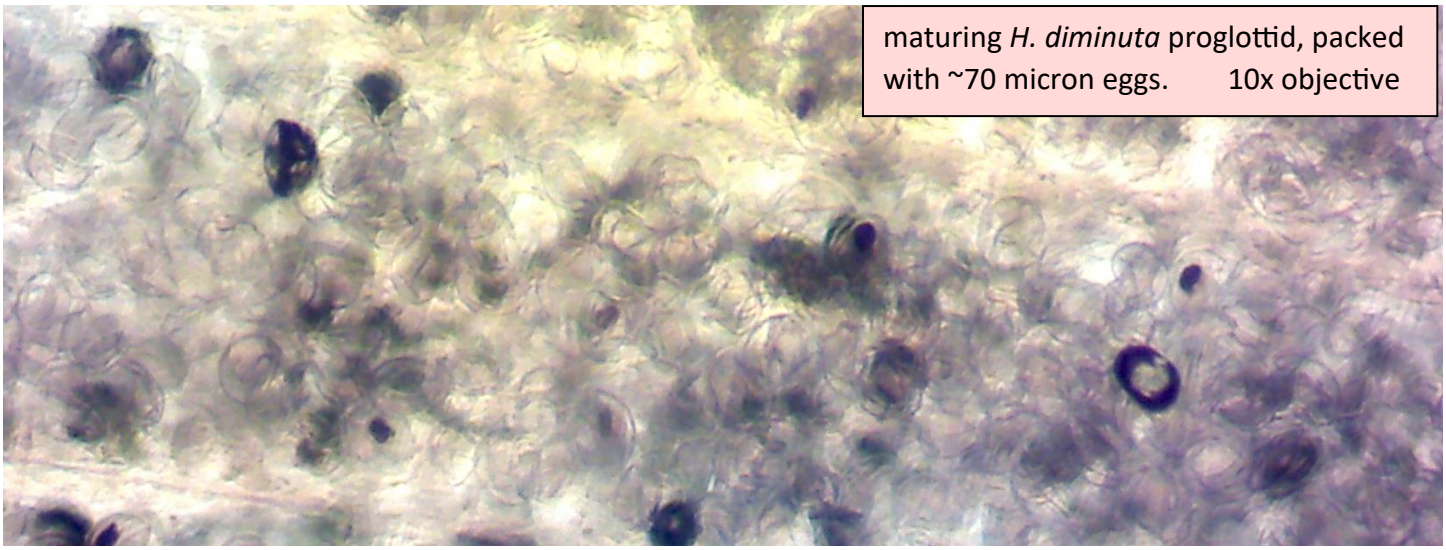
***H. diminuta* cysticercoid.** This is the larval stage, which develops from the central oncosphere of the egg, maturing in flour beetles. Either a beetle larva or adult may ingest the tapeworm eggs. To become adult worms, the cysticercoids must pass into a rat when it eats an infested beetle. Cysticercoid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

Adult *H. diminuta* with scolex. The tapeworms live and grow in a rat's intestine. The head of *H diminuta* has 4 suckers only; no hooks. Distally, 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 with self can occur. Eventually the proglottids are stuffed with eggs and little else. Mature proglottids that break off the posterior end of the animal and/or eggs are released into the colon and pass into the rat's poop to continue the great cycle of parasite life. 10X objective.



The vintage *H. diminuta* tapeworm slides were made at the University of Illinois, 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 of 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.

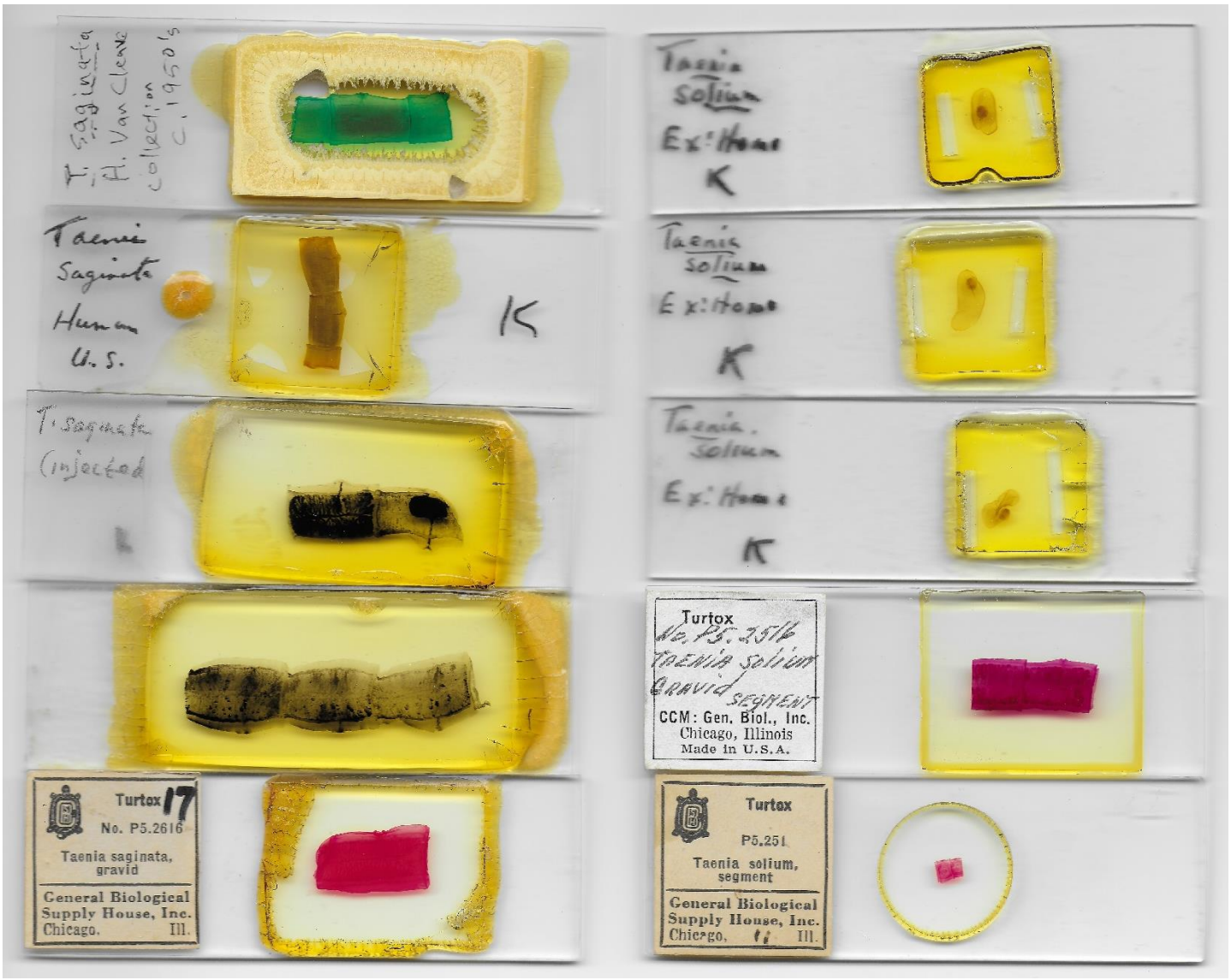
I was very fortunate to find two boxes of Dr. Van Cleave's teaching slides on eBay in 2014, listed by one of his previous graduate students, who used them in her own teaching. Most slides were made at the University of Illinois, and others were made by biological supply houses. Ward's Natural Science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



maturing *H. diminuta* proglottid, packed with ~70 micron eggs. 10x objective

more 75 µ *H. diminuta* eggs "*ex Rattus*" (from rat feces) 40X objective, oblique light

Tapeworms have been touted for weight loss since Victorian times, although the above ad was found to be a fake by Zarzo et al in The Tapeworm and Maria Callas Diet: A Mystery Revealed. **Parasitologia**. 2022. There is no proven weight loss fr tapeworms, but occasional harm from tapeworm egg pills occurs, i.e. Zhang et al Case Report: Disseminated Cysticercosis due to Intentional Ingestion of Parasitic Worm Eggs for Weight Loss. **Am J Trop Med Hyg** 2021



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). 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 all called “diseases” 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 may lose weight. If there is a high risk of complications or you feel sick, then we doctors will treat you with anti-parasitic drugs.

Most US doctors don’t need to know much about parasites as they’ll never see patients with them. Even head lice and minor pinworm infestations are becoming rarer. Apart from a year in Africa, I’ve seen 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. Some patients brought me “proof”: they caught a worm. In most cases it turned out to be tiny bits of toilet paper curled into something stringy. These poor people have become so anxious they really think rolled up toilet paper is a parasitic worm. I always consider the possibility that the patient could be right and usually send off a stool specimen to look for eggs, if the lab can do the test (technicians have lost their skill at identifying parasite eggs in stool). Negative tests won’t dissuade some people with delusional parasitism (an official diagnostic label) and some will find an alternative practitioner to give them arsenic, mercury or similar risky treatments.

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 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. Even in the developing world tapeworm disease is far less common than roundworms and flukes.

Tapeworms have a simple anatomy, but have evolved 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. Adult tapeworms invariably live in a vertebrate host’s intestines, but their 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 a 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 even 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.

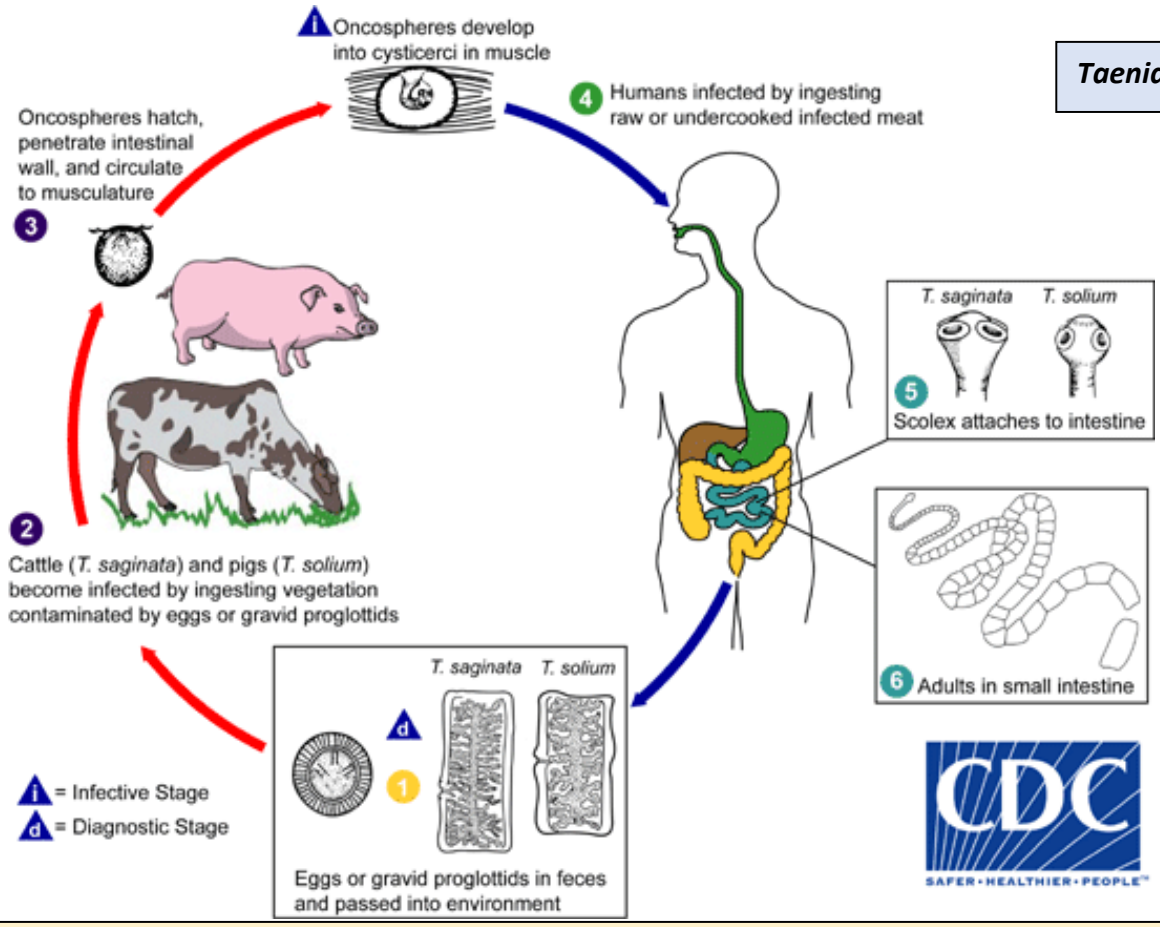
Taeniasis

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.

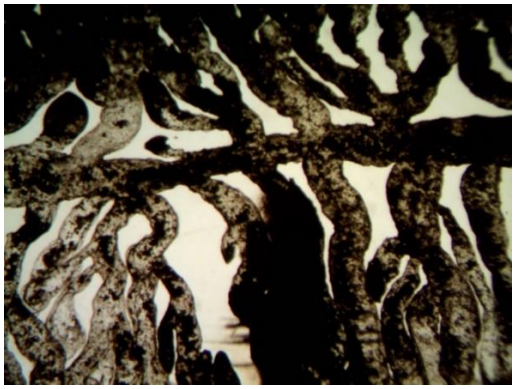
Taenia cysticerci ingested in food attach to the intestine and grow to adulthood in about 3 months. Full size Taenia are big tapeworms, often about 4 to 8 meters (12 to 25 feet) long (some *T. saginata* have reached 25 meters), with up to 2000 proglottid segments with up to 100,000 eggs in each segment (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. These are common veterinary drugs. Mild nausea or abdominal pain are common with the drugs (and also with the worms themselves).

Taenia sp. life cycle

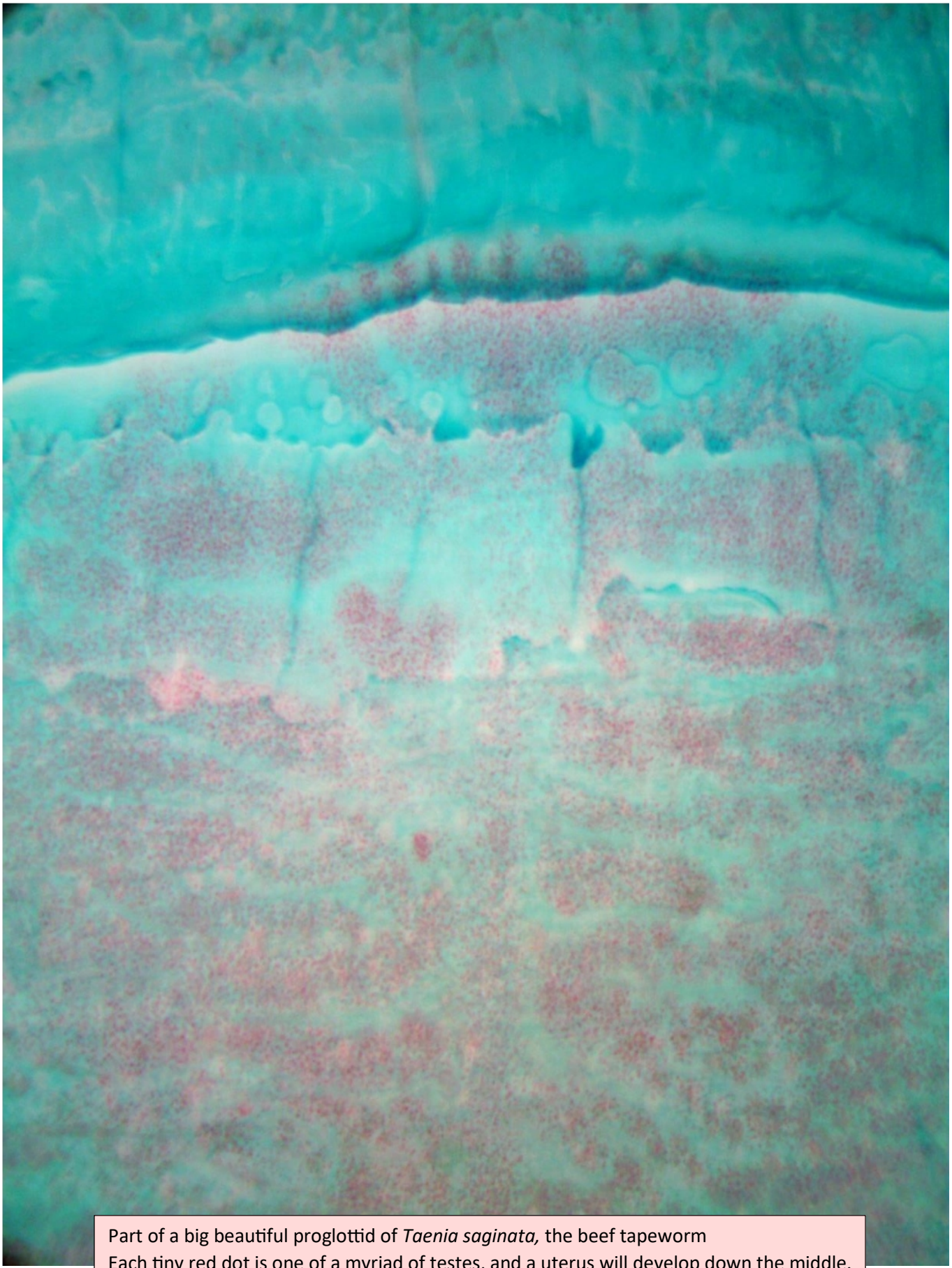


Taeniasis is infection of humans with adult *Taenia saginata* or *T. solium*. Humans are the only definitive hosts for *T. saginata* and *solium*. Eggs or gravid proglottids are passed in feces 1; eggs can survive for days to months in the environment. Cattle (*T. saginata*) and pigs (*T. solium*) get infected by ingesting vegetation tainted by eggs or gravid proglottids 2. In animal intestine, oncospheres hatch 3, invade intestinal wall, and migrate to the striated muscles, where they develop into cysticerci that can survive for several years in the animal. Humans get infected by eating raw or undercooked infected meat 4. In the human intestine, the cysticercus develops in 2 months into an adult worm which can survive for years. Adults attach by the scolex 5 in the small intestine 6. Length of adult worms is usually 5 m or less for *T. saginata* (but may reach up to 25 m) and 2 to 7 m for *T. solium*. Adults produce proglottids which mature, become gravid, detach from the worm, and migrate to the anus or are passed in the stool (about 6 per day). *T. saginata* adults have 1,000 to 2,000 proglottids, while *T. solium* average 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

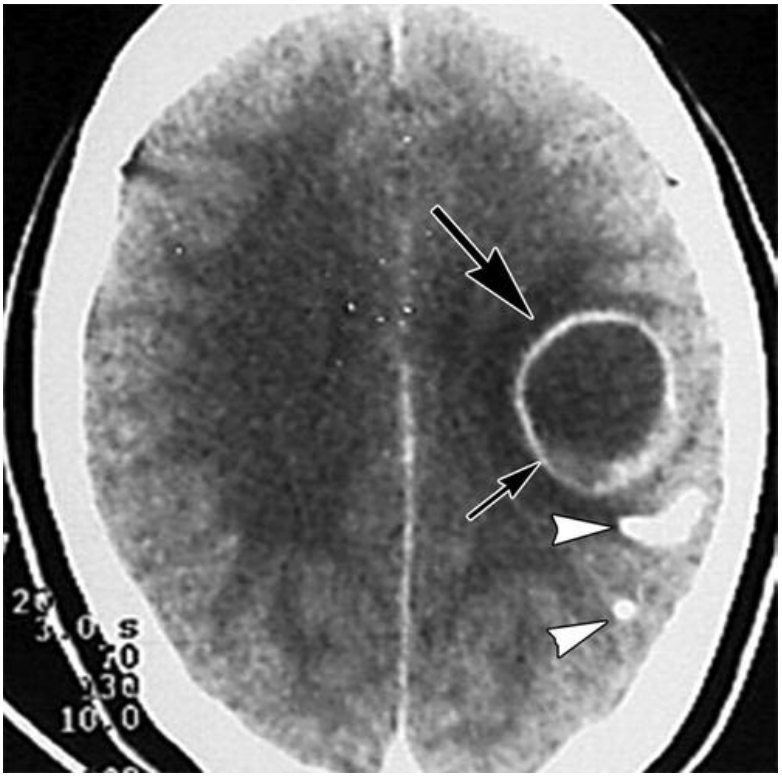
H van Cleave slide of 3 mature proglottids, injected, of *Taenia saginata* (beef tapeworm). 3" slide approximate life size depending on your monitor .



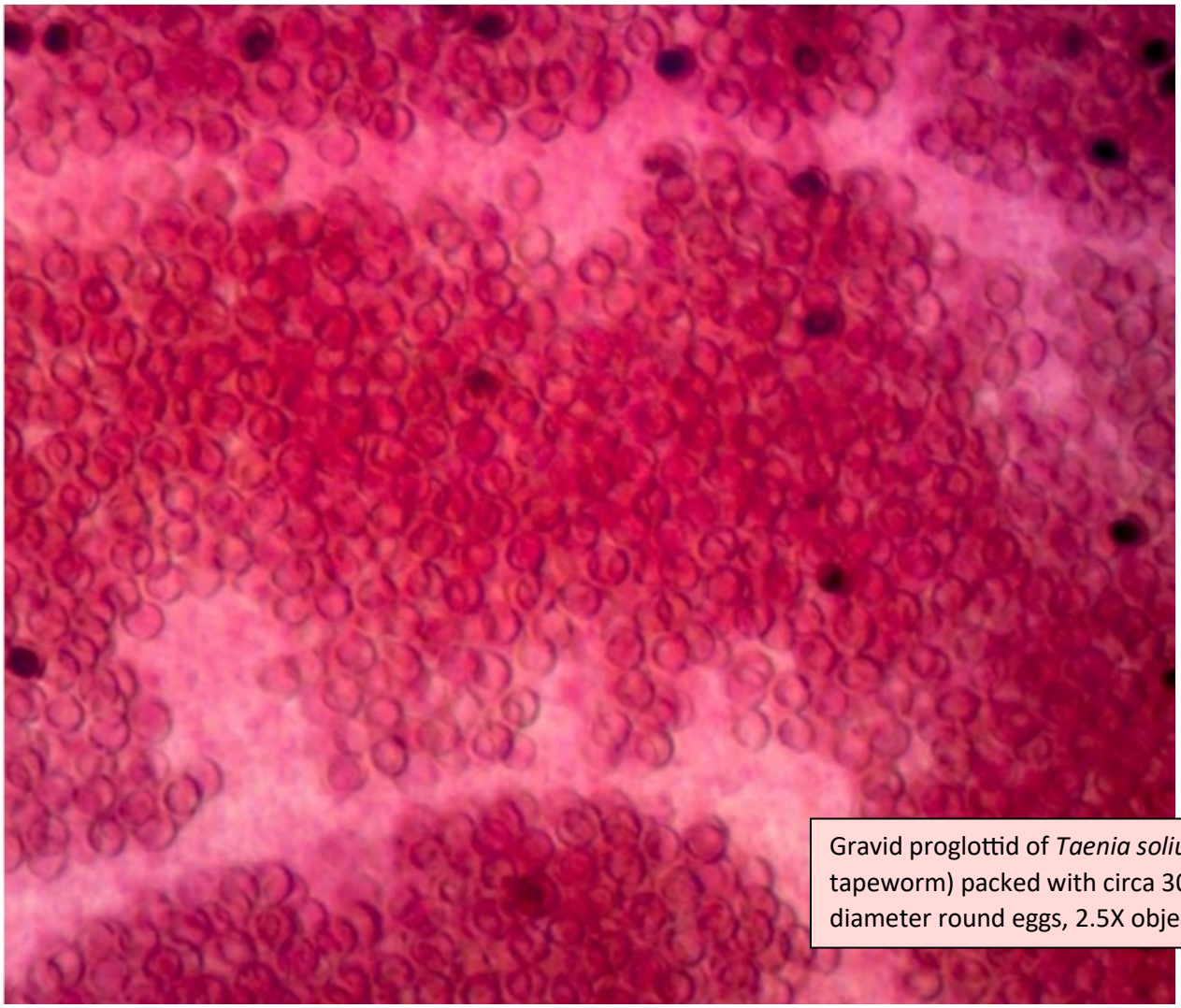
Part of a big beautiful proglottid of *Taenia saginata,* the beef tapeworm
Each tiny red dot is one of a myriad of testes, and a uterus will develop down the middle.
Nice stain by Professor Van Cleave. 2.5X objective, image about 5 mm tall

Cysticercosis

It can make a potentially huge difference whether tainted meat or food contaminated with eggs is eaten. Infested, undercooked beef or pork could pass cysticerci to your intestine that become adult worms, with ensuing taeniasis and usually mild or no symptoms. But if ***Taenia solium*** (pork tapeworm) eggs from an infested person making you a salad are ingested, and you are very unlucky, the eggs hatch into oncospheres that 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 cysticercoid larvae (also called "bladder worms") then create cysts. Sometimes the larva matures into a trapped adult. Neurocysticercosis (tapeworm brain cysts) can cause seizures and occurs regularly 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. Diagnosis usually happens when a CT or MRI brain scan for headaches or seizures has the surprise of ring like brain lesions. I have occasionally cared for Hispanic immigrants in both the southern and northern US for years. I think I have seen 3 cases of neurocysticercosis in as many decades. I recall a medical journal case report from many years ago involving an Orthodox Jew living in New York who developed seizures from *Taenia solium* brain cysts. He protested that he was kosher his whole life and never cheated. He didn't. But his housekeeper cook was from Latin America. 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.

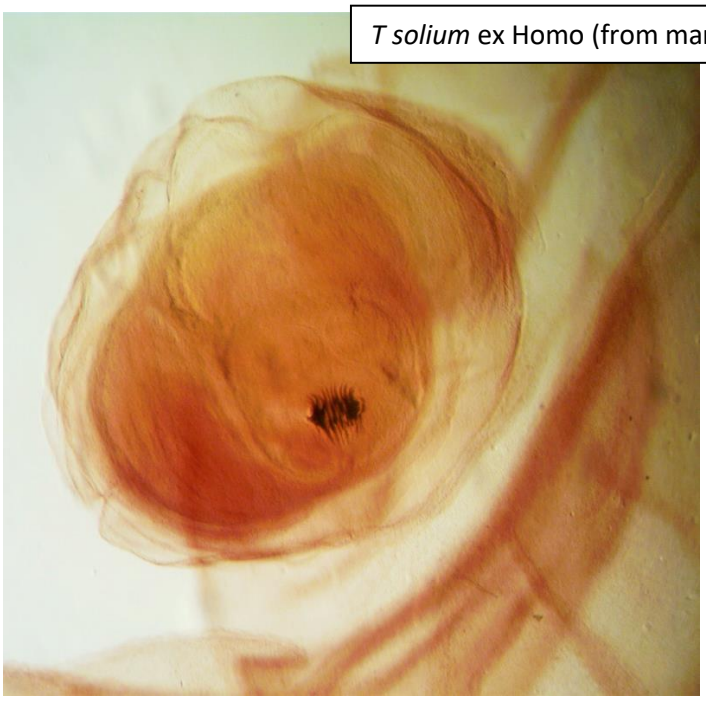


A brain CT scan you don't want, showing huge cyst and adult tapeworm that escaped from it., a tragedy for you and for the worm. Image Kimura-Hayama, Higuera et al Neurocysticercosis: Radiologic-Pathologic Correlation **RadioGraphics**

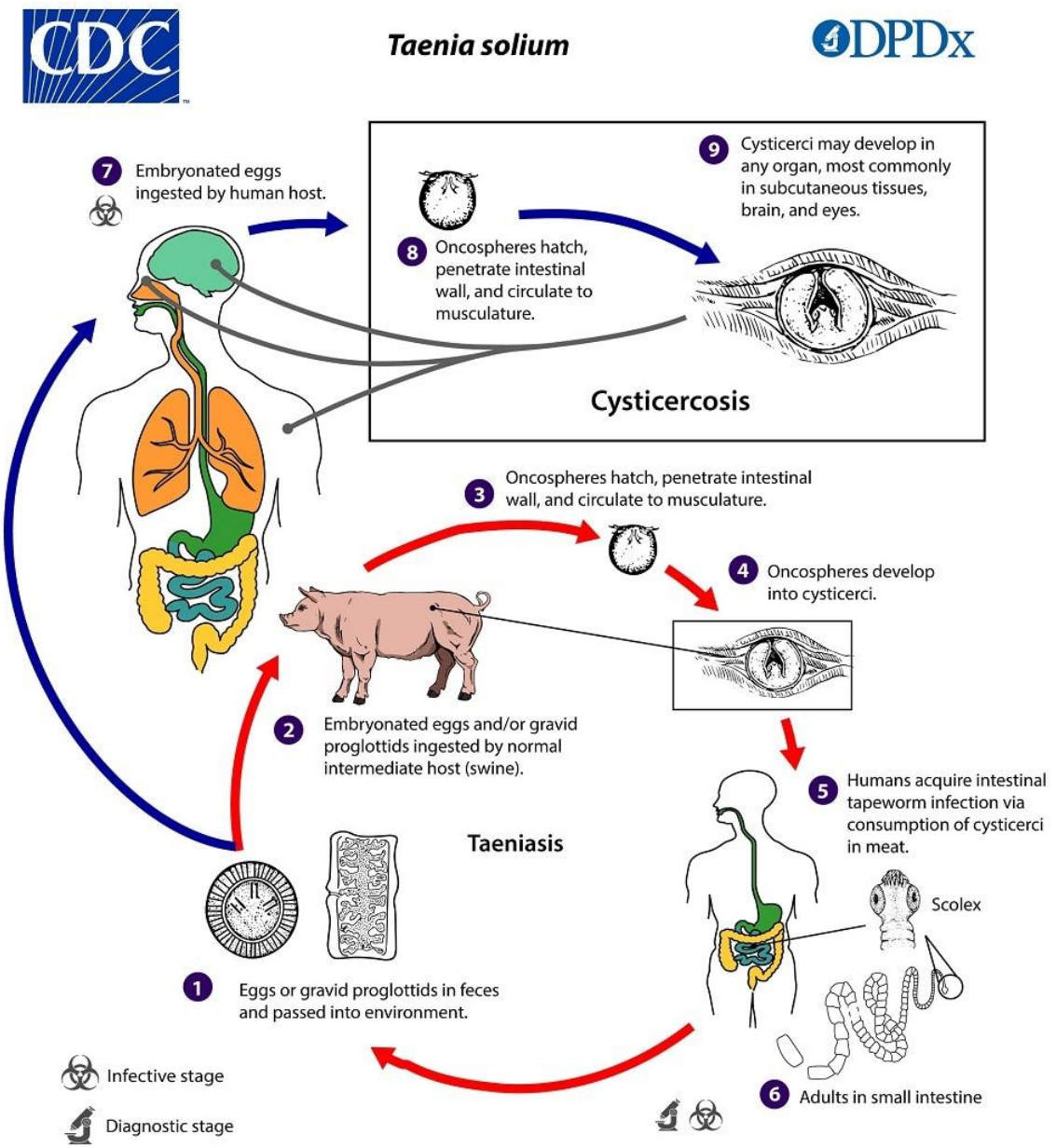


Gravid proglottid of *Taenia solium* (pork tapeworm) packed with circa 30 micron diameter round eggs, 2.5X objective

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



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



Cysticercosis is an infection of both humans and pigs with the larval stages of the parasitic cestode, *Taenia solium*. This infection is caused by ingestion of eggs shed in the feces of a human tapeworm carrier 1. These eggs are immediately infectious and do not require a developmental period outside the host. Pigs and humans become infected by ingesting eggs or gravid proglottids 2, 7. Humans are usually exposed to eggs by ingestion of food/water contaminated with feces containing these eggs or proglottids or by person-to-person spread. Tapeworm carriers can also infect themselves through fecal-oral transmission (e.g. caused by poor hand hygiene). Once eggs or proglottids are ingested, oncospheres hatch in the intestine 3, 8 invade the intestinal wall, enter the bloodstream, and migrate to multiple tissues and organs where they mature into cysticerci over 60–70 days 4, 9. Some cysticerci will migrate to the central nervous system, causing serious sequellae (neurocysticercosis).

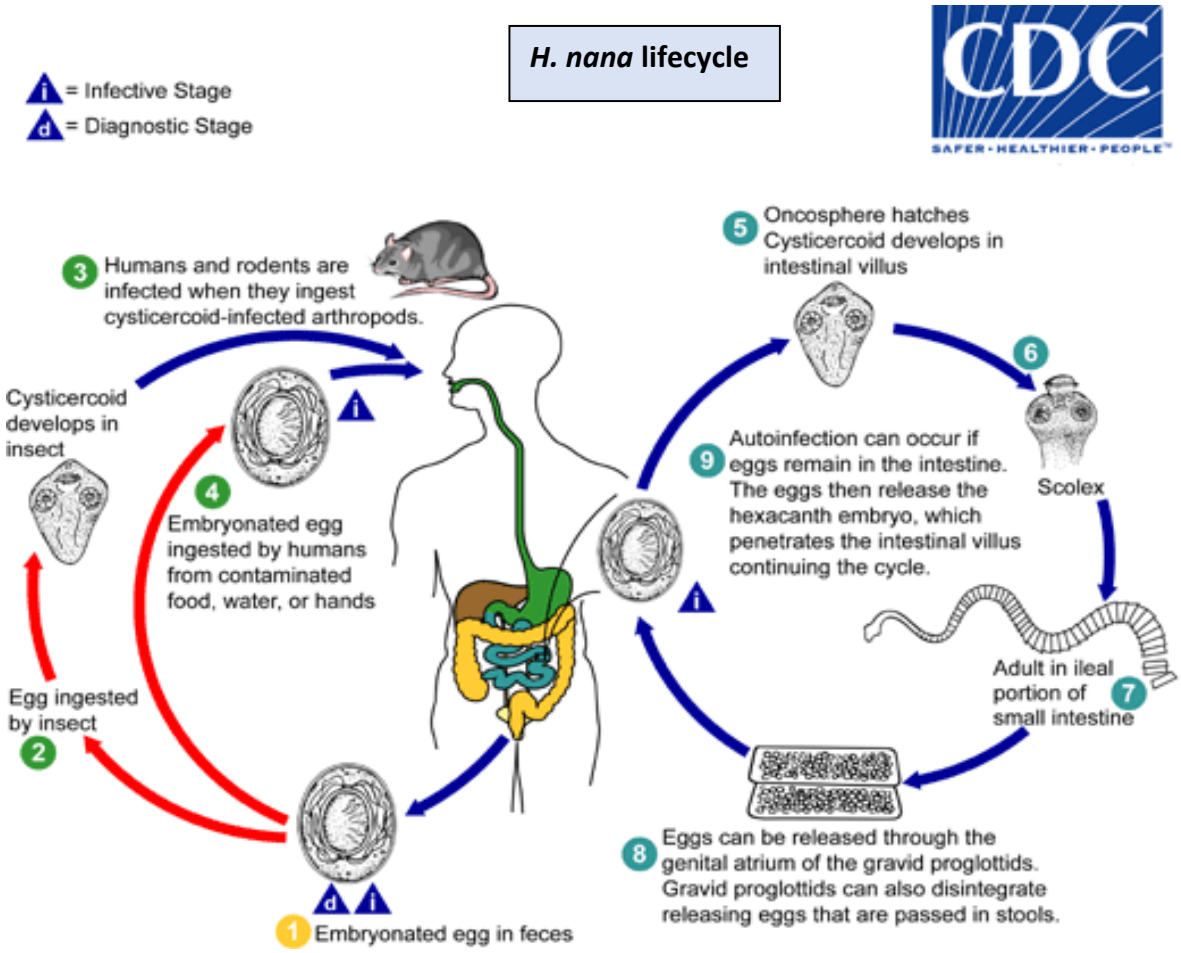
This differs from **taeniasis**, which is an intestinal infection with the adult tapeworm. Humans acquire intestinal infections with *T. solium* after eating undercooked pork containing cysticerci 5. Cysts evaginate and attach to the small intestine by their scolices. Adult tapeworms develop to maturity and may reside in the small intestine for years 6.

Scolex (head) of *Hymenolepis nana* the dwarf human tapeworm. Four suckers, hook circle about 0.25 mm across with 20-27 hooks
10X objective, cropped

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 often does the trick.

H. nana lifecycle



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)

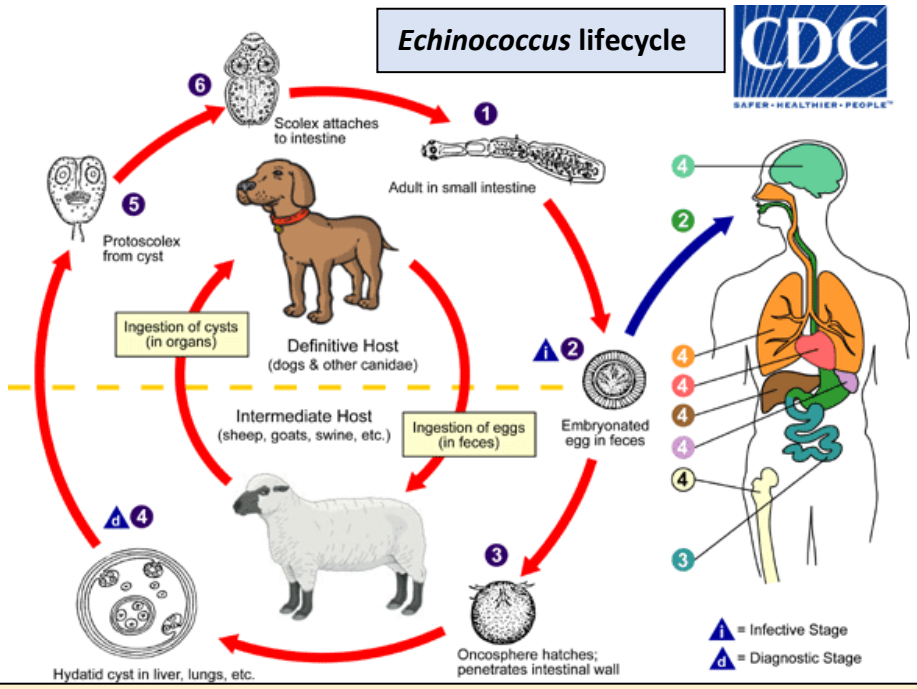
Hymenolepis diminuta is the rat tapeworm. Although smaller than most tapeworms it is 20 to 60 centimeters long, much bigger than *H. nana*. Rats are the definitive hast and fleas harbor cysticerci. Human children can rarely become accidental hosts if they eat an infected flea. Illness is usually mild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

Echinococcosis, aka Cystic echinocccosis (CE) or hydatid disease

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. Most cases are in Africa, Europe and Asia. The masses usually show up on CT scan, and blood tests can confirm the presence of *E. granulosus.* Surgery can remove the watery hydatid cysts, but needle drainage with chemical injection or no treatment at all are options.

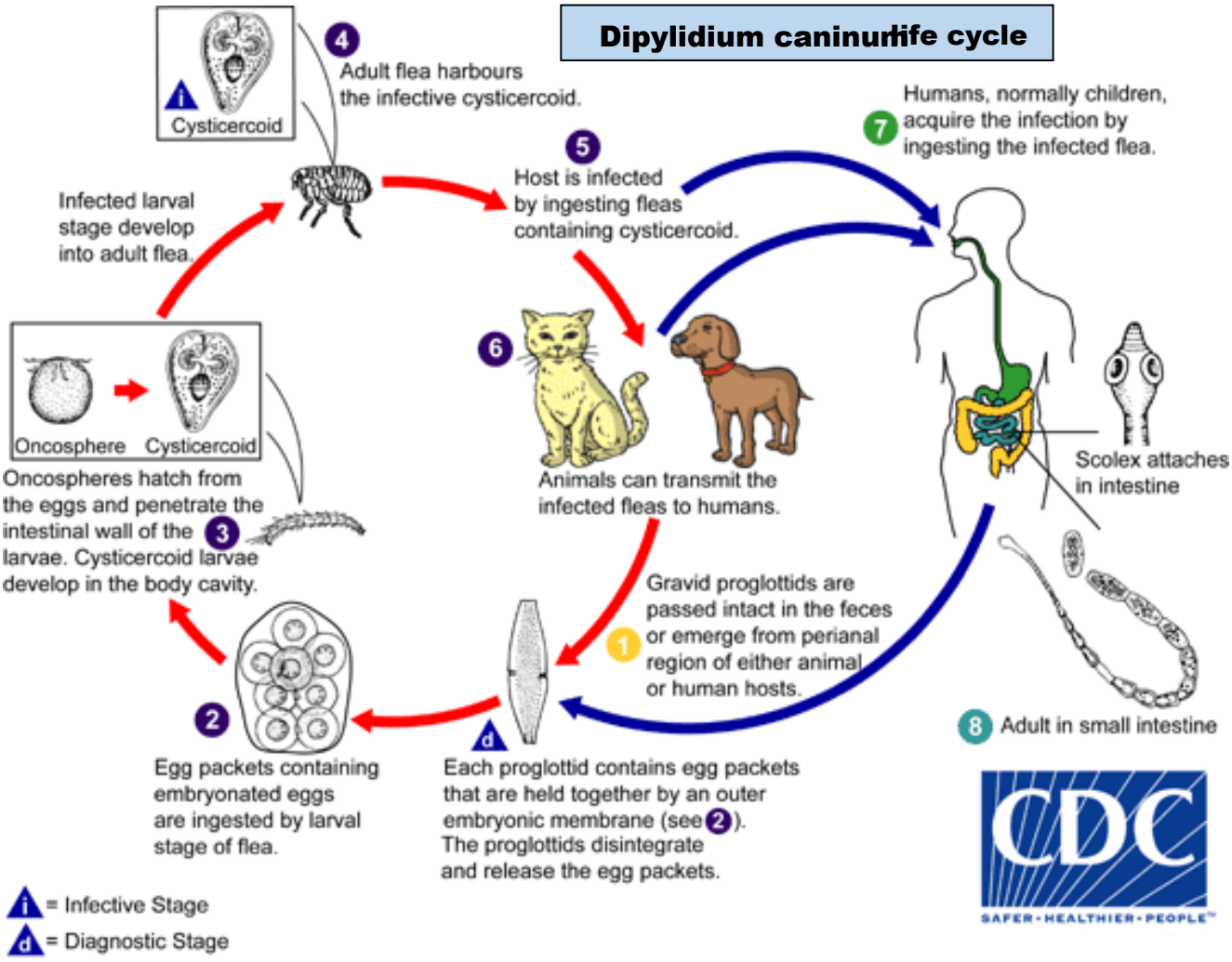
Echinococcus multilocularis causes alveolar echinococcosis, a rare disease of older men mostly in northern Europe, Asia and rarely North america that presents with liver failure and masses mimicking liver cancer. X-rays show tiny 2-4mm calcified rings. Blood tests may not be positive at first, and the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



Adult *Echinococcus granulosus* (3 to 6 mm long) ❶ resides in the small bowel of the definitive hosts, dogs or other canids. Gravid proglottids release eggs ❷ passed in the feces. After ingestion by a intermediate host (sheep, goat, swine, cattle, horses, camel), the egg hatches in the small bowel and releases an oncosphere ❸ that penetrates the intestinal wall and migrates through the blood to various organs, especially liver and lungs. There the oncosphere develops into a cyst ❹ that enlarges gradually, producing protoscolices and daughter cysts that fill the cyst interior. Definitive host is infected by eating cyst-containing organs of infected intermediate host. After ingestion, protoscolices ❺ evaginate, attach to intestinal mucosa ❻, develop into adult stages ❶ in 32- 80 days.
The same life cycle occurs in *E. multilocularis* (1.2 to 3.7 mm), with the following differences: the definitive hosts are usually foxes, and lees often dogs, cats, coyotes, wolves; the intermediate host are small rodents; 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 ❷, with resulting release of oncospheres ❸ in the intestine and the development of cysts ❹, ❹, ❹, ❹, ❹, ❹ in various organs. (CDC/DPDx)

Dipylidium infection

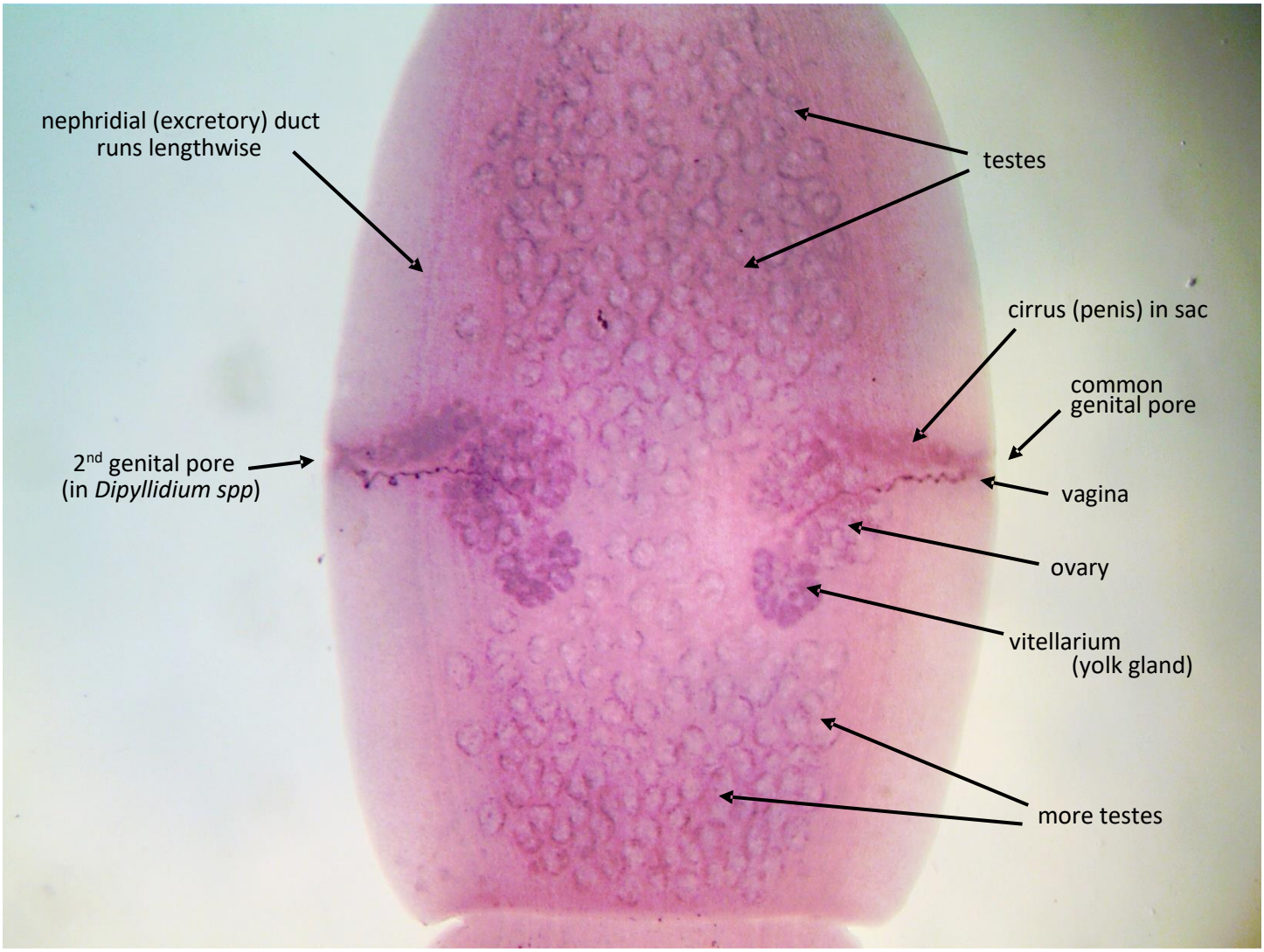
Dipylidium caninum is the two pored dog tapeworm (as its Latin name translates) also called the dog or flea tapeworm, or cucumber tapeworm, because of its usual hosts, and because of the seed-like shape and size of its segments. The definitive host (harbors adult worms) is dogs, but *D. caninum* occasionally 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.



Gravid proglottids passed in the feces or emerge from the perianal region of the host (1) Proglottids disintegrate and release egg packets, which are occasionally found free in the feces (2) Intermediate host (most often larval dog or cat flea *Ctenocephalides* spp.) ingests eggs, and oncosphere within is released into the larva's intestine. Oncosphere penetrates intestinal wall, invades the hemocoel (body cavity), develops into a cysticercoid (3) that remains in flea as it matures from larva to adult (4) A vertebrate host becomes infected by ingesting the adult flea (5) In the small intestine of vertebrate host, the cysticercoid develops into adult tapeworm in about 1 month. Adult tapeworms (measuring up to 60 cm in length and 3 mm in width) reside in the small intestine of the host, attached by scolex (6) . Gravid, double-pored proglottids detach from the strobila (body) and are shed in the feces. Humans also acquire infection by ingesting cysticercoids in a flea. Children are most frequently infected, maybe in close contact with flea-infested pets (7)

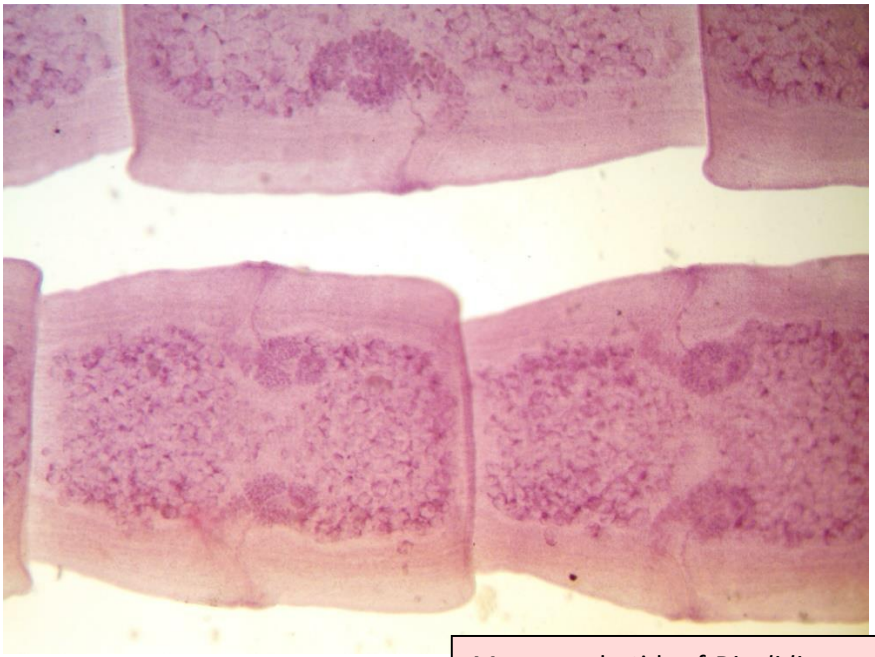
Mature segments (proglottids) break off the end of the adult worm and either pass out in the dog's feces or crawl out of the dog's anus. The proglottids release many thousands of eggs, most of which will perish on the ground. But a lucky few eggs are eaten by small fleas (in their larval stage). The 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, and a cycle that started over 270 million years ago with the first tapeworm is repeated.

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 wiggly segment's descendants.



Immature proglottid of *Dipylidium caninum* the 2-pored dog tapeworm. Tapeworms are prolific hermaphrodites with hundreds of gonads (both male and female) in each of hundreds of segments. 4X objective, cropped, proglottid is about 1.5 mm wide

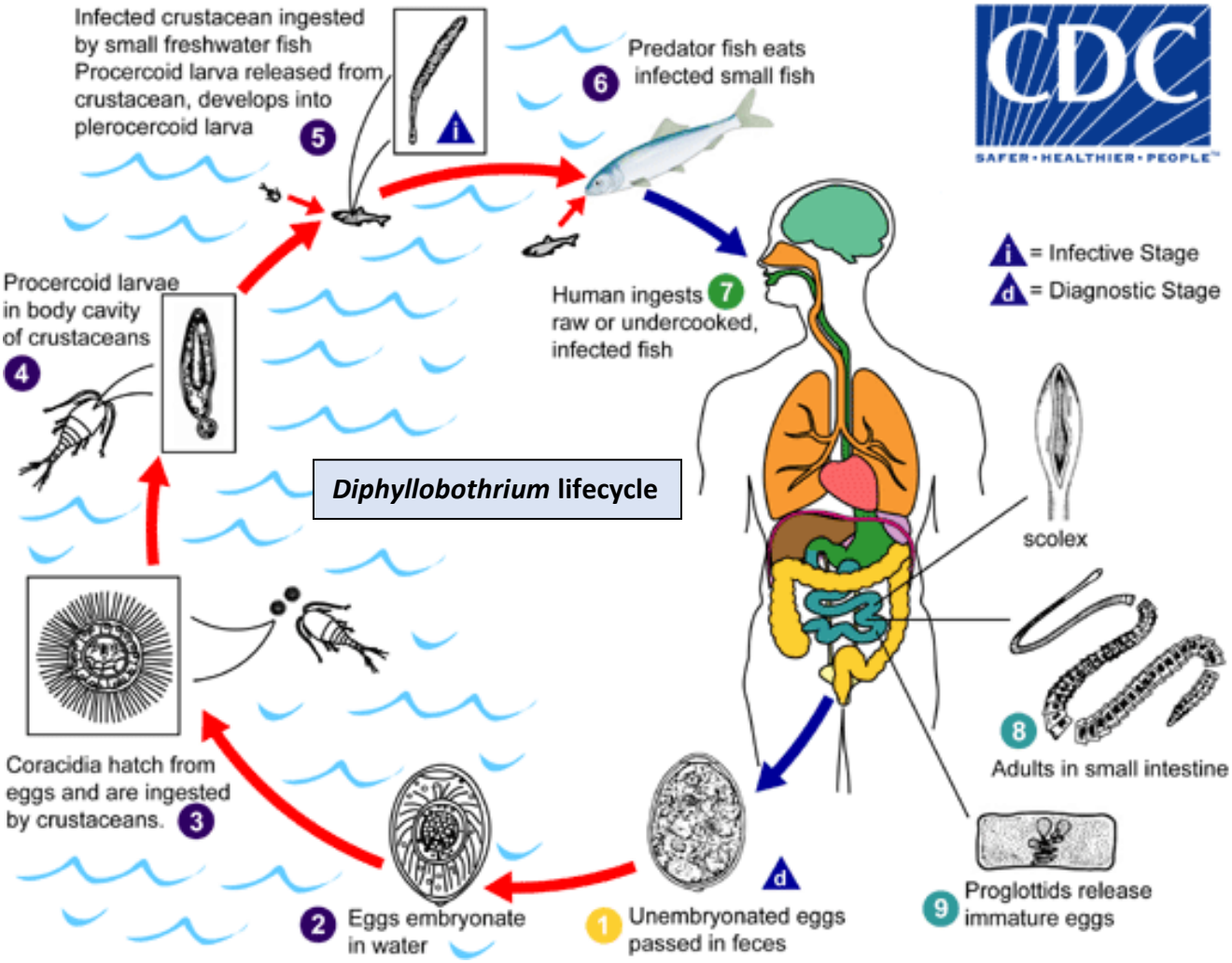
Scolex (head) of *Dipylidium caninum* the two pored dog tapeworm.
The scolex has four suckers and a retractable rostellum with several rings of thorn-shaped hooks, used for anchoring to the host's intestinal wall.
20X objective (direct, no reducer) image about 0.6 mm wide



More proglottids of *Dipylidium caninum,*
the two-pored dog tapeworm
4X obj. (with 0.5X reducer) image ~3 mm wide

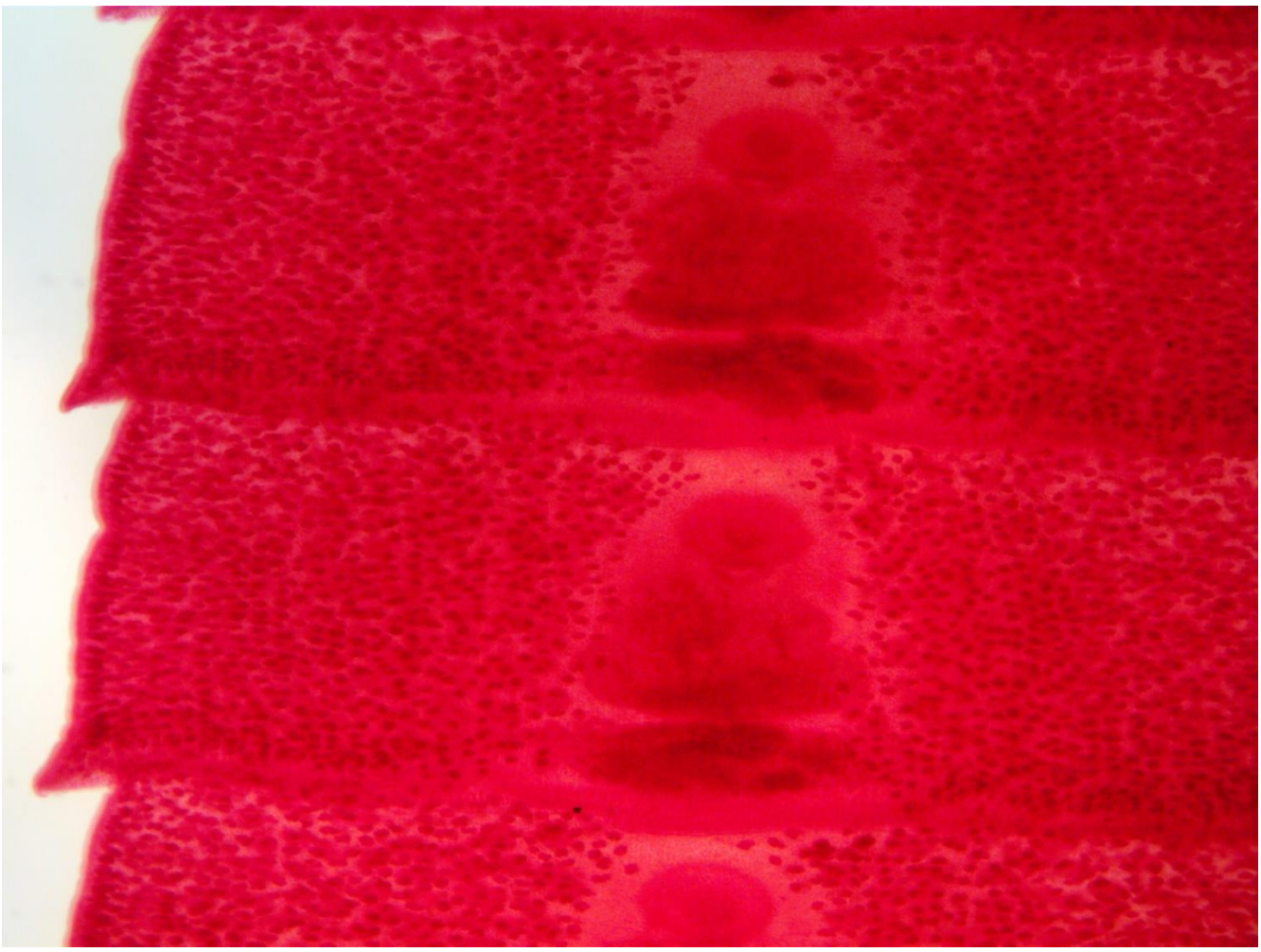
Diphyllobothriasis

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.

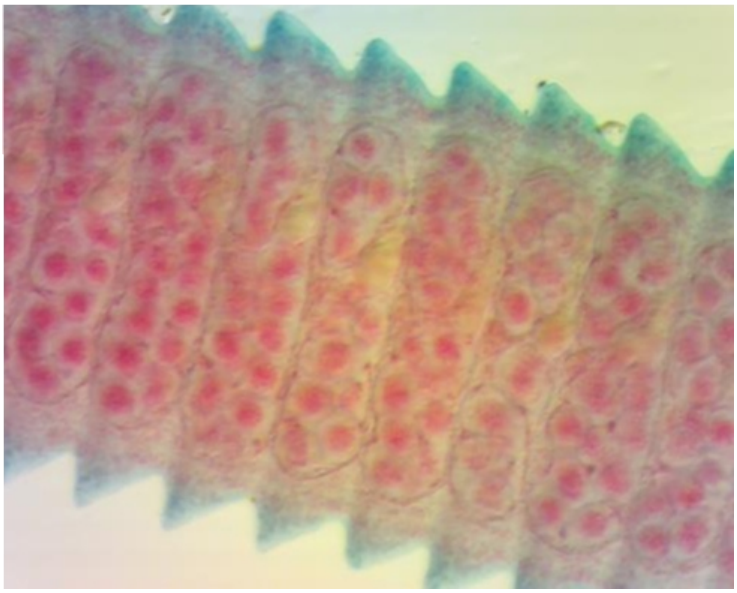


Immature eggs are passed in feces 1. Under appropriate conditions, the eggs mature (approximately 18 to 20 days) 2 and yield oncospheres which develop into a coracidia 3. After ingestion by a suitable freshwater crustacean (the copepod first intermediate host) the coracidia develop into procercoid larvae 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 objective with reducer, image about 3 mm wide

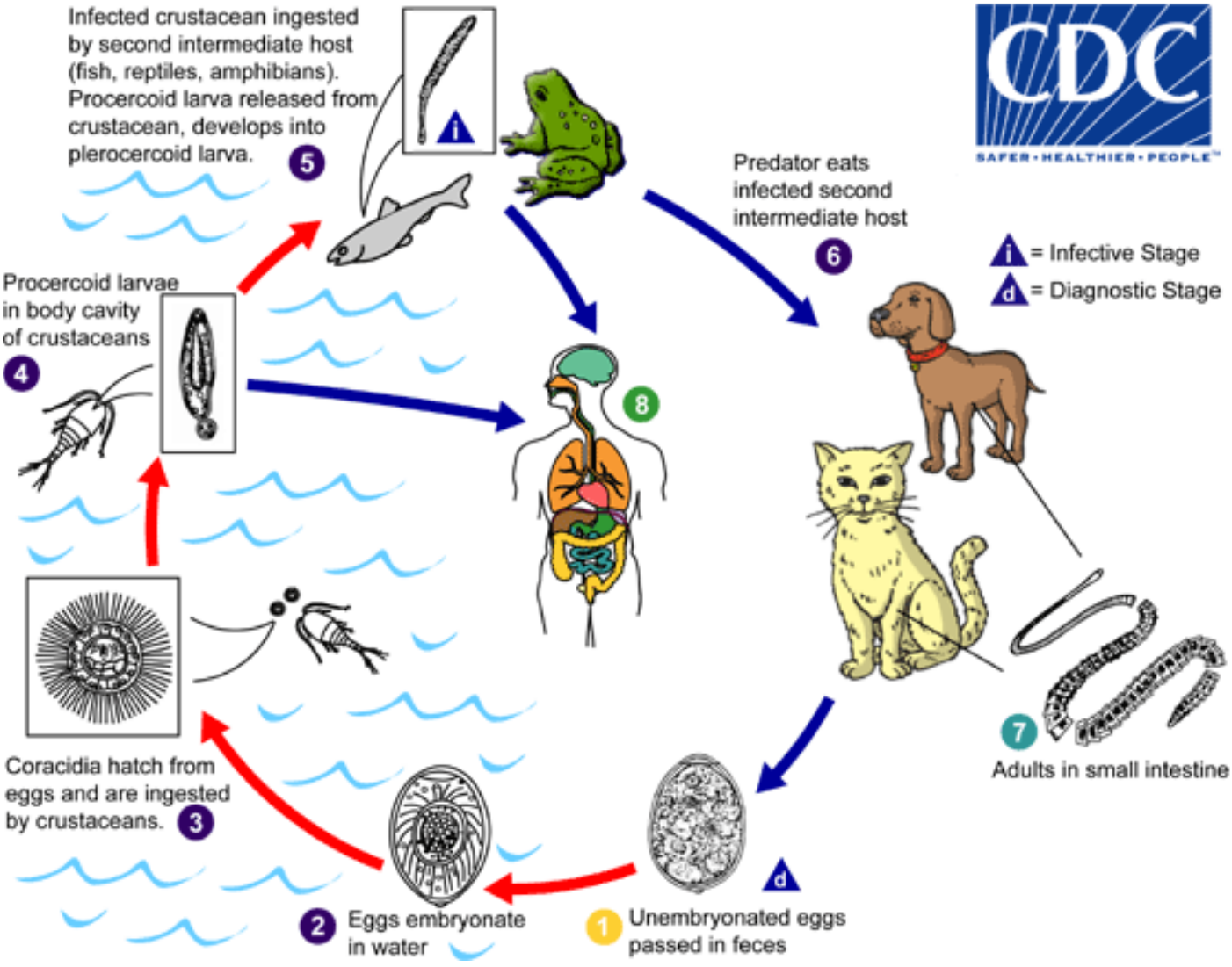


Above: more parasite slides from collection of Professor Van Cleave

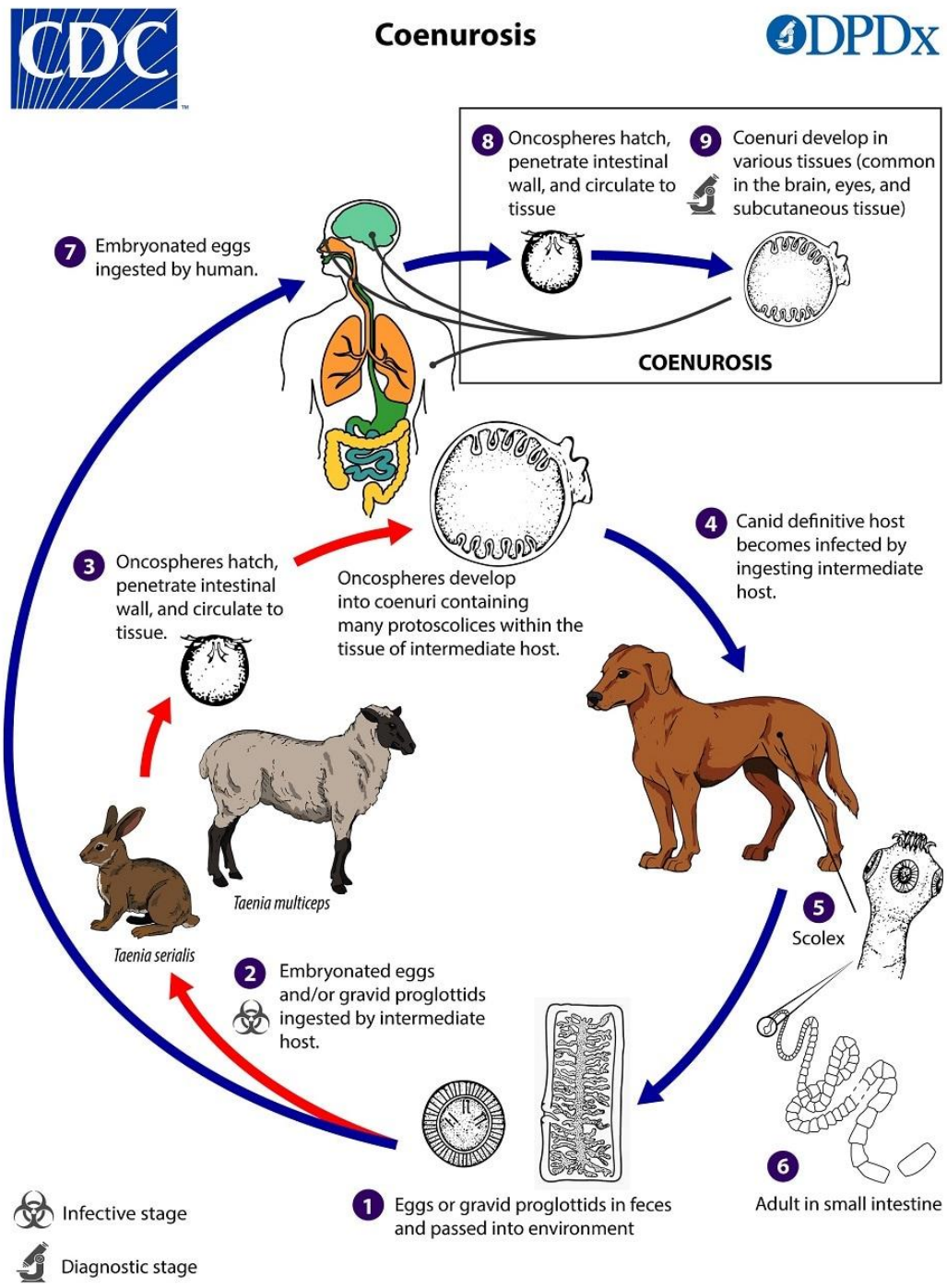
Left: proglottids of *Hymenolepis nana* dwarf human tapeworm, with maturing ovaries, 10X objective

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

Bonus: Two even rarer chronic tapeworm diseases: Sparganosis and Coenurosis



Sparganosis is infection by *Sparganum* or *Spirometra spp* tapeworms, occasionally acquired in mostly in southeast Asia by drinking water with infected copepods or eating uncooked fish or frog intermediate hosts. Carnivores are the definitive hosts; you are dead end. The worms migrate and can end up anywhere in the human body, living up to 20 years, causing slow growing masses under the skin, in the lungs or eyes or brain. Treatment is surgical removal.



Coenurosis is human infection by larva of one of 4 species of dog tapeworms. *Taenia* (=*Multiceps*) *multiceps*, *T. serialis, T. brauni*, and *T. glomeratus* produce cyst forming metacestode larva called coenuri or "bladder worms" and have canid definitive hosts and herbivore intermediate hosts. Ingestion of eggs in dog feces can lead to cysts under the skin or in muscle, brain or eye. Most cases occur in Africa, but a few cases occur in sheep raising areas of the Americas. Treatment may medical with praziquantel and/or surgery. Cysts in the eye should not be treated with praziquantel as a dead worm causes blinding inflammation.

Part 2 Impacts of parasitesPart 3

Parasite glossary: strange words to describe strange relationships

Parasite an organism that lives in or on another and takes nutrients from the host

Endoparasite lives inside of host

Ectoparasite lives on outside of host

Free living not a parasite; makes food or eats it as a predator/scavenger, does not live inside creatures

Parasite load number of parasites per host (affects potential harm of parasites)

Infestation harboring another animal (worm, arthropod) in or on the body (**infection** is microbes in body)

Host a larger organism that harbors a smaller parasitic (potentially harmful) organism

(smaller organisms helpful to, or neutral for a host are beneficial or commensal, not parasitic)

Definitive host organism that harbors adult (sexually reproductive stage) parasites

Intermediate host organism that harbors immature stages (which may reproduce asexually)

Vector an organism (usually intermediate host) that passes a parasitic organism between hosts

Reservoir a population or community of organisms that can permanently harbor a parasite population

Zoonosis a disease transmitted from animals to people; many parasitic diseases are zoonotic

Parasite life cycle a series of stages through which the parasite grows, reproduces and transmits itself

Monoxenous also known as direct parasitism; life cycle requires only a single host species

Heteroxenous indirect parasitism; life cycle requires definitive host plus one or more intermediate hosts

Direct transmission hosts touch each other (sex counts), passing on a free-living life stage (including skin to skin passing lice) or by ingestion of free-living parasite or eggs (i.e. fecal-oral, by food with contaminated dirt)

Indirect transmission from one host to another through an intermediate host (i.e. a vector such as a tick)

Trophic transmission by eating an organism that contains a parasite (i.e. from prey, or uncooked pork or fish)

Iatrogenic transmission by medical care (i.e. malaria from a blood transfusion or organ transplant)

Parasitoid tiny wasps (some are "fairy flies") whose larva eat a host from inside, eventually killing it

Hyperparasite a parasite of a parasite; i.e. some parasitoid wasps prey on other parasitoid wasps

Parasitic castration some trematode and arthropod parasites gain added resources by neutering the host

Kleptoparasitism stealing food from another species, i.e. as do frigatebirds and hyenas

Social parasitism i.e. some butterfly larvae mimic ants in shape and smell and are cared for by ant colonies

Brood parasitism raised by parents of another species, i.e. cuckoo birds lay eggs in another species' nests

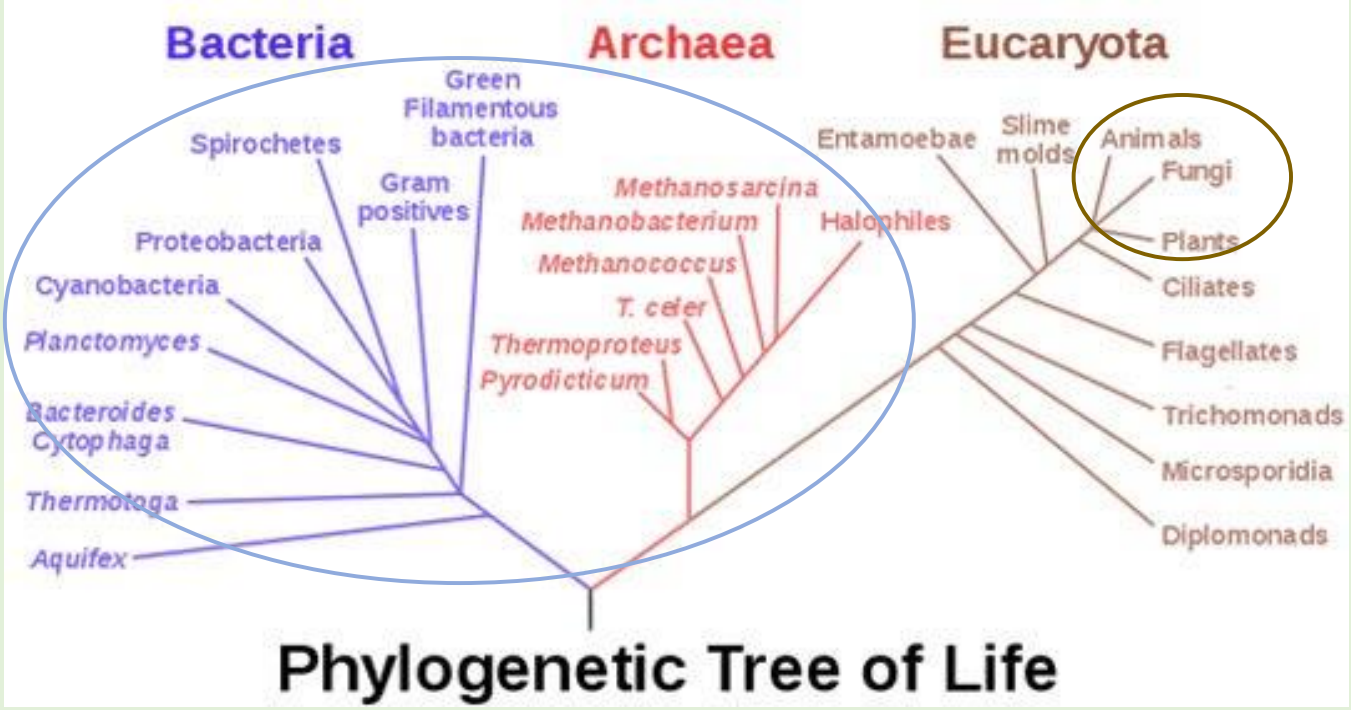
Sexual parasitism i.e. male anglerfish attach to a female and shrink to just tiny sperm-making parasites

Evolution explains a lot

In 1859 evolution was a new theory, laid out in clear, logical and humble detail by Charles Darwin in his book *On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life*. Darwin had gathered thousands of his own and others' observations about the varieties of life, but at that time known fossils were fewer and the mechanisms of inheritance were unknown (actually Czech monk Gregor Mendel discovered the laws of genetics in pea plants in the 1860's but no one knew of it). Evolution is now a proven fact: millions of new bits of evidence show life slowly evolved into a myriad of different forms on planet earth. Evolution remains also a powerful and changing (all science is subject to modification by additional information) central theory in biology that makes sense of new evidence from biologic and medical research. I see evolution in action in the hospital as bacteria evolve to be resistant to commonly used antibiotics, and the COVID-19 virus luckily evolved to be more docile.

Darwin's theory is amazing in that upon careful reflection it seems inevitable. People create different breeds of dogs, pigeons and other domesticated animals through selective breeding. Darwin showed nature does much the same thing. It can be observed that all organisms come from the reproduction of previous organisms, that there are differences between individuals in a group (i.e. some are faster or slower) and that parents make imperfect copies of themselves (we now know genes are shuffled and sometimes mutate). Darwin noticed that there is a struggle in nature for organisms to survive and produce offspring. In real circumstances (gazelles being chased by cheetahs for example) survival is not just random but favors certain bodily abilities (i.e. running faster) so the next generation comes from selected (faster) surviving parents and so each generation becomes slightly adapted in particular ways. Over deep time (the earth is now known to be about 4.55 billion years old) a single cell became all the amazing life on the planet today, from bacteria to *Paramecium* to grass to mushrooms to worms to you. Every living thing becomes fined tuned for its way of life, making life look like it was designed. Yet there was no designer, just the logical results of how natural life processes worked out based on chemistry, physics and maths.

Most life is prokaryotic: very tiny, no nucleus, the Bacteria and Archaea, on left. All Metazoans (multicellular organisms) are in the small circle on right. Between are Protists, bigger than bacteria, but mostly microscopic, nucleated single celled life. Carl Woese used ribosome RNA data for the tree.



Privileged to be parasite-free

Most people reading this article don't need to worry much about parasites personally, as they are probably living in a privileged place in a privileged time.

Since the origin of *Homo sapiens* in Africa about 300,000 years ago, most people harbored potentially harmful parasites in and on their bodies. Lice and intestinal worms were nearly universal. Then a combination of industrial and social revolutions starting almost 300 years ago greatly improved health and comfort for most people today. If you are reading this then it is likely you have clean water and food supplies, shoes, indoor plumbing, window screens, floor boards and a solid roof, all diminishing the chances of worms burrowing into your feet or being swallowing in contaminated water, and of exposures to mosquitoes and reduviid bugs. **Good living standards, scientific knowledge and public health measures have eliminated most significant human parasites from most developed nations.**

Great strides continue to made fighting parasites and poverty in the world. The WHO estimates intestinal worm infestations dropped from 60% to 25% of all humans so far in this century. Global median annual income more than doubled between 2000 and 2019 from $1325 to $2759 (with the mean about $12000 in 2019, and yours is likely higher). Global life expectancy increased 6+ years between 2000 and 2019 from 66.8 to 73.4 years average (even as life expectancy in the US began to decline during the same timeframe).

But the global gains in well being are far from being evenly distributed. Severe inequalities make averages (means) deceptive when **almost half of the world's total wealth is held by the top 1%, and the bottom half divvies up just 0.74%**. Most people are poor and live in the "majority world" (a newer term for what we also call the third or developing world) and they are still lacking in money, health and governance. Without all the luxuries we take for granted, the parasites they suffer from are just a small part of the unfair miseries (wars, famines, and imprisonment without trial if they denounce the dictator) borne by the powerless majority. **Most people (4.3 billion) live in 95 countries under authoritarian regimes today**.

Its normal to feel bad about this sorry state of affairs. For some readers the best way to worry about parasites is by helping out people with parasites who have little way to help themselves. You might consider a charitable donation to Oxfam, Against Malaria Foundation or Deworm the World.

It's also perfectly fine to feel grateful for the cosmic lottery you've won. You weren't born in medieval times, living 30 miserable years with lice and worms. Average *Micscape* readers are often males in rich European or North American countries. You likely know a European language and have computers and microscopes. You may be privileged by your race, gender, citizenship (in a former imperial power), and by your political and economic systems. You were likely born in a country with the full modern liberal package: democracy, good schools, free speech and press, universal health care (not in US) and private property.

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For 2024 I offer *Micscape's* readers a series of articles about parasites, illustrated in part from my slide collection.

I am incurably curious about parasites and keep thinking I should know more. The internet makes it easy to learn more, so my articles are always longer than I intended at first.

Just look at the interesting pictures if you want. Don't be freaked out by parasites. They are everywhere but seldom cause harm in the developed world.

Some people are real experts and know much more than I do on these subjects. I would be pleased to have any mistakes or misunderstandings corrected.

I am Ed Ward in the state of Minnesota, USA.
Your comments are always welcomed, my email is eward1897 AT gmail DOT com

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