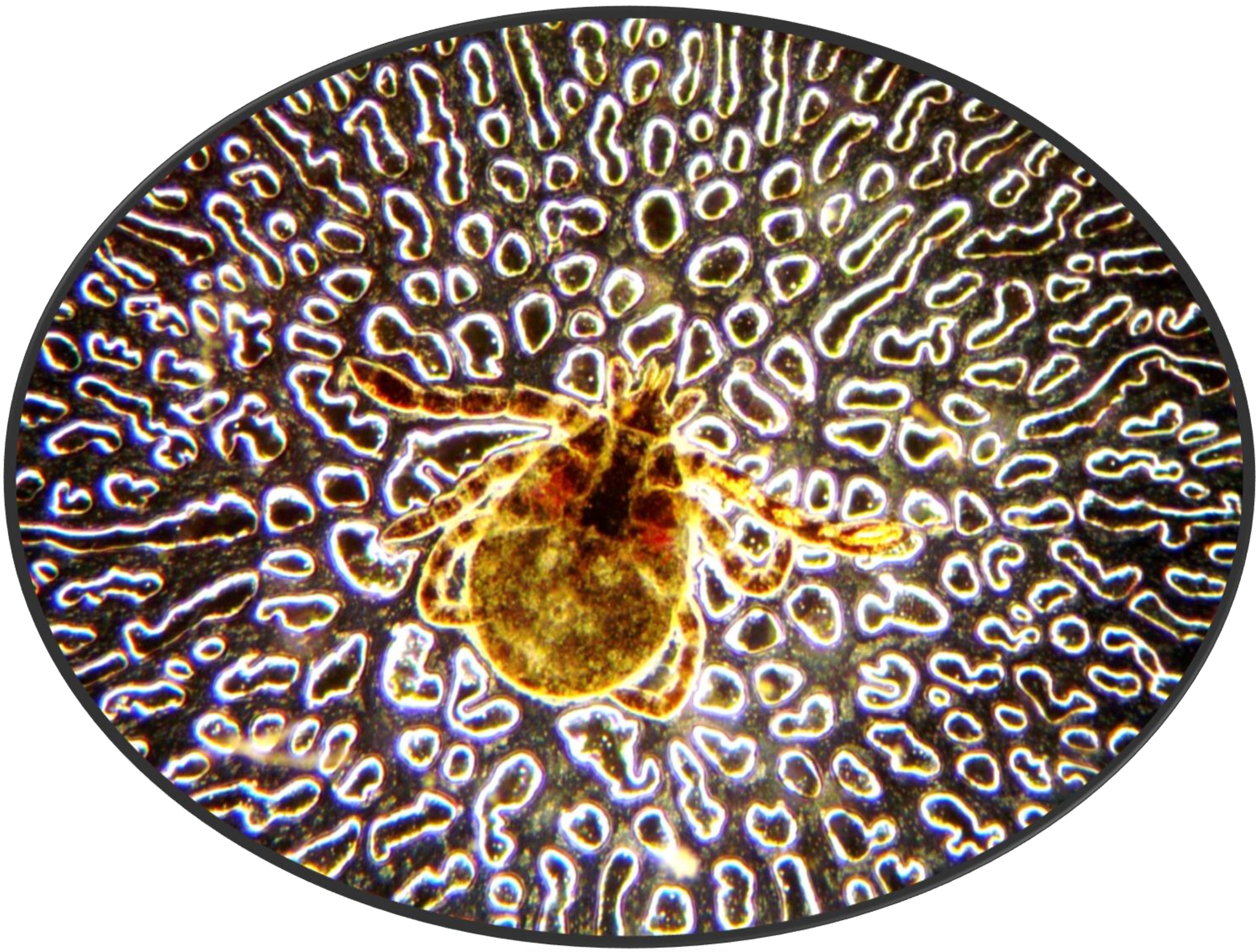
Parasites part 1



Ed Ward MD, Minnesota USA

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Origins of this article

I have long been fascinated by creepy crawly things. During my training and office practice I gave talks about Lyme, West Nile disease and the bugs that spread them. I got to live and work in West Africa in 2004, a wonderful experience, including seeing and 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 soon made my article too long. I will publish an introduction and overview this month, then future installments about specific parasites. I'll eventually 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 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 very 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 the doctor will likely dismiss your self diagnosis and offer you $100 of anxiety pills, as serious human parasites are now rare here. An alternative healer might happily order $200 of parasite tests and sell you a $200 herbal based treatment you don't need. Soap, water, shoes and indoor plumbing are your best bets against parasites.

Cover page illustration

Ixodid tick nymph (6 legs, adults have 8)
family Ixodidae includes deer ticks and dog/wood ticks, the most important hard tick vectors in North America
4X objective, dark field; tick about 1 mm long. Vintage slide is from 1950's and ruined by bubbles in mountant

Contents

Abstract

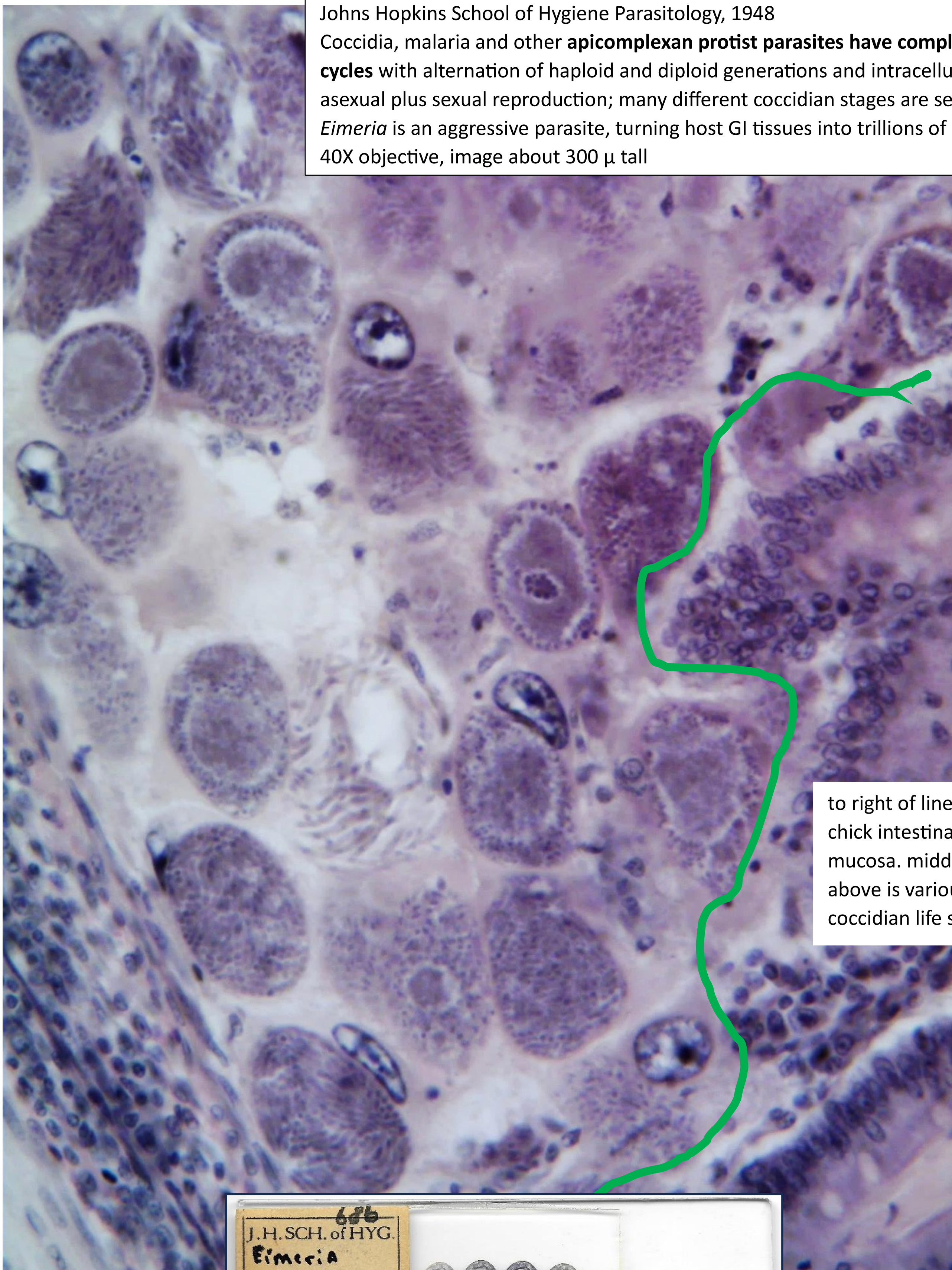
Life spreads and adapts to everywhere it can survive, including inside and outside the bodies of animals. The bodies of animals turned out to be comfy and tasty. Evolution therefore produces many endoparasites (like intestinal worms) and ectoparasites (such as lice). Most wild animals have parasites, and most humans used to have them. 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 over 600,000 annual deaths from malaria. Parasites can also act as vectors to spread bacteria and viruses that cause Lyme disease, viral encephalitis and plague. Almost 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.

The harms of parasites are highest 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 are also part of the balance of nature, which might be hurt if we continue to extinct parasite species faster than we can discover them.

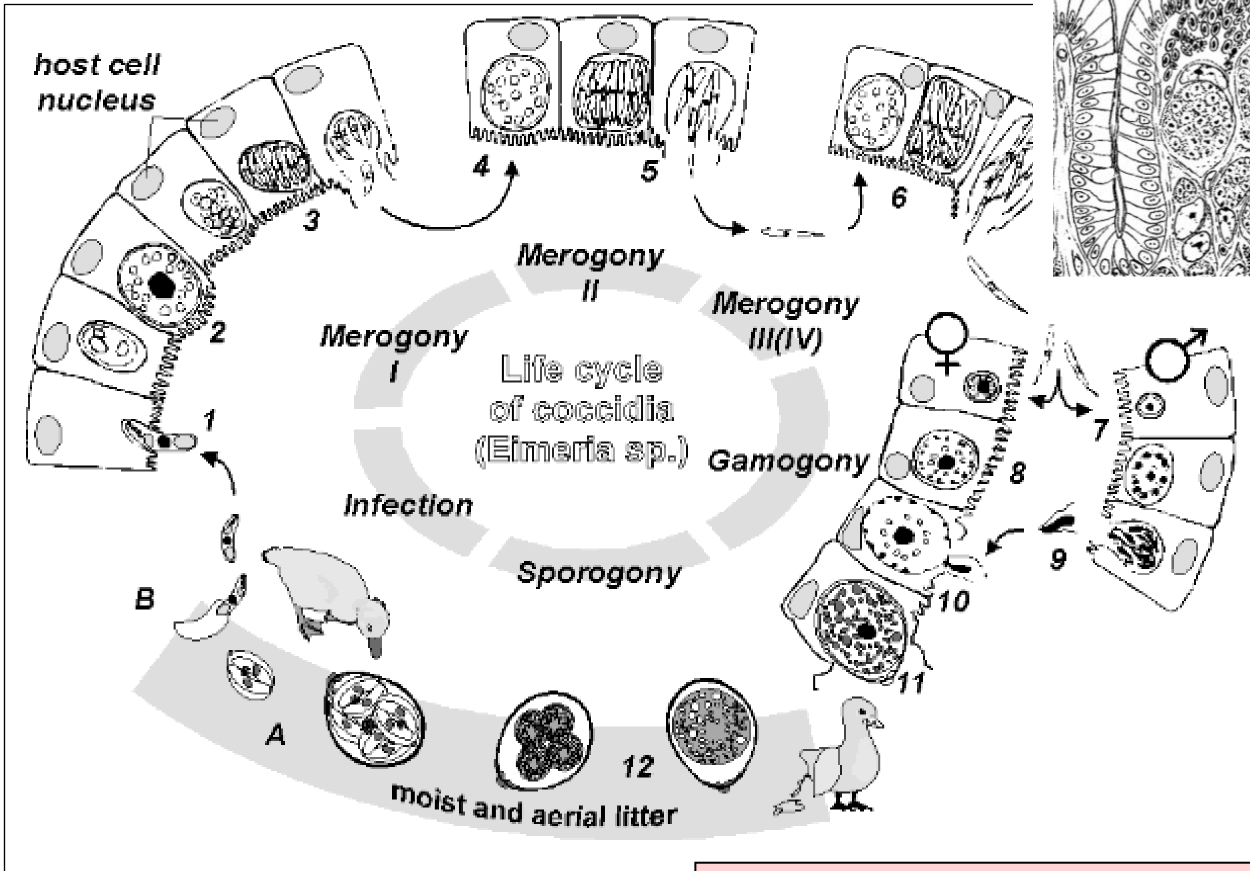
vintage slide of nematode endoparasite of turtle
4X objective, worm about 0.6 mm diameter

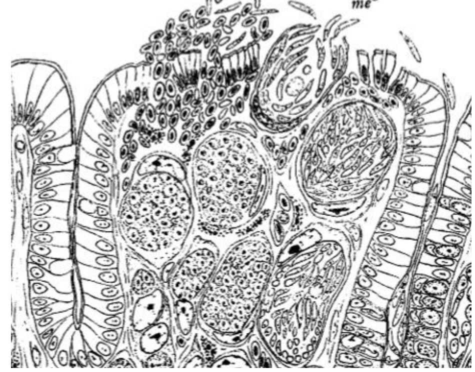
antique slide of hog louse, ectoparasitic insect
louse about 5 mm long (stereomicroscope shot)

Eimeria tenella, coccidian parasite *in situ*, chick hemorrhagic colitis, slide by Johns Hopkins School of Hygiene Parasitology, 1948
Coccidia, malaria and other **apicomplexan protist parasites have complex life cycles** with alternation of haploid and diploid generations and intracellular asexual plus sexual reproduction; many different coccidian stages are seen here. *Eimeria* is an aggressive parasite, turning host GI tissues into trillions of parasites. 40X objective, image about 300 µ tall



to right of line is chick intestinal mucosa. middle and above is various coccidian life stages





drawing Tyzzer, 1929

Life cycle of *Eimeria* coccidia In birds
7 species of *Eimeria* are exclusive to chickens

Labels above:
1. sporozoites freed by digestive enzymes invade intestinal cells 2. sporozoites round up and 3. become schizont, by dividing into hundreds or thousands of merozoites 4. Host cells destroyed, releasing merozoites to infect more cells 5. 2nd generation of merozoites, some 6. lead to 3rd generation merozoites some 7. become male microgametes and 8. female macrogametes. 10. fertilization leads to 11. oocyst, which destroys host cell and is released into feces. In warm moist soil the oocyst sporulates 12. creating 4 sporocysts containing 2 sporozoites each (details vary in some other coccidia) which are picked up by fecal-oral transmission to continue life cycle.

Eimeria's life cycle is simple monoxenous: only one host, aka direct. Many parasites have even more complex, heteroxenous life cycles.

image- saxonet.de, original at USDA, NCAT 2008

Years ago, I bought a used microscope with several boxes of slides. Because the microscope was a substandard toy I wasn't expecting much. But the owner must have gone from young student to biomedical professional, as they had many quality parasite slides. The one on the proceeding page was made at the Johns Hopkins School of Hygiene, the first public health university in the world (started in 1916).

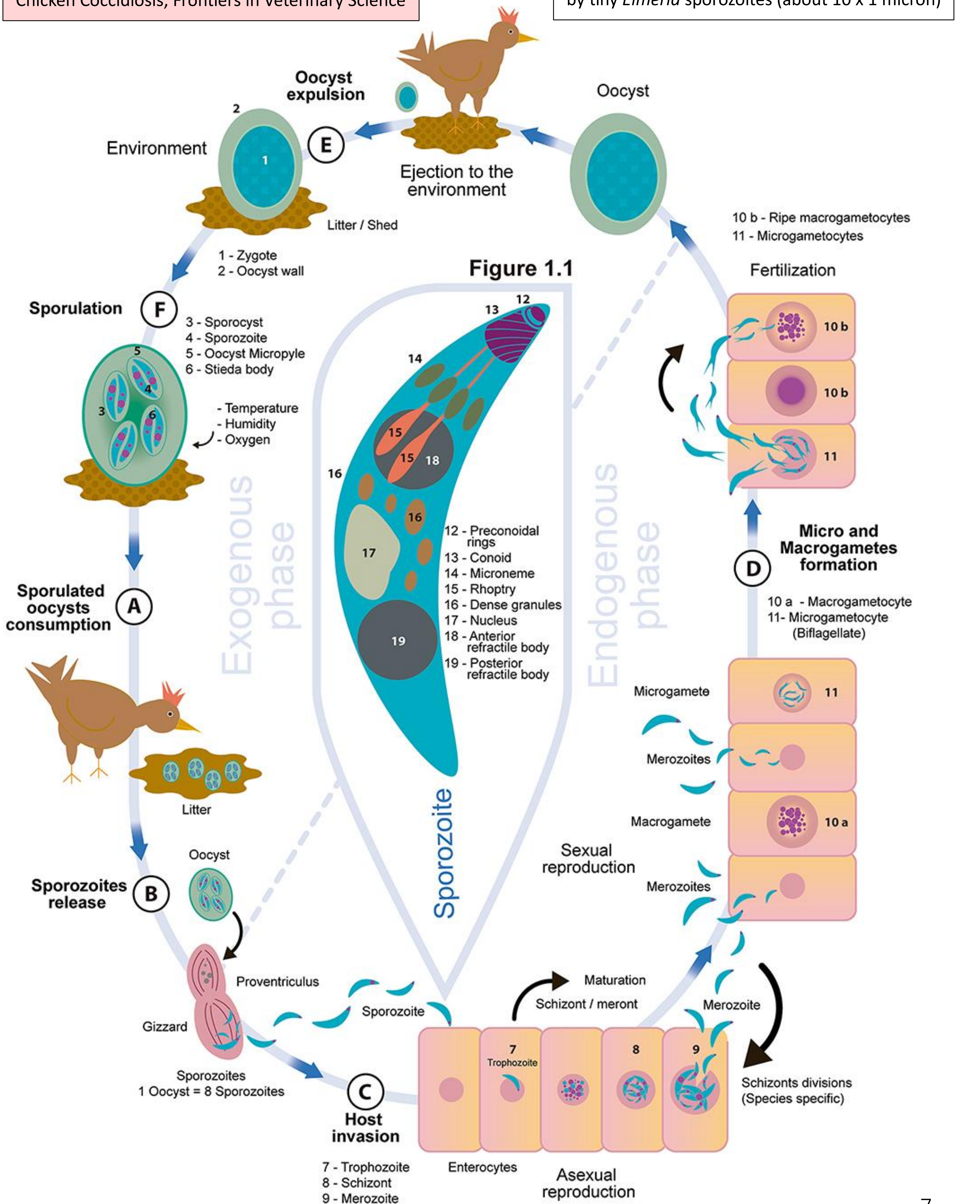
I wasn't at first familiar with *Eimeria*, but being a livestock parasite, it was studied early on, and in depth.

The world today is amazingly connected by the internet. Google found hundreds of articles on *Eimeria* in a fraction of a second. Imagine all the hard microscopic research it took to untangle coccidian life cycles a century ago. HB Fantom at Cambridge University figured out a coccidian life cycle in red grouse in 1910, and EE Tyzzer at Harvard University elucidated the life cycle of *Eimeria* in chickens in 1929, using slides much like the one I illustrate. Tyzzer was also the first to discover *Cryptosporidium*, in 1910.

Today's internet lets you gain post-graduate college level knowledge in an obscure scientific subject, or you can find out who a made up celebrity is sleeping with tonight. If more people did the former then the world might be better off.

Eimeria infographic by Mesa-Pineda et al
Chicken Coccidiosis, Frontiers in Veterinary Science

Small can be complex and destructive, as shown by tiny *Eimeria* sporozoites (about 10 x 1 micron)



Introduction

A parasite is an organism that lives in or on another organism and takes resources in an intricate long term relationship. They can cause harm, yet parasites are a common and essential part of nature, with more species of parasites than there are of free-living animals. Parasites help balance nature. All life exists as communities of interdependent species and evolves as new opportunities to gain a bit of biological material arise. The biosphere is a complex web of relationships, including some species working intimately for mutual advantage, like plants paying insects in nectar for pollination services. In the big picture, plants and some bacteria (cyanobacteria, aka blue green algae) are photosynthetic producers. They miraculously make sugar and other food molecules from sunlight, carbon dioxide and water, and conveniently produce oxygen as a waste product, thus enabling animal life. Herbivore animals eat plants. Carnivores eat herbivores (or other carnivores). And parasites consume just a little bit of another living organism, usually without killing it. The witty biologist EO Wilson said parasites are carnivores that consume less than 1 unit of their prey.

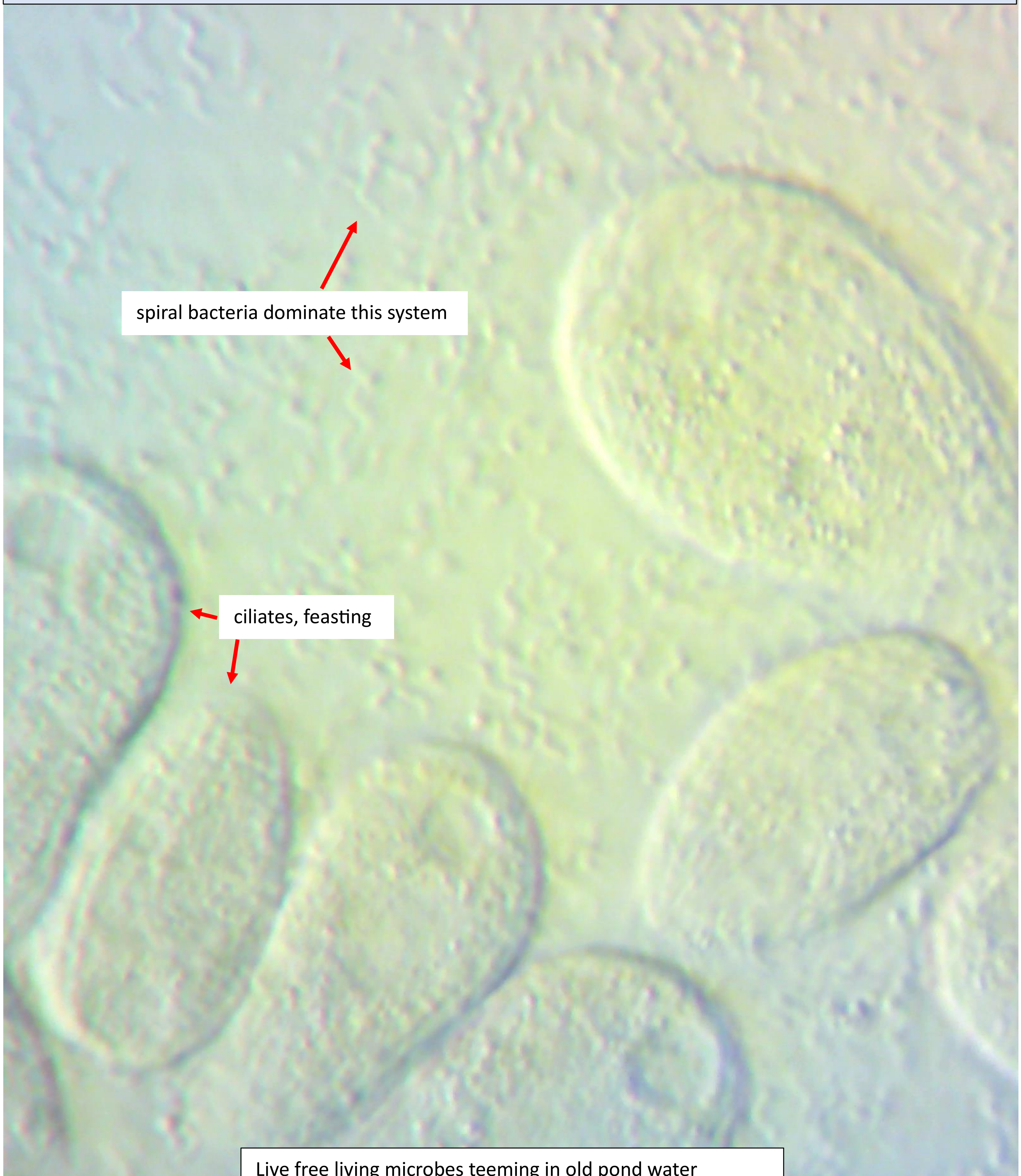
All organisms are subject to parasitism and many kinds have become parasites themselves. I will talk mostly about some protozoa or animals living on or in a host animal in a symbiotic (close, ongoing) relationship that is potentially harmful to the host. I will go further into defining different types of parasites later but consider some broad types. Endoparasites are organisms living inside another organism. Malaria parasites and intestinal worms are endoparasites. Ectoparasites feed on part of another organism from the outside; blood sucking mosquitos, lice and leeches are examples. A few parasites are generalists, able to live off many different host species. Many other parasites are specific to only one or two host species, having become finely adapted in shape, chemistry and life cycle to those hosts.

Parasites can be defined by the branch of life they come from. Not all parasites are tiny animals. Some protists (aka protozoa, single celled eukaryotes), fungi and plants are parasites. The fungi that cause athletes foot are growing inside and deriving nutrition from your outer skin layer, so they are parasites. Some plants (dodder, mistletoe) are parasites on other plants. Some parasites can be seen with the naked eye. But many are microscopic, or just tiny specks needing magnification for details. With so many parasites I will concentrate on protozoan, worm and arthropod parasites of animals.

I borrowed repeatedly from the CDC and other online sources for parasite life cycle and phylogenic tree images. Unless noted otherwise the photomicrographs (pictures taken through a microscope) are mine. Most were taken with vintage AO/Reichert Microstar or Diastar microscopes using a simple 3 Mp USB camera with 0.5X reducer lens. I state objective used rather than an overall magnification. Unless noted otherwise the **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 images about 125 microns across.**

The living world belongs to the microbes

Some parasites are microbes (microscopic organisms) and some are bigger, visible to the naked eye. In numbers of individuals the world is overwhelming microbial. A guestimate is 10^{30} bacteria versus 10^{20} animals on earth. Eukaryote cells are much more complex and typically thousands of times bigger in volume compared to bacteria.



Live free living microbes teeming in old pond water
spiral bacteria- about 8 micron long, big for **prokaryotes**
small ciliate protists- about 35 micron long **eukaryotes**
40X objective without reducer, cropped, oblique lighting

Microbes are everywhere

Some people freak out when they learn that microbes (microscopic organisms) are everywhere. Research published in 2015 found an average of 7000 species of bacteria and 2000 species of fungi in each of 1200 houses (over 110, 000 total species in their samples). This was just from airborne dust. There are even greater numbers of dirt and water associated microbes in your house. And the biggest microbe reservoir is you, containing more bacterial cells on your skin and in your gut than the number of human cells in your body (bacteria $3.8 \cdot 10^{13}$, nucleated human cells $0.3 \cdot 10^{13}$ by one 2016 estimate, >10X more bacteria, although others estimate ratio close to 1:1). When I let a vial of pond water sit a few days, one tiny drop of the smelly water is seen as a soup of hundreds of thousands of swarming decomposer bacteria using a 40X phase contrast objective. We are bobbing around in an ocean of microorganisms.

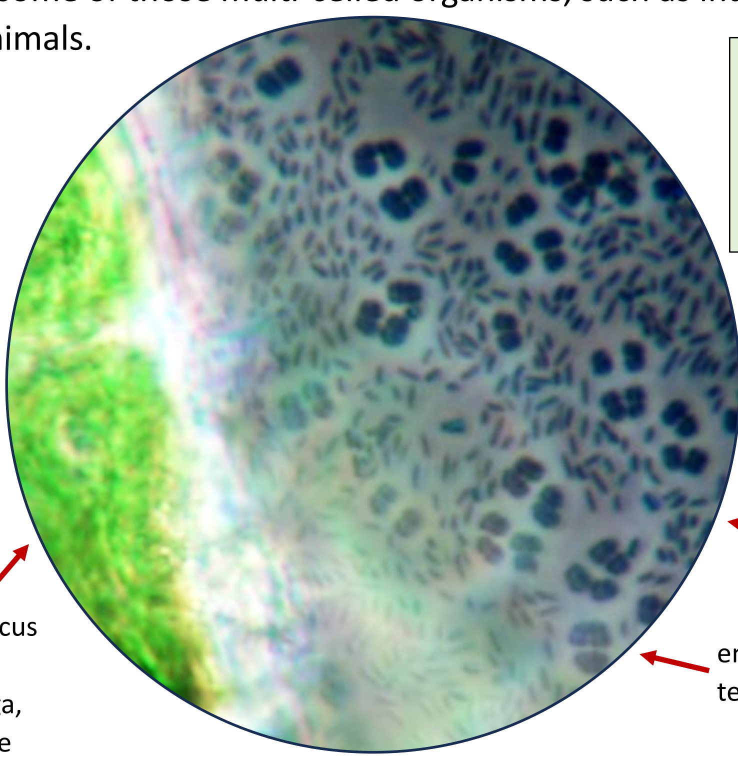
While some freak out, I have the opposite reaction to this reality. Living without breathing in, eating or touching microbes just isn't possible. But our ancestors survived living in a sea of microbes and so will we. Infections dropped from the number 1 to about the number 5 cause of death during the 20th century. Wash your hands before dinner and after pooping. Shower regularly, not excessively, as most skin bacteria are your friends. Eat fruits, vegetables, and whole grains to help feed healthy gut bacteria. And maybe eat some yogurt, swarming with bacteria under a 40X objective, but good probiotic ones.

If, like most readers of this article, your country has eliminated malaria and you have clean indoor plumbing and safe food, don't worry about parasites. Parasites are probably not in your top 20 causes of death and disability.

An exception is people whose immune system is turned down by medical treatments. That used to be a relatively few people on cancer treatments, but now includes many with arthritis, skin problems and other diseases. Before COVID vaccine, adalimumab (I avoid advertising names but you've seen it on US TV) was the most profitable drug in the US, $21 billion in yearly sales. If you take this or related "biologic drugs" you may be at high risk for rare and severe viral, bacterial and parasitic infections, including some "tropical and neglected diseases" like TB (ironic for modern high tech treatments).

In terms of numbers of organisms, **most living things are tiny microbes**. Microbes are so small and so numerous as to defy comprehension. Taking a very broad definition, the most common parasites are viruses, for they must enter cells and use the resources there if they are to reproduce. Viruses are the smallest (thousands of times smaller than cellular life) and most numerous "biological entities" (not organisms, as viruses are not fully alive), probably over 10^{31} total on earth, just nanoscopic bits of nucleic acid in protein shells that straddle the definition of dead vs. alive. All living things have their viruses, and the most common viruses are bacteriophages, which reproduce in the smallest, most numerous and oldest kind of cellular life: bacteria. Most of the about 10^{30} bacteria and archaea on earth are free-living in nature but some bacteria enter our bodies, and a few (often with reduced genomes) can live only as intracellular parasites (*Mycoplasma*, *Chlamydia, Anaplasma, Ehrlichia, Rickettsia Coxiella* and others) and some are intracellular pathogens/parasites only at some times in their infectious cycle (*Listeria, Brucella*, some species of *Mycobacterium, Salmonella, Anthrax and Yersinia,* and others). Because many of these bacterial diseases are acute, highly symptomatic (sometimes fatal) and well defined illnesses (typhoid fever from *Salmonella enteritica,* for example) we usually call those bacteria **pathogens**, rather than parasites, even though being inside our living cells is an intricate symbiotic relationship harmful to the host. Crossing the line between **prokaryotes** (tiny bacterial type cells with simpler internal compartments) and **eukaryotes** (life made of larger, more complex cells with nuclei, chromosomes and mitochondria) brings us to some "classical" parasites. Single celled eukaryotes are called **protists**, a group including *Paramecium, Amoeba* and other protozoa (same thing, both names are valid) well known to most microscope hobbyists. A relatively few protozoa are dangerous parasites, causing animal and human diseases including toxoplasmosis and malaria. Eventually some protists evolved into multicellular life (**metazoans**) including plants, fungi and animals. And some of those multi-celled organisms, such as intestinal worms, became classic parasites of animals.

Eukaryotes are bigger but prokaryotes win in numbers
Old pond water with green alga, bacilli, diplococci.
40X objective, phase contrast, cropped
bacilli are about 3 microns long, twice as big as E coli,
the green alga cell is thousands of times bigger



In the web of life, all living things require biological material and energy, and all are producers or consumers. Being a consumer without killing the victim shouldn't automatically produce revulsion. But with many parasites living inside the hosts, they get under our skin metaphorically as well. Being adapted to living in our bodies leads to some unusual and sometimes scary body shapes. **Parasites need better public relations**. We think of herbivores as cute and docile, like baby lambs. Even if we sometimes fear them, we acknowledge the sleek, efficient beauty of amazing predators like jaguars and peregrine falcons. But parasites are often unfairly perceived as ugly little thieves (my previous *Micscape* article on tapeworms contained particularly egregious examples). Parasites may sometimes confer benefits. Parasites and the rest of nature are not subject to our moral judgement.

Parasites do not choose to be good or evil. Only we, dear humans, do that (some ultra-rational thinkers claim choice is an illusion).

Where this article is headed

Parasitism is a huge and fascinating topic, and like the rest of science, parasitology knowledge is incomplete. In this paper I will give a brief overview of some harms done by parasites, summarize the taxonomy (biologic classification by relatedness) of some different types of parasites, visit some amazing life cycles and different groups of parasites and discuss the potential benefit of some parasites. In later installments I'll talk about some clinical aspects of a few human parasites, which today are mostly seen in the developing world. I have some true bedside tales of human disease caused by parasites. Unless otherwise stated, photomicrographs are by me, of old slides I obtained commercially as an amateur. My photos of African patients are from Monrovia, the capital city of Liberia in West Africa, where I was a volunteer with Medicines sans Frontières (Doctors without Borders) in 2004.

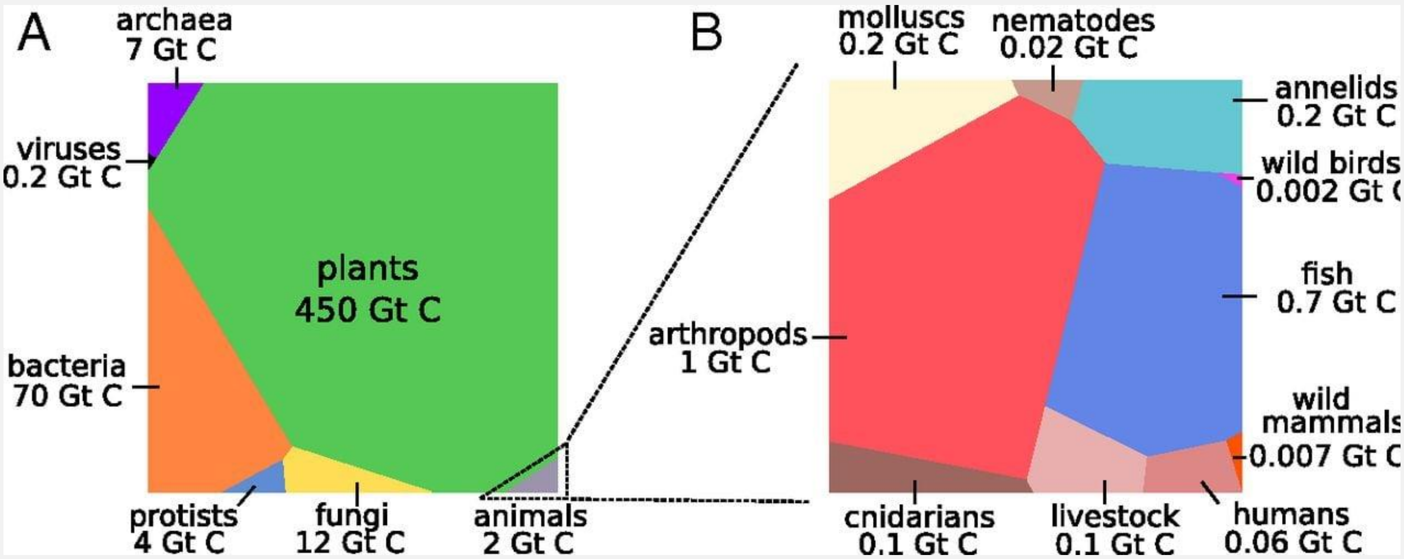
Loa loa microfilaria (nematode larva) in blood, Ward's slide 40X obj., image about 0.3 mm wide, worm about 150 μ long

"Leopard skin" rash caused by *Onchocerca volvulus* nematode microfilaria in skin. Monrovia, Liberia, 2004

What do all the microbes add up to?

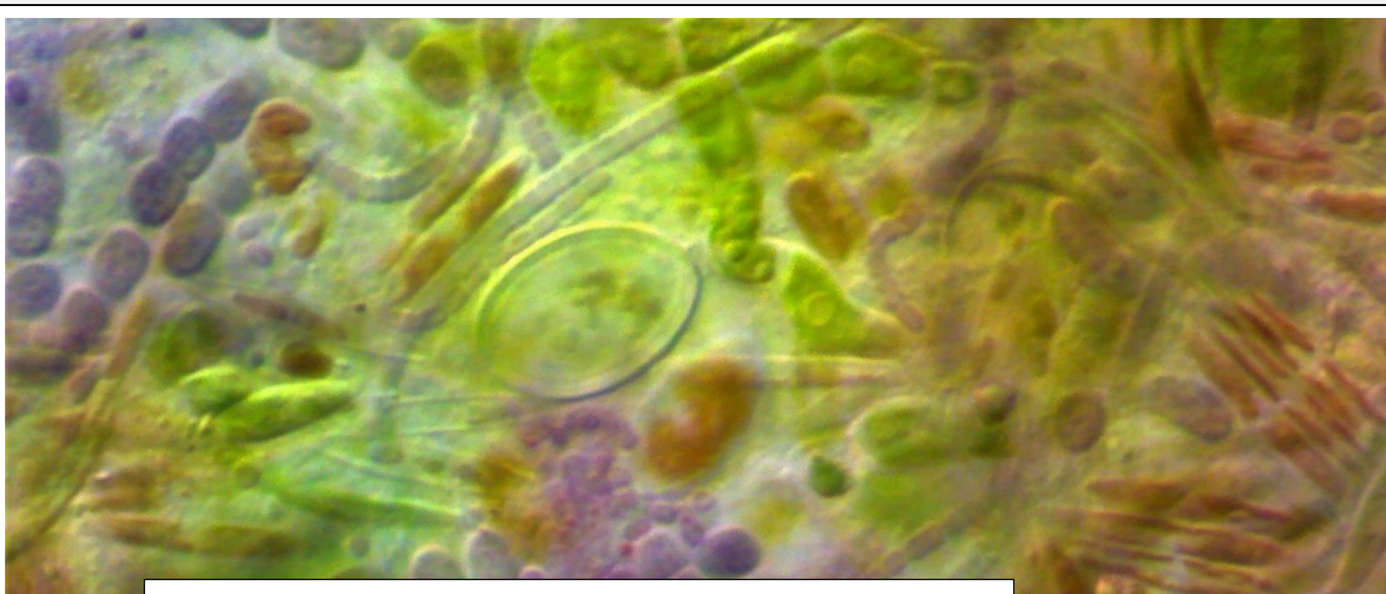
You have more bacterial cells and bacterial genes than human cells and genes. But because bacteria have very tiny prokaryotic cells thousands of times smaller than your own cells, all the bacteria in your biome (the ecosystem that is you) only add up to about 0.2 to 1.5 kg, so you are still 99% human.

Bacteria and archaea are the oldest and most widely distributed life on earth, living everywhere from hot spring vents on the ocean floor (life's point of origin?) to rocks 5 km underground to forests to you. How much do all these bacteria add up to? A fascinating 2018 review estimated the total dry carbon weight of groups of organisms on planet earth. Bacteria and archaea may be 14% of a total 550 gigatons of carbon biomass. Protozoa may add another 1%. It adds up: microbes outweigh mammals by about 24 fold!



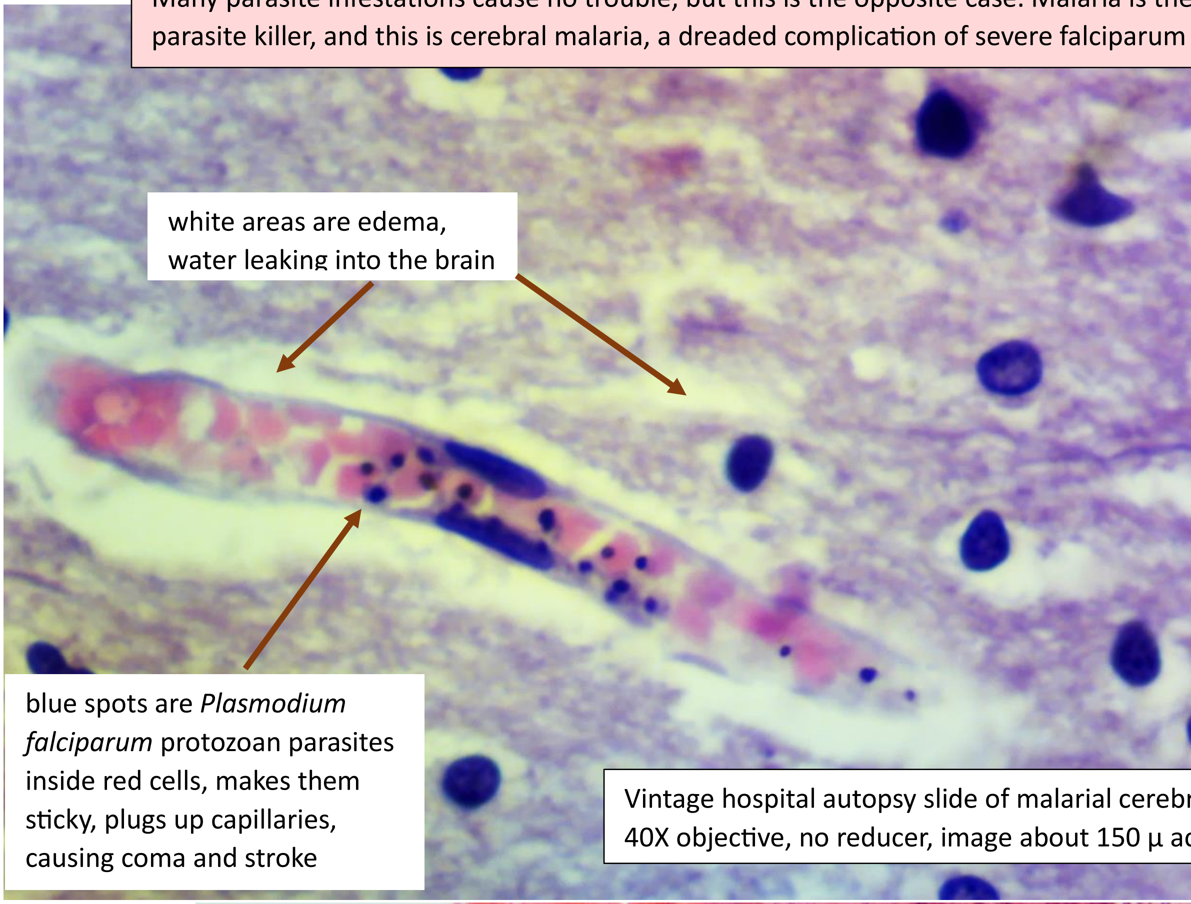
Most living biologic carbon is in plants, particularly in trees. Animals contribute little to earth's biomass and most of that is in arthropods and fish. All the mammals add up to about half the mass of earthworms and their kin. Despite being just 1/100 of 1% of the biomass on earth, we humans have certainly left a dirty stain on the planet surface, beginning a new geologic period, the Anthropocene. Humans and livestock are about 34% and 62%, and the remaining wild mammals we did not kill are just 4% of total mammal mass.

-chart from Bar-On, Phillips, Milo, Biomass distribution on earth, PNAS 2018



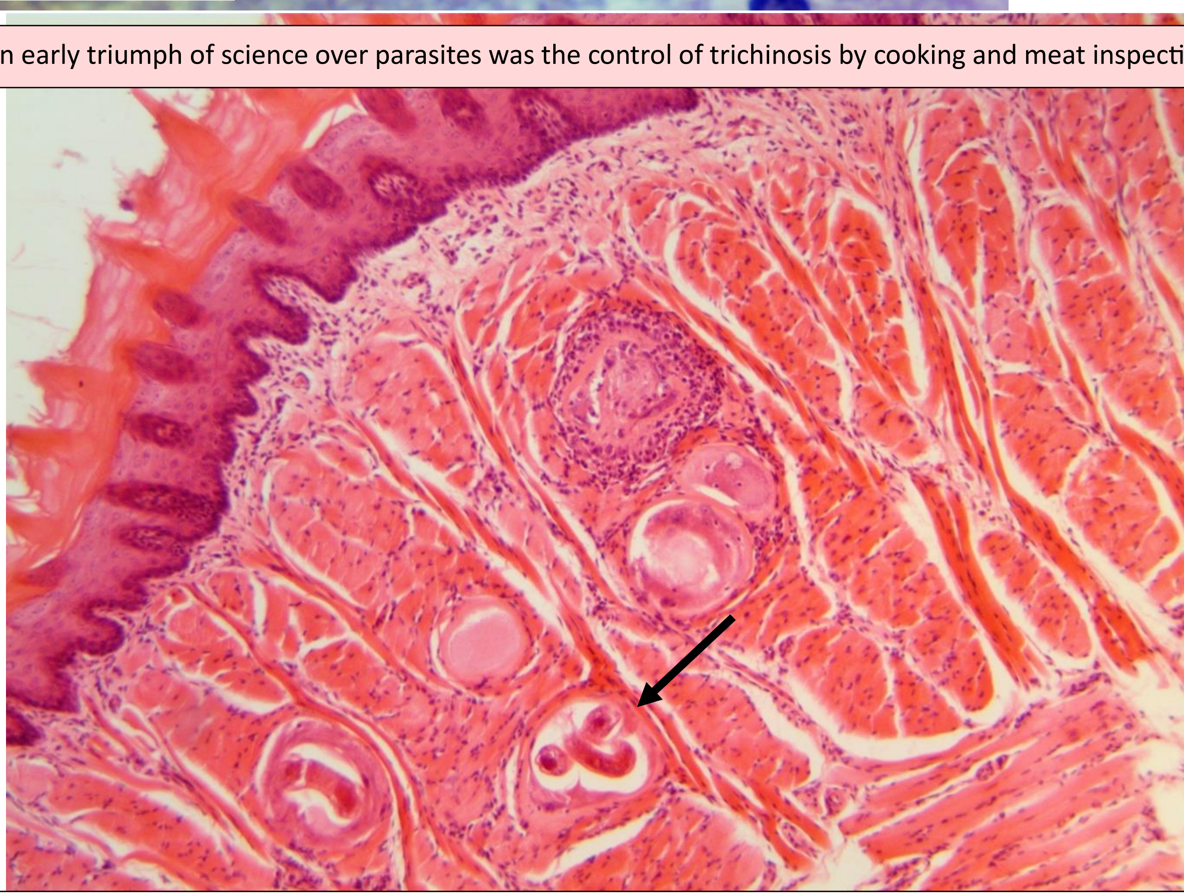
Lots of microbes. Side of dirty aquarium, biofilm of green and purple algae, cyanobacteria, diatoms. 40X objective, image about 300 µ wide

Many parasite infestations cause no trouble, but this is the opposite case. Malaria is the biggest parasite killer, and this is cerebral malaria, a dreaded complication of severe falciparum malaria



Vintage hospital autopsy slide of malarial cerebritis 40X objective, no reducer, image about 150 µ across

An early triumph of science over parasites was the control of trichinosis by cooking and meat inspection



Trichinella spiralis larvae in rat tongue, slide c1950. Trichinosis is a disease of tainted pork; parasite was discovered by microscopy 1860s. Coiled nematode worm arrowed, 10X obj, image about 1.1 mm across.

Parasite glossary: strange words to describe worlds of 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

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

Brood parasitism i.e. cuckoo birds lay eggs in another species nests, to be raised by host parents

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

Wonderfully Disgusting

Parasites and what they do seems disgusting and scary. Maybe it's an evolutionary prerogative to be revolted by parasites. Parasites might harm you. Darwin himself thought experiencing disgust could sometimes be advantageous by preventing our ancestors from eating rotten meat, writing "how readily this feeling is excited by anything unusual in the appearance, odour, or nature of our food." The appearance of many parasites seems disgusting, ugly and wrong to us. Perhaps it's because their bodies are often strangely different than our own, being adapted to the cramped, dark insides of animals instead of to the open sun lit world outside. Bodies that are pale, eyeless and bear hooks instead of limbs look gross and just not right according to our expectations learned from looking at other animals.

Yet, I was fascinated by gross, disgusting things as a young boy. Many of us were. At least I wasn't as bad as David, a 5 year old boy on my block who loved to walk barefoot in fresh soft dog turds. All the adults around, and even me (a few years older than David) were grossed out. I can still remember the sudden nausea when I watched David wiggle his toes in order to work more slimy brown dog poop deeper in between them. Especially the girls would shriek when David performed his special talent. Maybe the reaction he raised in other people was part of the appeal. Perhaps David's subconscious thought it better to be noticed for something disgusting than to not be noticed at all. Many boys take pleasure in grossing out the girls.

Poop, slimy slugs, creeping ticks and scuttling spiders are yucky, scary and yet very interesting at the same time. Intestinal parasites are often slithery worms that spread their eggs in feces. Parasites are misfits and oddballs. I suppose with thick glasses and poor social skills I was also a misfit as a child, and perhaps I feel sympathy for nature's oddballs now. Some of my luckiest, favorite days with a microscope were when I was shocked to discover *Ichthyophthirius* on my goldfish and strange blood red *Camallanus* on my daughter's bluegill fish. (I have nothing against fish; we share a closer common ancestor than I have with nematodes and protists).

Fake dog poop and radio controlled centipede, both from Amazon online

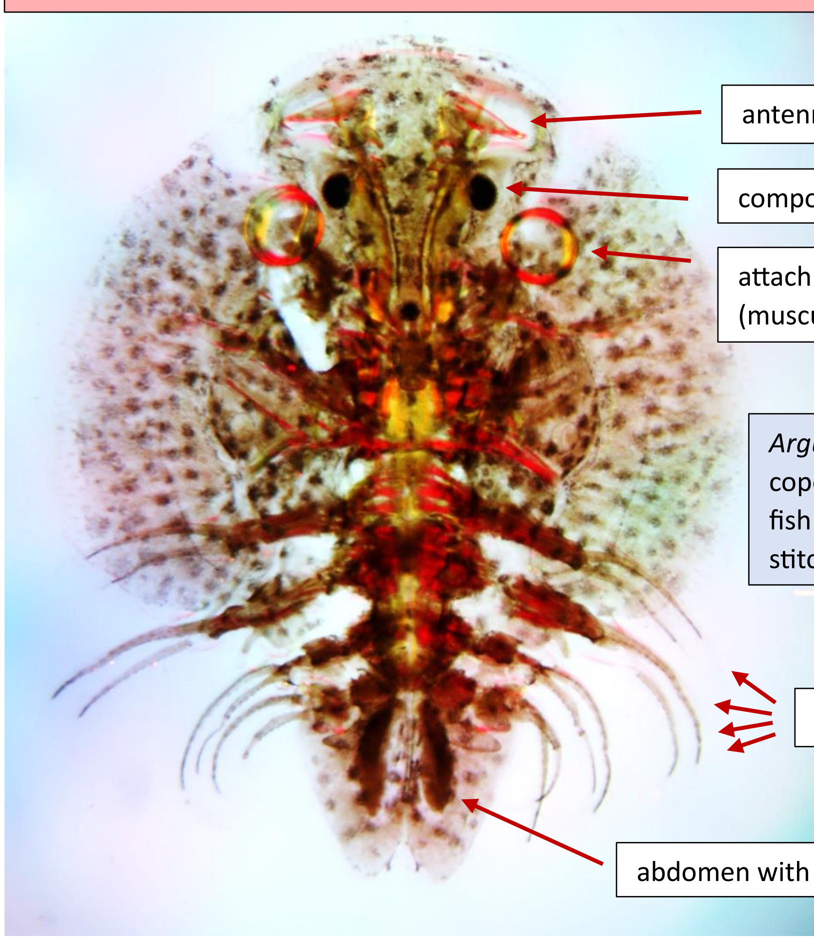
In the US we recently passed Halloween, a whole holiday dedicated to scaring people. Fear is clearly a negative emotion yet millions of people go to slasher horror movies to be entertained by fake blood and guts. Movies let us be aroused by a blast of fear hormones without being in actual danger. **Parasites can also make great science fiction monsters**. I remember to this day gasping out loud at the showing of the first Ridley Scott *Alien* movie in 1979. Do you remember the alien monster bursting bloodily from the sick crewmember's chest and running across the sickbay like some sort of alien crustacean? The adult alien designed by artist HR Giger seems inspired by *Phromina*, a 1 cm long marine amphipod (crustacean) parasite that hollows out floating salp (tunicate chordate) planktons for its home.

Phromina a crustacean parasite at BBC.com xenomorph queen from *Aliens* movies at IMDb.com
Did *Aliens* creature creator HR Giger see images of *Phromina,* or was it convergent evolution?

This is a free living crustacean from pond water, not a parasite!

Amphipods are flattened laterally (body tall and narrow, opposite of isopods). I often find *Gammarus sp.* (scuds) in freshwater lakes. They can present nice side views showing heart and gills beating.
2.5 mm long amphipod lighted with combination of dark field, polar (shows muscles) and epi, 4X obj.

This is a crustacean ectoparasite of fish, flattened dorsoventrally



Argulus spp. are freshwater and marine **fish lice**. Once called copepods, now assigned subclass Branchiura, they attach to fish skin or gills and use a stylet to suck blood and fluids.
stitch w/2.5X object., polar light; 6 mm long. slide LA Bircham

I am not the only one fascinated by parasites. Odd also means interesting and I never lost my childhood curiosity for what things are and why they are that way. Teachers sometimes collect a box of their favorite educational microscope slides, and that box often contains a few parasite slides. Teachers find parasites hold their pupils' interest, facilitating better teaching of biology and evolution. I collect old medical and educational slides. In a box of 100 there are often a few to occasionally many slides of parasites. I feel lucky when there are many. With the elimination of most parasites from the US and Europe, fewer old parasite slides come up on eBay. Educational supply houses like Carolina Biological still sell sets of parasite slides, $255 US for 19 general parasitology slides, and $875 for 65 medical parasitology slides (too expensive for my taste). Asian slides (Amscope and similar) are cheaper but usually not as well done in my experience. Like many teachers, I have a soft spot for nice and affordable parasite slides.

Parasite slides in my family

Not really; we're not related as far as I know. I do have the same name, **Edward Ward**, as the prolific Victorian (c1870 to 1900) slide maker in Manchester, England. Science talks and microscopes became popular with the lay public at that time, as it became obvious that scientific technologies were improving everyday life. Among many other subjects (marine, botany, insects, geology, chemicals, fabrics, etc.) Ward mounted some ectoparsites in balsam (noted as CB on his labels). Hog louse image page 4 is of antique slide by Edward Ward.

Another coincidence is sharing my name with **Ward's Science,** founded by Henry A Ward in 1862 in Rochester, New York. They sell all kinds of educational items, including parasite and other teaching slides. The Ward company merged and split from Turtox and Macmillan educational suppliers, among others. It is currently associated with Boreal Science and Sargent-Welch. Ward's supplies a wide range of science educational materials from various manufacturers including a large variety of histology and parasite slides to this day.

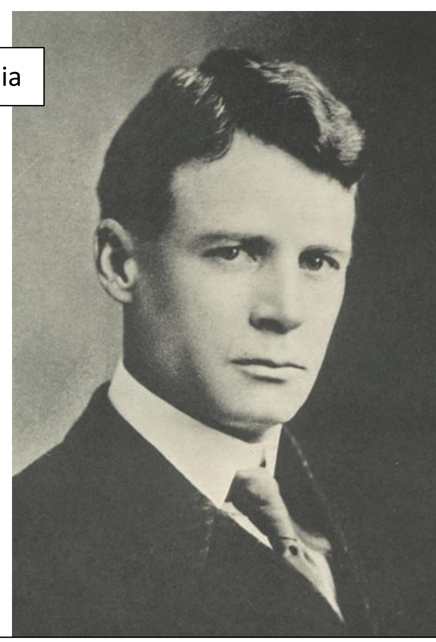
Brief history of parasitology

The existence of some human parasites, particularly intestinal worms, has been known for several millennia. An ancient Egyptian medical text, the Ebers papyrus from about 1550 BCE, seems to mention worms. The ancient Greeks and Romans described human roundworms and tapeworms. They did not have a modern understanding of infection or body functions, believing some illnesses were caused by miasma, the inhalation of bad air. Other illness was thought caused by an imbalance of the humors, four imaginary liquids in the body. The ancients thought parasites arose spontaneously inside bodies, rather than being the progeny of previous parasites. Arab physicians in the tenth century described some human parasite diseases in detail, but adhered to the same classical beliefs about the origins of diseases and parasites.

At the end of the Italian Renaissance, physician and poet **Francisco Redi became the father of parasitology**. He published *Osservazioni intorno agli animali viventi che si trovano negli animali viventi* (*Observations on Living Animals, that are in Living Animals*) in 1684, and eventually described over 180 parasites in detail. Redi was also one of the first experimental biologists. By covering bowls of rotting meat with mesh to prevent contact with flies, the formation of maggots was prevented, arguing against the prevailing theory of spontaneous generation. Around the same time, Dutch cloth Merchant and scientist **Antonie van Leeuwenhoek** used his own design of microscope (first invented in the Dutch Renaissance) to see a microscopic parasite, drawing pictures of *Giardia lamblia* in 1681. Leeuwenhoek saw the coccidia *Eimeria stiedae* in rabbit liver in 1684. The important nematode parasitic worm *Ascaris lumbricoides* was named by **Carl Linnaeus**, the father of taxonomy, in 1758 in Sweden. Linnaeus also named *Ascaris vermicularis* (now *Enterobius vermicularis*), *Gordius medinensis* (now *Dracunculus medinensis*), *Fasciola hepatica, Taenia solium*, and *Taenia lata* (now *Diphyllobothrium latum*). By the late 1800's many more parasites of people and animals were investigated closely. Many parasites are dependent on complex life cycles with drastically different life stages living in different who species. These elaborate life cycles are amazing. Each of the 50 or so parasite life cycle charts published by the CDC represents years of field and laboratory work linking one to dozens of species of hosts and often several drastically different life stages of the parasite inside different host organs. The first transmission cycle to be worked out in detail may have been that of *Trichinella,* a nematode worm of people and pigs, discovered by **Rudolph Virchow** (he found the adult worms) and **Friedrich Zenker** (he found transmission by eating pork) in the 1860s. Virchow was the "Father of Pathology" and used the discoveries to set up microscopic examination of meat in 1870 Berlin to prevent the spread of trichinosis. The time from about 1870 to 1930 was a golden age for parasitologists. Their discoveries of other helminth life cycles and of the malaria parasite were scientific *tour de forces* that greatly benefitted human health. Scientists have been working on the biology and life cycle of malaria since the parasite was discovered in blood by French military doctor **A Laveran** in Algeria in 1880. The history of parasitology is full of heroes, including **HT Ricketts**, who discovered the intracellular bacterium that causes Rocky Mountain spotted fever and was researching typhus when he died after using himself as a test subject in Mexico in 1910 (the bacteria causing epidemic typhus, now known as *Rickettsia prowazekii,* cannot be cultured in broth). As more was learned about parasites, ways to prevent and treat them also developed. Prevention, such as sanitary sewers and mosquito bed nets, is very important because in many parts of the world even if we cure a parasitic infection, it will be reacquired again within months. Toxic mercury, arsenic, and antimony have been long been used against parasite infections. (The first emperor of ancient China may have been inadvertently mercury poisoned by his doctors). The 1st modern anti-worm drug, thiabendazole, was invented in 1960. The 2015 Nobel prize in medicine was given for the development of ivermectin, a new dewormer, and of artemisinin, a new antimalarial. Recently, nearly 150 years after the discovery of the *Plasmodium* parasite, the fruit of thousands of researchers around the world finally yielded a promising vaccine candidate for the deadliest of all human parasitic diseases. The World Health Organization wanted to buy 18,000,000 doses of malaria vaccine for $170 million in 2022. Sadly, the vaccine developer GSK put the project on hold to concentrate on yet another shingles vaccine (a painful but non fatal disease; people in the United States and Europe pay much more for vaccines than the WHO). The modern healthcare industrial complex has produced many amazing medical treatments, but largely ignores the global South, where deadly parasitic diseases remain neglected.

images Wikipedia

Francesco Redi (1626 –1697) Italian physician, naturalist, biologist, poet, Father of Parasitology and founder of experimental biology

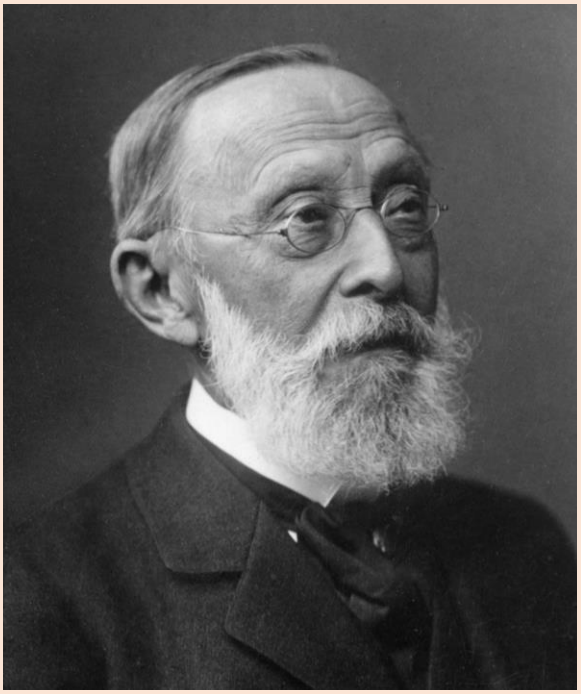


Howard Taylor Ricketts (1871 –martyred 1910) American microbiologist and pathologist found the bacterial pathogens now called rickettsia

Rudolph Virchow, Father of Cellular Pathology, early parasitologist, social reformer

Rudolph Virchow (1821 to 1902) invented the modern biomedical understanding of health and also demonstrated the social determinism of disease (which is slowly catching on as a “new” idea in recent decades).

Virchow was “the father of pathology” and one of the most important and remarkable physicians in all of history. Born in eastern Prussia in 1821, he went to medical school in Berlin and went on to bring medicine into the scientific era, largely via a microscopic view of human anatomy. He also became a progressive politician.



Virchow’s medical discoveries were almost endless, as he was one of the first to replace millennia of theories about imbalances of imaginary body fluids with a new, scientific view of bodies being made of cells, and their malfunction causing disease. His 1855 axiom “every cell arises from another cell” seeded a scientific revolution. Virchow started a medical journal, wrote textbooks and taught doctors from around the world. Among his discoveries: leukemia (blood cancer), chordoma (a spinal tumor), thrombosis and embolism (blood clots)), myelin (sheath around some nerves), amyloid (an abnormal protein causing disease), chromatin (the stuff that makes chromosomes), cells inside bone, zoonoses (diseases acquired from animals), Virchow’s node (swelling above collarbone from spread of stomach cancer), how to do a proper autopsy, the lifecycle of the parasitic worm Trichinella, microscopic meat inspection, and numerous human skull details and diseases.

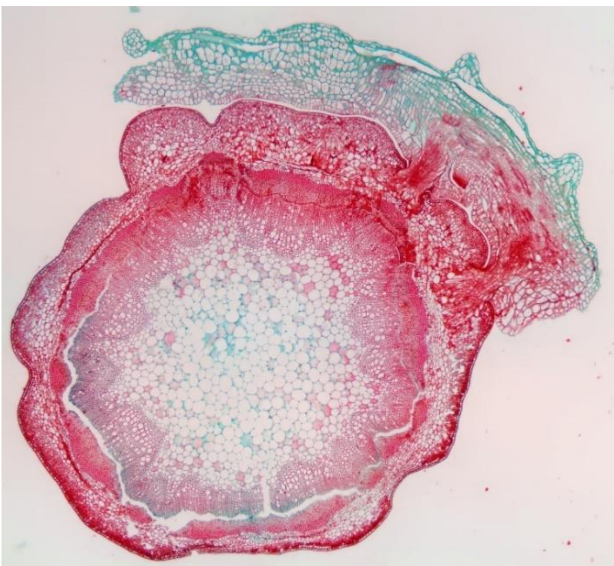
Virchow adopted the microscope from Mueller. Virchow told his students to “think microscopically” and taught cellular pathology to visiting professors from around the world, spreading the modern way of medical thinking still used today. But Virchow was much more than a doctor and medical professor. He travelled to a typhus outbreak and investigated tuberculosis, deeming them “social diseases” because they killed the poor much more often than the rich. Advocating sewers and clean water for Berlin, he was the father of public health. He was the German father of anthropology, and dug for artifacts in Germany, Troy and Egypt. He prescribed democracy and education to improve the health of the masses and became a reformist politician. He claimed “politics is medicine on a grand scale”, opposing racism and high military spending. Virchow died in 1902, age 80.

Virchow wasn’t perfect. He argued against the germ theory of disease and against the theory of evolution, deeply mistaken both times. At least Virchow’s heart was in the right place. Many proponents of evolution, including his own student Ernst Haeckel, used evolution to argue for eugenics, stating undesirable peoples should be sterilized or killed. Half a century later, that pseudoscientific evil led Germany into profound catastrophe.

Rudolph Virchow was a fascinating figure. He was the first modern doctor, a genius and a good guy. You can read more about Virchow in the 2 part “Think Microscopically, Act on a Grand Scale” in *Micscape Magazine*, 2023.

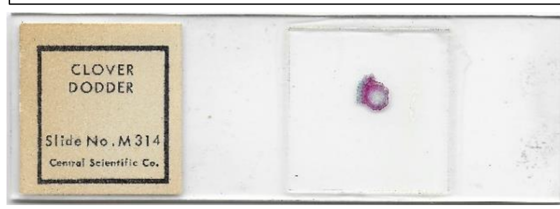
Overview of kinds of parasites

The overarching definition of a parasite is an organism living on or in another organism while gaining nutrition from the host. This would confusingly include a lot of disease pathogens (microorganisms that quickly harm or kill another organism), so I will focus on the "classical" parasites. All these terms are made up by humans trying to understand the world, and our scientific knowledge will be forever incomplete, even as it grows each year. The **classic parasites are protozoa or animals living long term on or in bigger animals** (even "bigger" can be ambiguous; tapeworms can get 10 meters or 30 feet long, but are very skinny and curled up, so they can still fit into your intestines). Parasites can be classified by the biological relations of the parasite, or by the general behavior of the parasite (endo- or ectoparasitic). I'll start with the former, with a shallow look at the taxonomy of kinds of parasites.



Two "non-classic parasites"
Viruses, bacteria, plants and fungi are not "classical" parasites but some take nutrients while growing on or in other organisms.

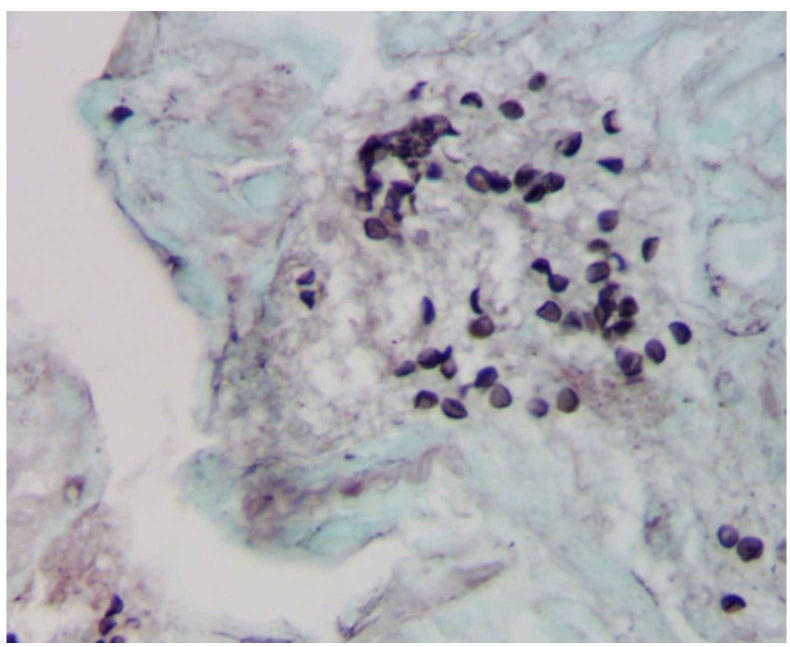
Plants can parasitize other plants; at left a clover dodder (upper, green) is growing on a host stem, using (red) haustoria to gain food. stitched, 4X objective, stem about 3.5mm wide

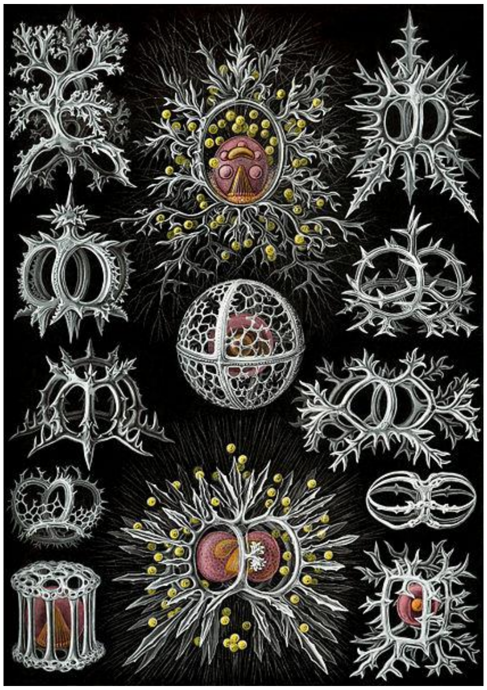


Pneumocystis jirovecii is a fungal pathogen of immunocompromised humans; "PCP" killed a lot of AIDS patients. Thought to be a fungus and a mouse pathogen, was renamed after DNA data.

Right- infected human lung, silver stain,
by expert histologist and microphotographer
A. J. DiDanato of Philadelphia, USA
40X objective, cropped, cysts 5-8 microns wide

See del Cerro *Micscape* Oct 2008 for more info





13 new species of “Stephoidea”/Radiolaria, free living marine amoeboid protists in intricate glass houses. Drawing by controversial late 19th century German biologist, artist and eugenicist Ernst Haeckel. Published in his 1904 book *Kunstformen der Natur* .

Protozoans

Also known as protists, these are a diverse group of single celled microorganisms. Like us multicellular organisms, protozoans are eukaryotes; their cells are far larger and more complex than those of bacteria or archaea. Problematic German genius Ernst Haeckel gave protozoans their own kingdom, Protista, in 1874. Still until the late 20th century we divided protists into animal-like and plant-like kinds, but eventually nucleic acid and other molecular data showed protists are not just little plants or animals. Protist taxonomy is still unsettled to this day.

Amateur microscopists are usually familiar with protozoa, especially if they look at pond water. *Euglena* is a common green **flagellate** protist with a whip like “tail” for swimming and a red eyespot. It was hard for scientists to tell whether it was plant or animal since it had qualities of both. We now consider protozoans to be neither. The parasites that cause sleeping sickness, Chagas disease and leishmaniasis are flagellate protists, related to *Euglena*. You may recall slipper shaped *Paramecium* from school or your hobby. It’s a **ciliate**, covered in tiny moving hairs. Some ciliates are among the biggest protists and the biggest eukaryotic cells. *Stentor*, the common trumpet shaped ciliate can be up to 2 mm long, visible to the naked eye (its relatives are microbes, so it is still considered a microbe). The ciliate *Spirostomum* can be even longer, up to 4 mm, but is skinny like a little worm. *Balantidium* is a ciliate human parasite. A sister group to the ciliates, the **Apicomplexa**, is parasitic. The group includes the Coccidia, intracellular parasites that reproduce sexually in the gut of vertebrates. The *Plasmodium* parasite that causes malaria is also an apicomplexan. As illustrated on pages 5 and 6 apicomplexans (like the coccidia *Eimeria*) have complex alternating asexual and sexual life cycles. A few **amoebas** and some other amoeba like protist shape shifters are parasites.

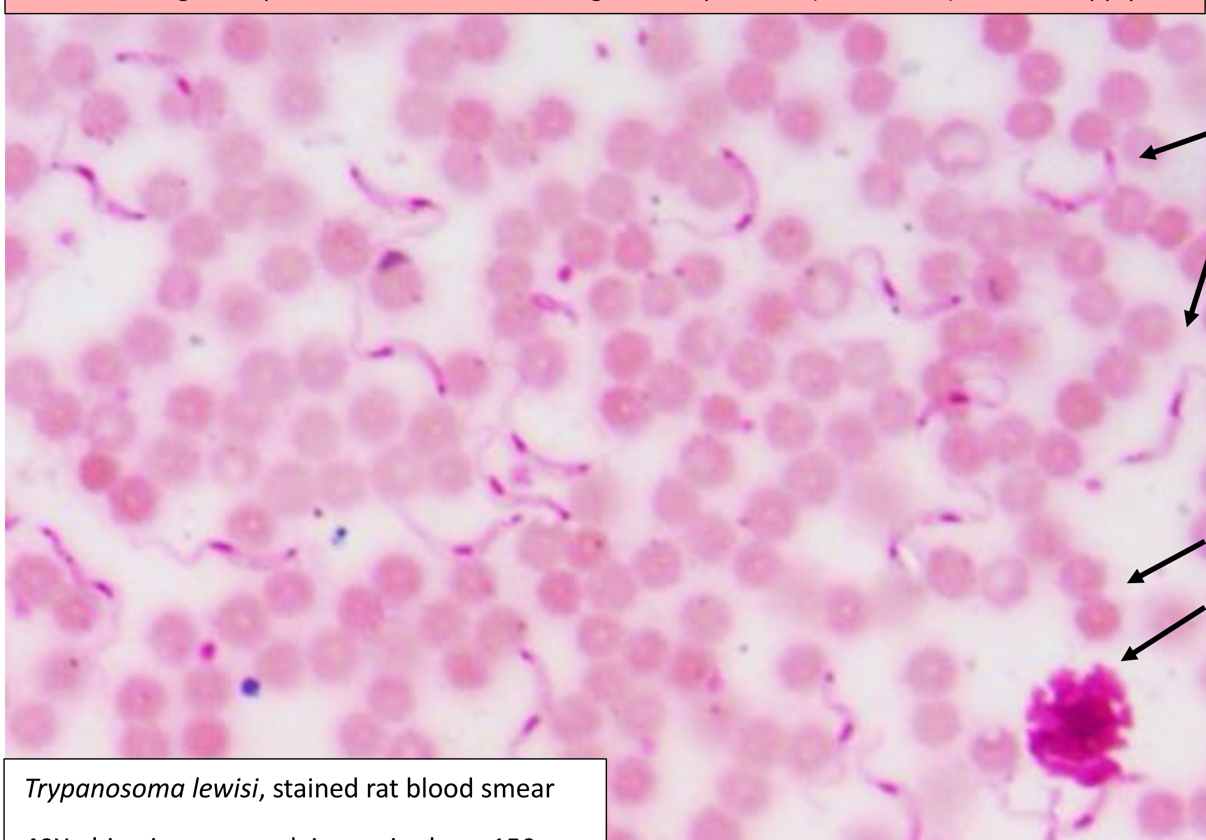
This is a group of free living photosynthetic euglenoid flagellates in resting stage, from pond water, not parasites!

Note gelatinous membrane around a group. Like their parasitic cousins, euglenoids have complex life cycles including sexual and asexual reproduction, active and cyst forms.

Green euglenoid flagellates, from a farm pond

40X objective, oblique light
cropped, group is about 150 microns across

These are flagellate parasites in rat blood. Vintage slide by Ward's (no relation) Science Supply



Numerous trypanosome parasites

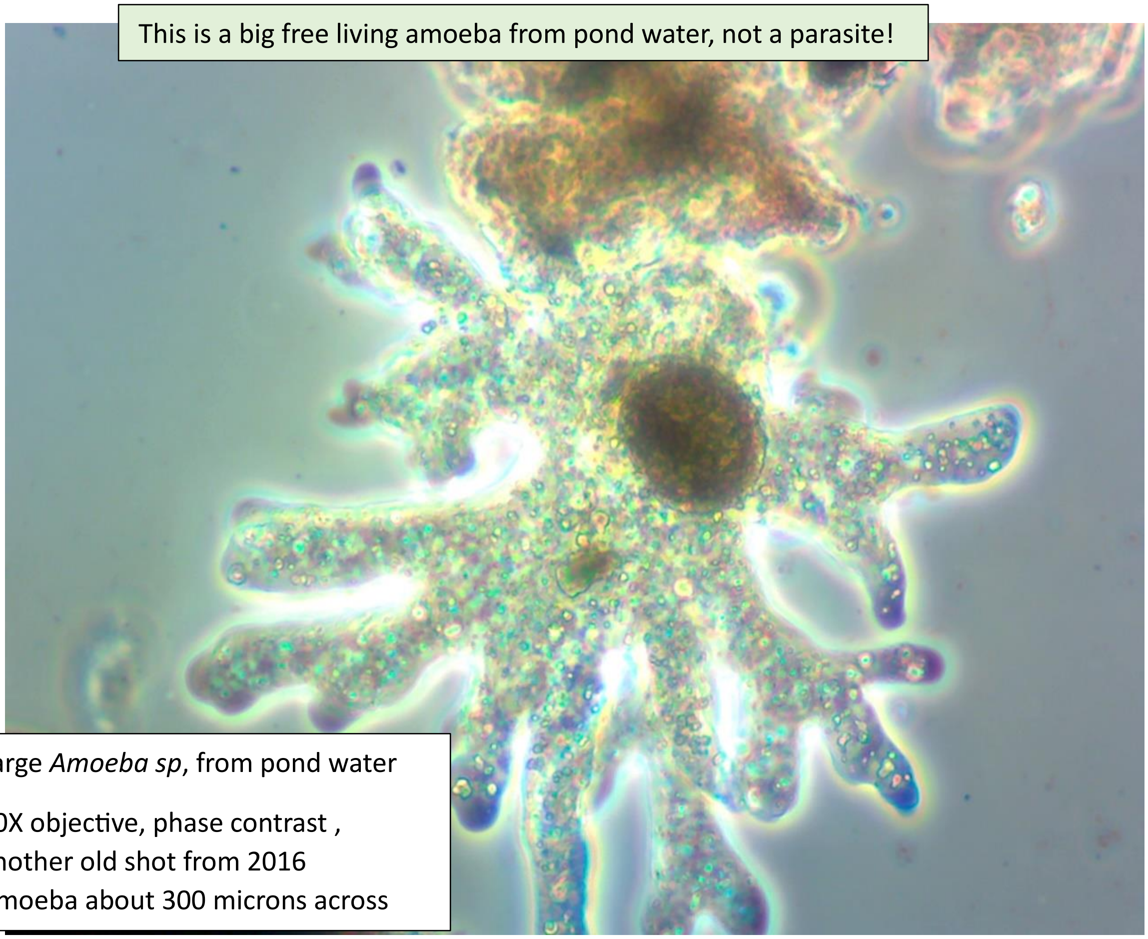
Rat red blood cell

Rat white blood cell

Trypanosoma lewisi, stained rat blood smear

40X objective, cropped, image is about 150 microns across, trypanosomes about 15 µ long

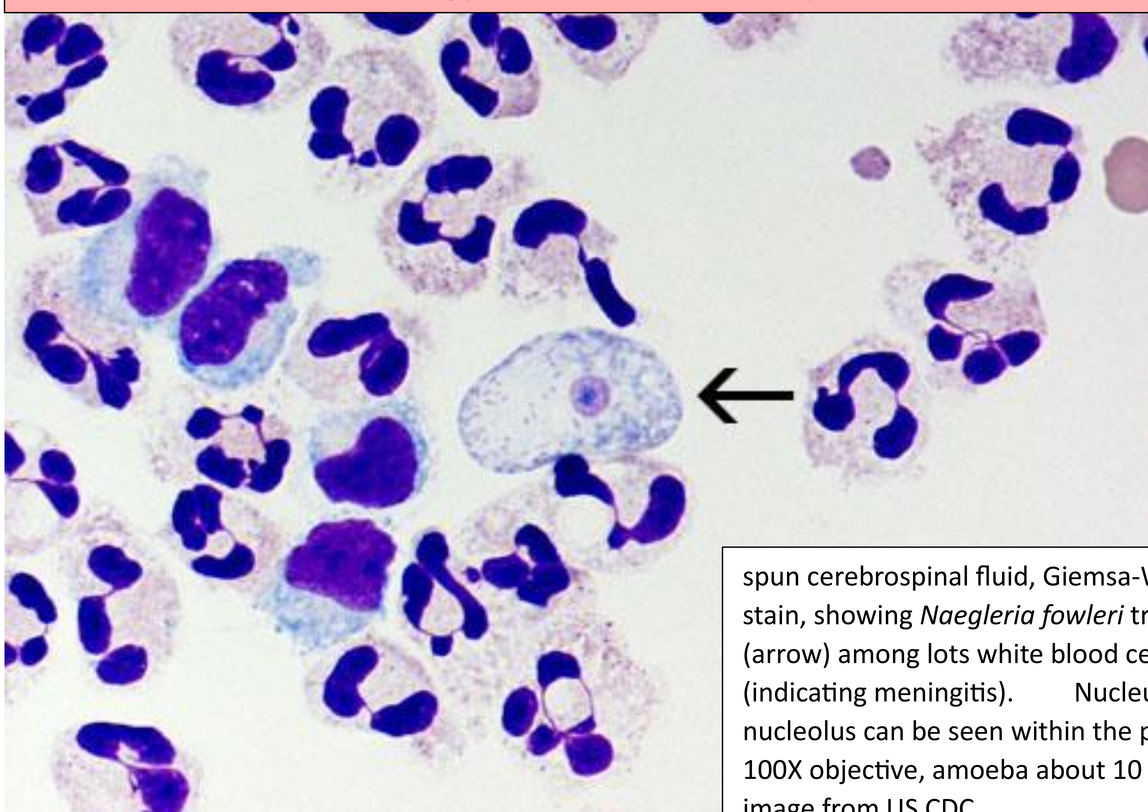
This is a big free living amoeba from pond water, not a parasite!



Large *Amoeba sp*, from pond water

10X objective, phase contrast , another old shot from 2016 Amoeba about 300 microns across

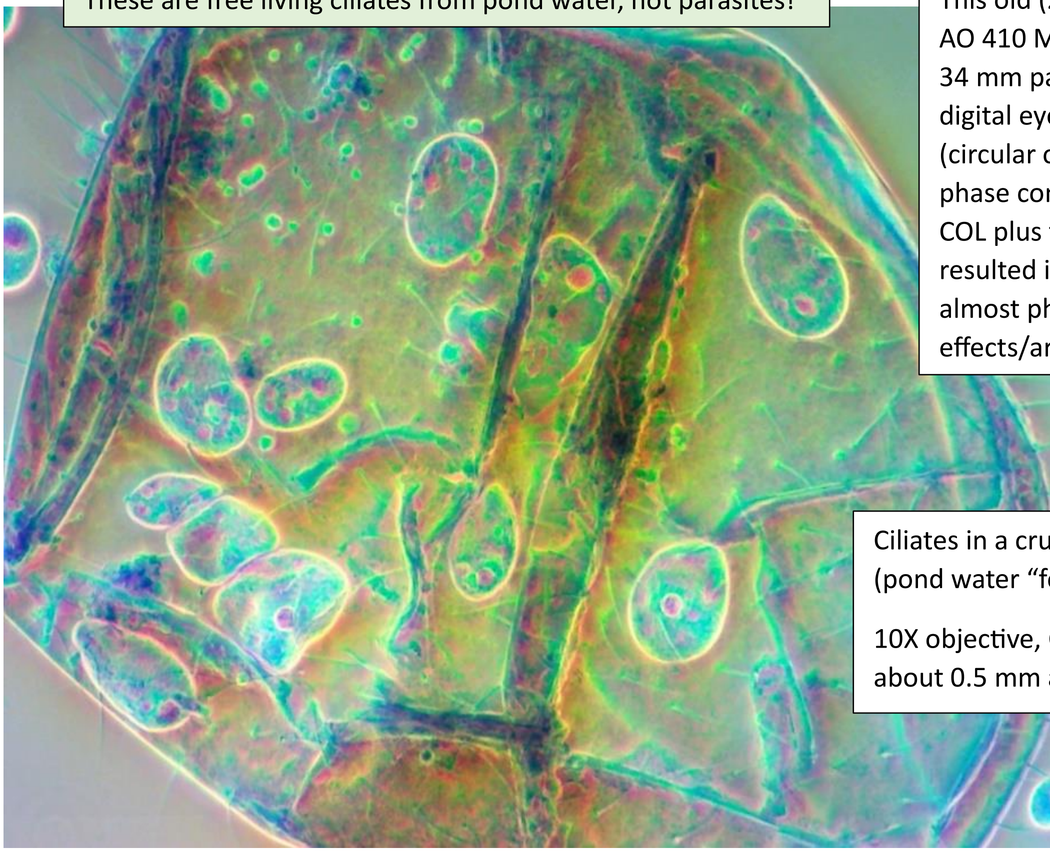
This is a brain eating parasitic amoeba in human spinal fluid.



spun cerebrospinal fluid, Giemsa-Wright stain, showing *Naegleria fowleri* trophozoite (arrow) among lots white blood cells (indicating meningitis). Nucleus and nucleolus can be seen within the parasite. 100X objective, amoeba about 10 µ across. image from US CDC

These are free living ciliates from pond water, not parasites!

This old (2016) photomicrograph through an AO 410 Microstar microscope using older AO 34 mm parfocal objectives and a cheap $30 digital eyepiece with no reduction lens. COL (circular oblique lighting) by using a 20X phase contrast annulus with 10X objective. COL plus the wrong telan lens in the head resulted in extreme chromatic aberration, an almost phase like effect. I liked the colorful effects/artifacts back then, but less so now.

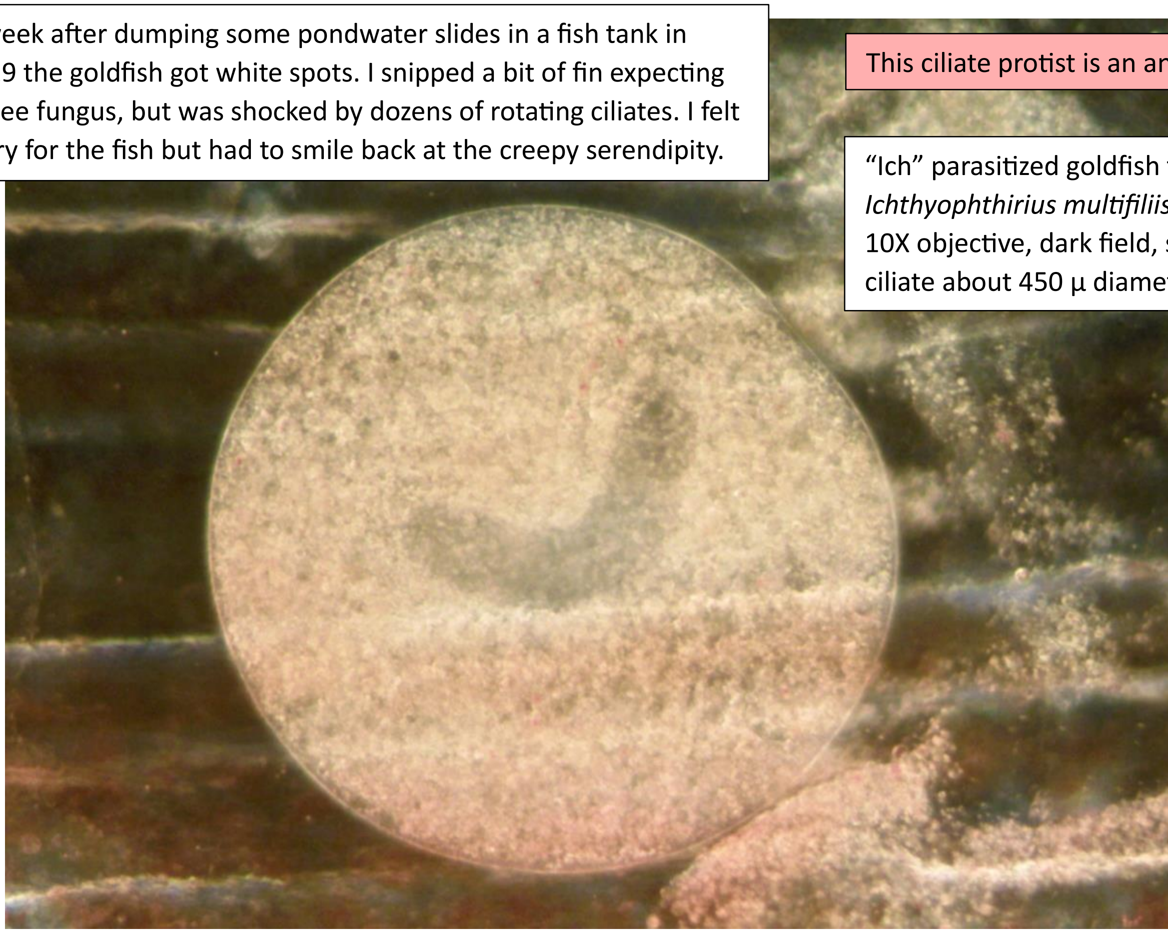


Ciliates in a crustacean molt, from infusoria (pond water "fed" with some hay)

10X objective, COL (circular oblique lighting) image about 0.5 mm across, ciliates about 50 µ diameter

A week after dumping some pondwater slides in a fish tank in 2019 the goldfish got white spots. I snipped a bit of fin expecting to see fungus, but was shocked by dozens of rotating ciliates. I felt sorry for the fish but had to smile back at the creepy serendipity.

This ciliate protist is an animal parasite



"Ich" parasitized goldfish tail with 'smiley' ciliate *Ichthyophthirius multifiliis* churning just under skin
10X objective, dark field, slightly cropped
ciliate about 450 µ diameter (some were bigger)

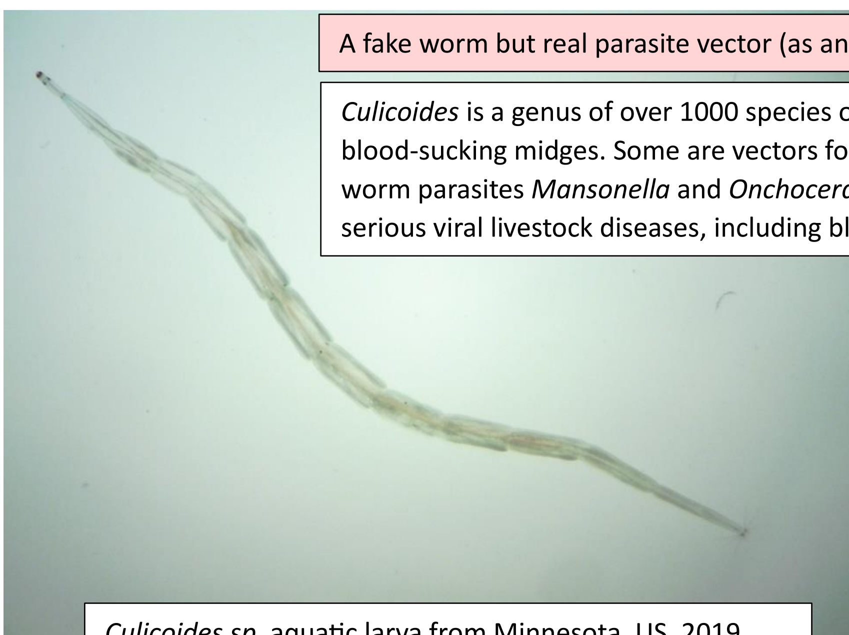
Edges of a fine bone in the fin

Worms

Animals vary greatly in size, but being multicellular they are mostly bigger that protists (but a single cell *Stentor* can be bigger than a small rotifer made of a thousand or so cells). Worm is a colloquial term for small tubular animals. “Helminth” is medical science speak for the same thing, any kind of worm. Science classifies animals into phyla, high level groups based on general body plan, which usually reflects relatedness. Animals called worms reside in 3 major and several minor phyla. Some worms are microscopic (microfilaria and many adult nematodes for instance), and some are big. Being flexible and cylindrical is a good shape for pushing through dirt, mud, and the insides of other animals. Evolution discovered the shape is also good for many non-worms, such as insect larvae and even many vertebrates (snakes).

Farm pond water, 2.5X objective, dark field
this *Tubifex* about 0.5 mm diameter, 15 mm long

The simplest animal body plans are amorphic (sponges) or a simple radial ring of tentacles (jellyfish). Flatworms, Phylum **Platyhelminthes**, “invented” bilateral symmetry. They are the first animals to have a right and left, head and tail ends, and proper eyes (in some cases). Flatworms have two embryonic tissue layers. Many of the over 20,000 known flatworm species are scavengers or predators and many became parasites over time. Planaria are free living freshwater flatworms you might recall from school or from pond water. Two classes of platyhelminths are all parasitic: Class Cestoda, the **tapeworms** (long segmented bodies) and Class Trematoda, the **flukes** (lancet shaped bodies). Even though often smaller, roundworms, Phylum **Nematoda**, have some added features. They have three “germ layers” and grow by molting their skin. Nematodes are extremely successful, and are among the most numerous tiny animals. About 30,000 species are named but experts guess a million species remain to be named (they largely look alike to us nonexperts). The three most common intestinal worms of humans today remain *Ascaris*, hookworm and whipworm, all nematodes. Although most parasitic worm infestations are intestinal, some nematodes and flatworms can end up in really inconvenient places like the liver, lungs, heart and brain. Some helminth infections can be fatal; luckily these types are rare in the developed world today. Phylum **Annelida** (over 22,000 known species) are the segmented worms including earthworms, marine bristle-worms and their freshwater relatives like *Tubifex*, the detritus worm. Few annelids are parasites. A smaller phylum is **Nemertea**, about 1300 named ribbon or proboscis worms. Most are predators in marine sediments but some are parasites. Another small worm phylum is **Acanthocephala** or spiny head worms. All 1400 known species are gut parasites (most are small, but one can reach 65 cm long) that turned out to be evolved from rotifers. One small class of free living marine worms are hemichordates, related to the ancestor of vertebrates.



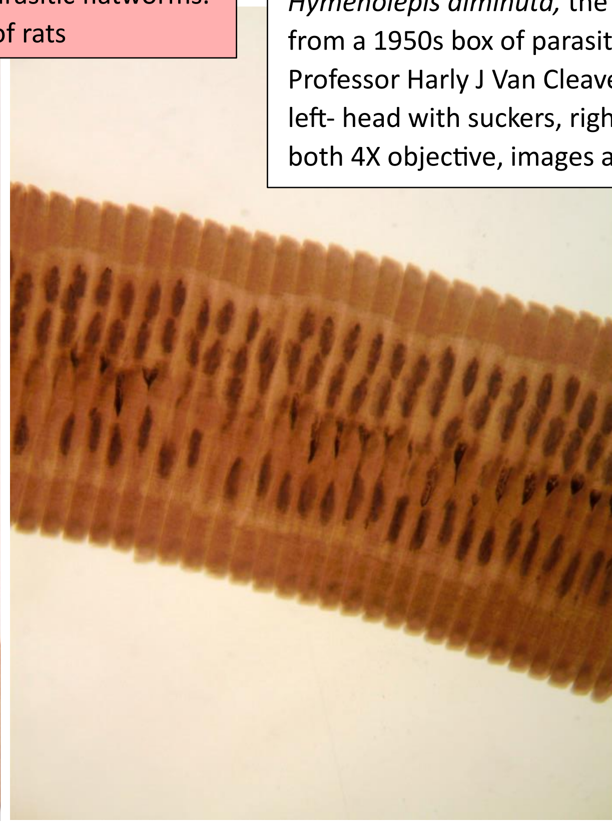
A fake worm but real parasite vector (as an adult micropredator fly)

Culicoides is a genus of over 1000 species of tiny biting, blood-sucking midges. Some are vectors for the nematode worm parasites *Mansonella* and *Onchocera* as well as for serious viral livestock diseases, including blue tongue.

Culicoides sp. aquatic larva from Minnesota, US, 2019
above AO stereostar microscope at 1.1X objective setting
right 4X objective, darkfield. Insect larva about 1 cm long

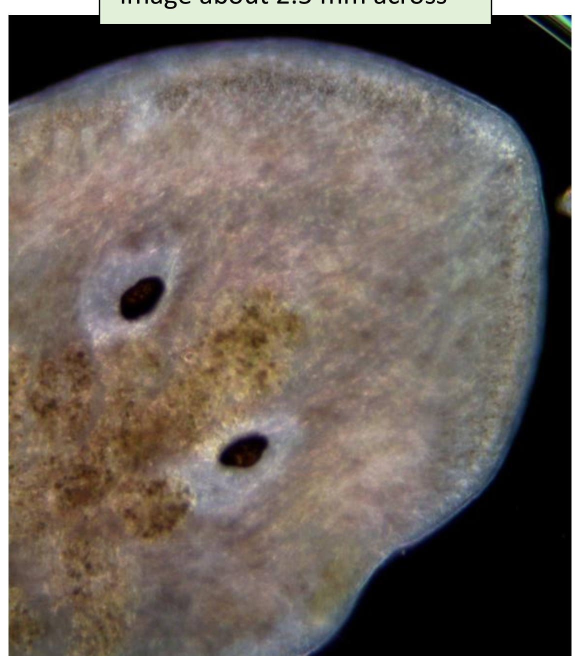
Tapeworms and flukes are parasitic flatworms. This is a tapeworm parasite of rats

Hymenolepis diminuta, the dwarf rat tapeworm from a 1950s box of parasite slides by the late Professor Harly J Van Cleave, University of Illinois
left- head with suckers, right- segmented body
both 4X objective, images about 3 mm tall

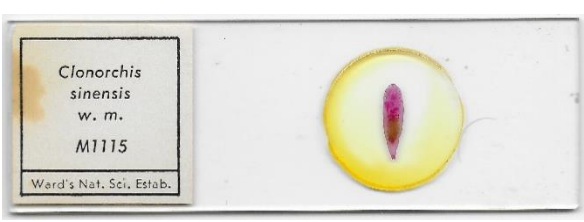


This is the Chinese liver fluke, a human parasite with snail and fish intermediate hosts

Paired eyes of *Planaria*, a friendly freshwater flatworm, not a parasite! 4X objective, epi lighting, sl. cropped, image about 2.5 mm across



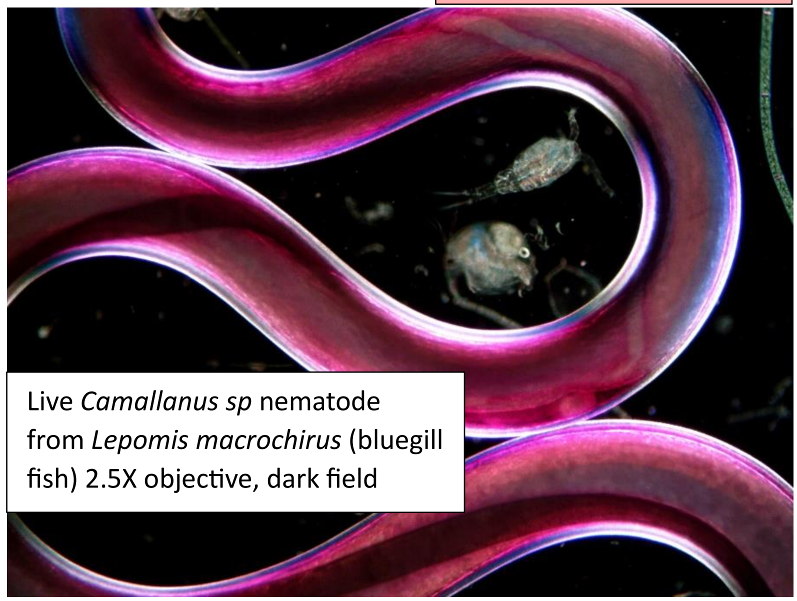
Clonorchis sinensis from the vintage Ward's slide below, stained. Approximate life size depending on your monitor. Fluke is about 12 mm long, head is at the bottom.
Enlarged image at right stitched with 4X objective



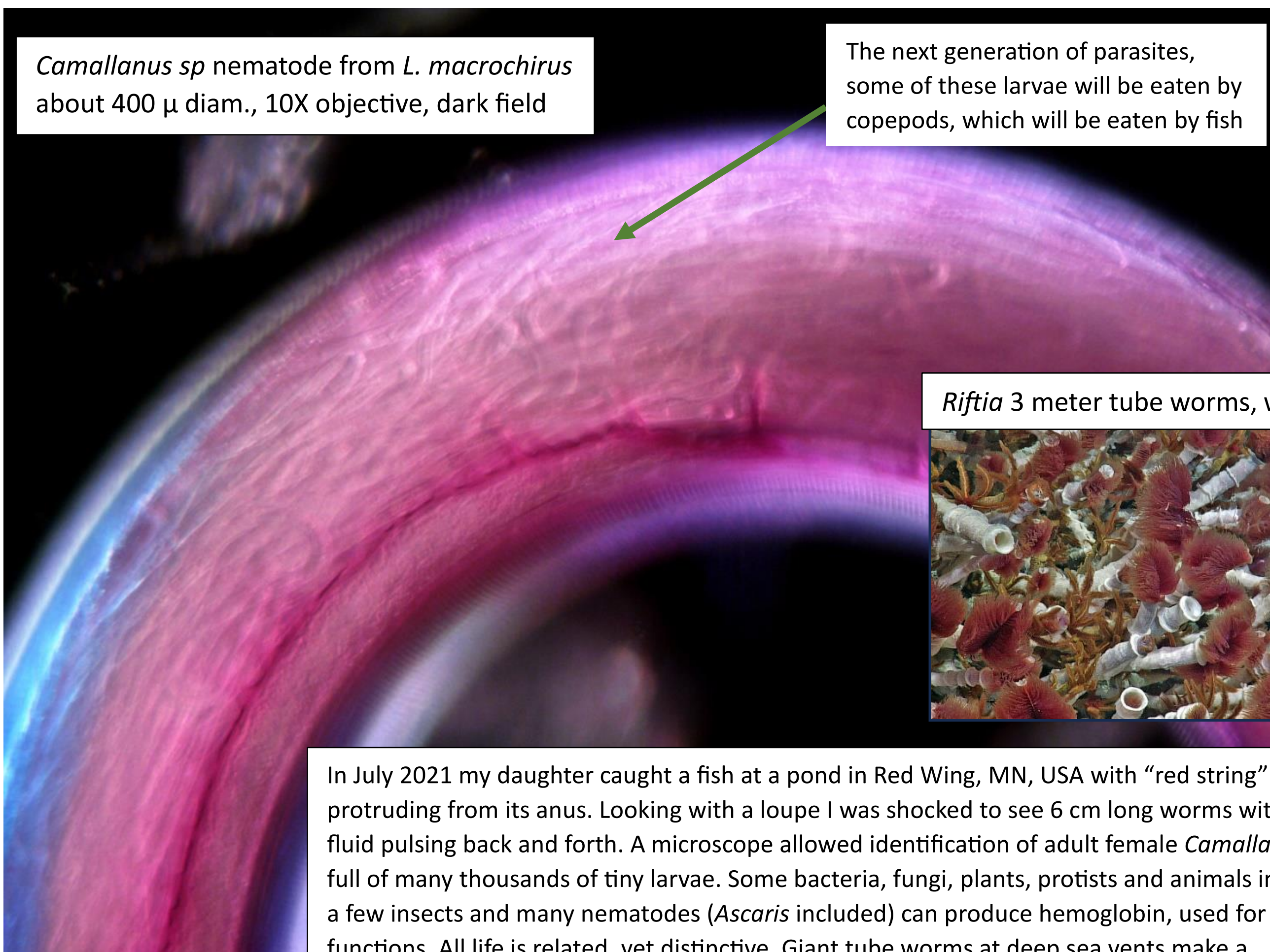
Free living nematode worm, not a parasite!

Nematode from Mississippi River about 350 µ long, 25 µ diameter 40X objective, oblique light

Camallanus sp. nematode parasite of freshwater fish



Live *Camallanus sp* nematode from *Lepomis macrochirus* (bluegill fish) 2.5X objective, dark field



Camallanus sp nematode from *L. macrochirus* about 400 µ diam., 10X objective, dark field

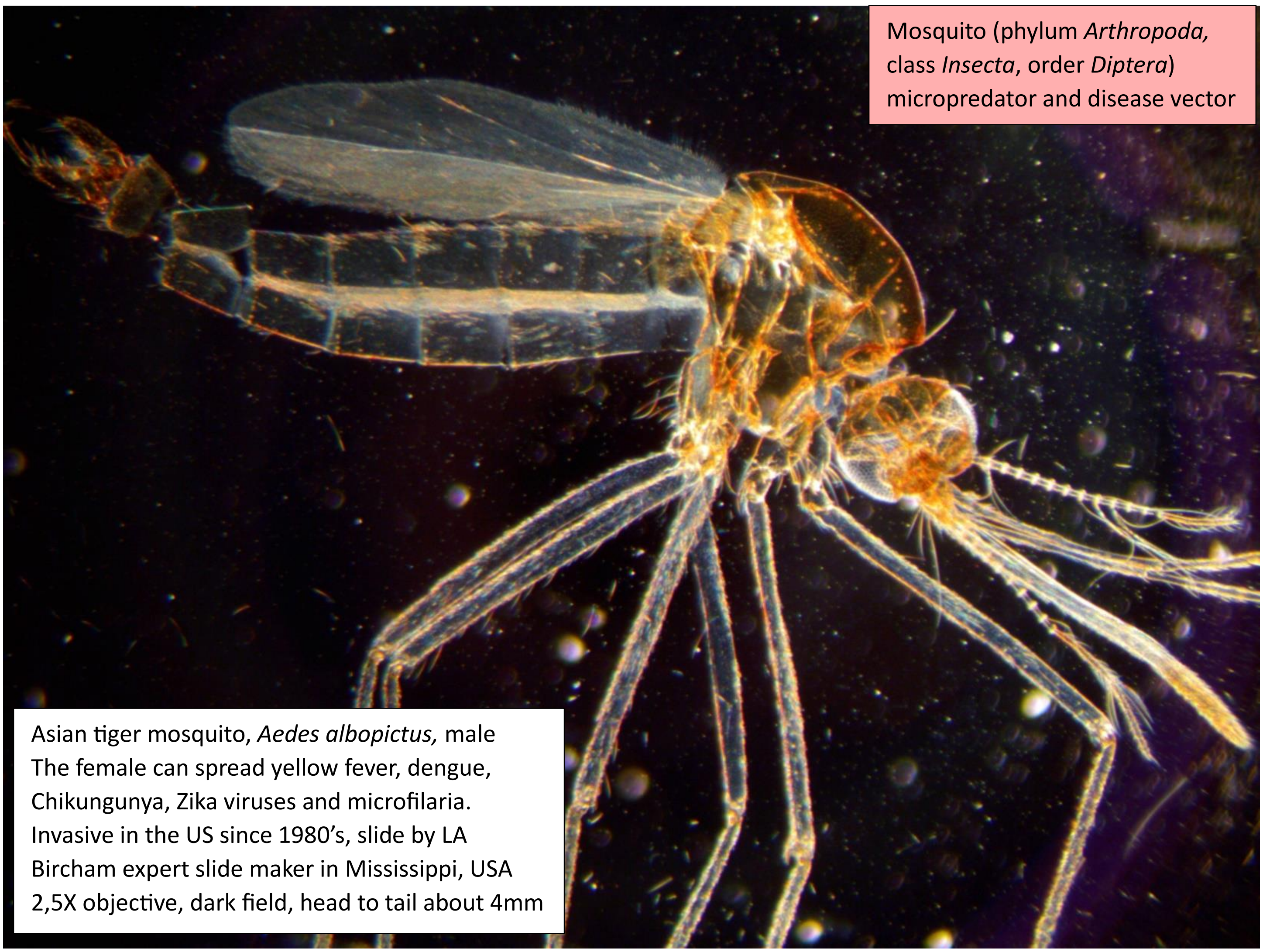
The next generation of parasites, some of these larvae will be eaten by copepods, which will be eaten by fish

Riftia 3 meter tube worms, wikipedia

In July 2021 my daughter caught a fish at a pond in Red Wing, MN, USA with “red string” protruding from its anus. Looking with a loupe I was shocked to see 6 cm long worms with red fluid pulsing back and forth. A microscope allowed identification of adult female *Camallanus sp,* full of many thousands of tiny larvae. Some bacteria, fungi, plants, protists and animals including a few insects and many nematodes (*Ascaris* included) can produce hemoglobin, used for various functions. All life is related, yet distinctive. Giant tube worms at deep sea vents make a hemoglobin with 144 globin and 36 linker chains, functioning in the equivalent of a pressure cooker of sulfuric acid; yours has just 4 goblin chains and works at our tepid body temperature.

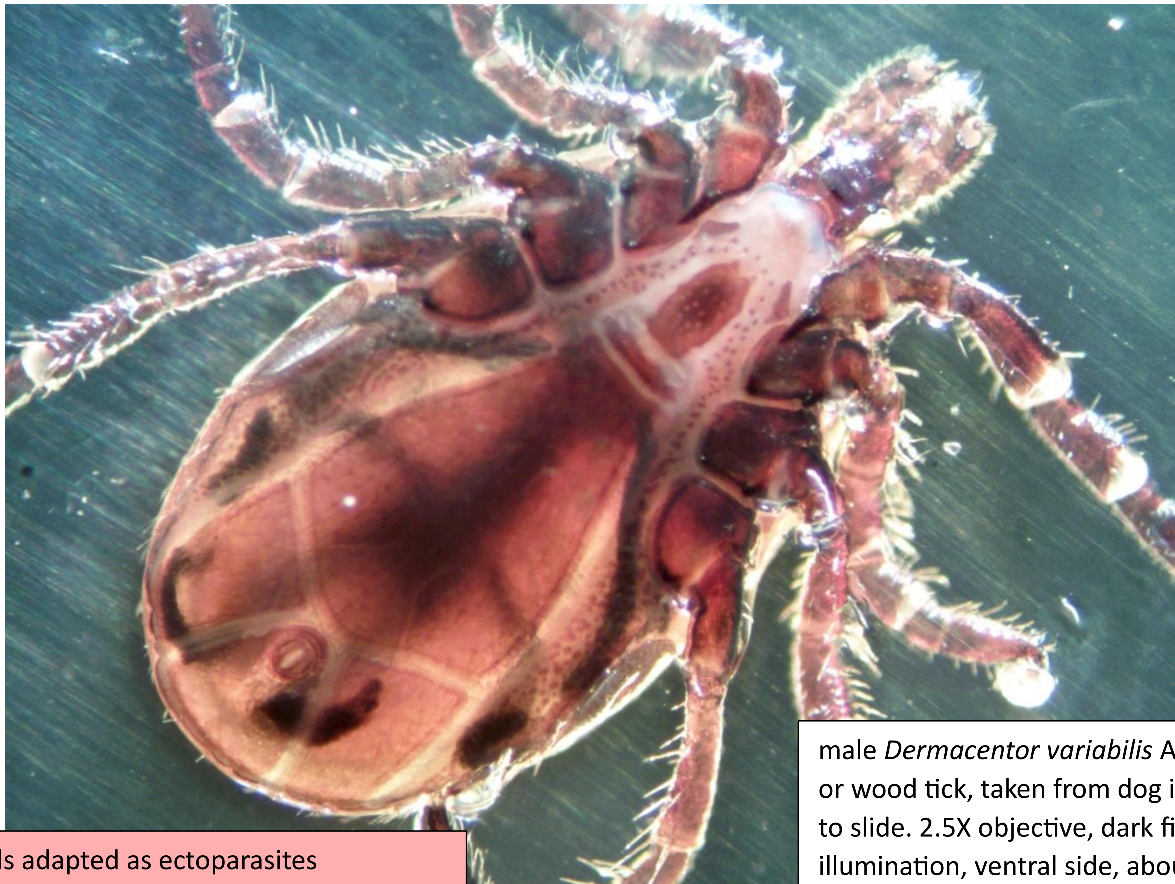
Ectoparasites

Ectoparasites are organisms that infest the skin (including fur, feather and scales) of other organisms. Keeping with the parasite definition of harming a little, ectoparasites can lessen host fitness by burrowing into, feeding, and reproducing in skin (mites, fleas) or by eating blood or tissue fluid (fleas, lice, mites, ticks). Note that strictly speaking mosquitoes and ticks aren't full card carrying parasites in that they don't live long term on the host, even though they do take blood meals and ticks might stay attached for a couple of days to eat supper. These arthropods that interact just briefly with hosts can also be referred to as micropredators (their meals are tiny), and they are intricately connected to some parasites by serving as their vectors and intermediate hosts. Some nonarthropod animals, including leeches and vampire bats, also live as hematophagous micropredators.



Mosquito (phylum *Arthropoda,* class *Insecta*, order *Diptera*) micropredator and disease vector

Asian tiger mosquito, *Aedes albopictus,* male
The female can spread yellow fever, dengue, Chikungunya, Zika viruses and microfilaria. Invasive in the US since 1980's, slide by LA Bircham expert slide maker in Mississippi, USA
2,5X objective, dark field, head to tail about 4mm



male *Dermacentor variabilis* American dog or wood tick, taken from dog in 2019, taped to slide. 2.5X objective, dark field and epi illumination, ventral side, about 5 mm long

2 arthropods adapted as ectoparasites
Ticks are chelicerates, superorder Parasitiformes
Lice are insects, the biggest class of arthropods

'Hoplopleura scuricola' louse, an ectoparasitic **insect**, order Psocodea (Phthiraptera now superfamily Anoplura), found on woodrat, Rankin County, Mississippi, USA. Slide and identification by LA Bircham, 10X objective, dark field, image about 1.1 mm across

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

For Christmas 2023 I offer *Micscape's* readers not a lump of coal, but an article full of homemade images of creepy parasites. Merry Christmas!

I am not the only *Micscape* reader and author interested in parasites. The recently passed professor of philosophy and great amateur microscopist Richard Hovey often pointed out strange creatures in his natural history essays, including parasites. He was fond of the commensal ciliates in termite guts and made great images of them. In 1996 Mike Morgan shared how to dissect earthworms and said we'd find *Monocystis,* an apicomplexan parasite, there. I'll have to try that someday. With rare exceptions amateur microscopists will find animal parasites, not human ones. If you are out in the field, dipping in aquaria or caring for pets then with luck and a prepared mind you'll likely come across some parasites eventually. Ticks come up fairly often, but blood red parasitic worms from a fish butt was a rare treat.

Next time I'll talk about some of the strangest of the strange parasites, including bizarre *Sacculina* and possibly mind controlling *Toxoplasma*. Eventually I'll make my way to worms then ectoparasites.

I'll be trying to find some *Demodex* commensal skin mites in the future. M. Halit Umar shared his successful results in the *Micscape* May 2000 edition, with a list of references.

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