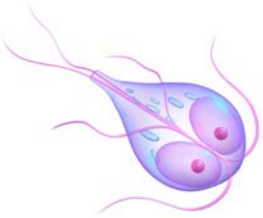


HUMAN PARASITES OF INTEREST

Sharlene Peterson, BS Biology, HHP, MH
Genesis School of Natural Health, 2020

When the subject of parasites arises, it tends to create visions of six foot tape worms and anorexia. While there are plenty of parasitic worms, most infections in the United States involve microscopic organisms. As a natural health professional you will encounter many undiagnosed and asymptomatic cases of parasitism.

Traveling by ship, plane, and car to and from the U.S., immigration, importing meat, vegetables, fruit, nuts & seeds, and a wide selection of consumer products are everyday occurrences. These activities are wonderful opportunities for humans however, we, medical establishments and in general, need to be aware that the activities also result in sharing various parasitic micro-organisms. Most infections can be avoided by washing our hands and fresh foods and by cooking meat properly. Washing clothing and other consumer goods is important but it is often ignored or unknown.

As natural health professionals we need to be aware of past travels (even months or years ago), eating preferences (sushi, raw tuna, and other uncooked or under-cooked meat), if they have dogs, cats, turtles, or other pets, and many other aspects of their life. Each individual has unique susceptibilities and strengths. One member of the family may become infected with a parasite while the others, eating the same food, did not become infected. When working with herbal and homeopathic parasite remedies we also need to be mindful of the body's ecosystem.

An ecosystem includes all the living organisms (biotic factors) in an area and its physical environment (abiotic factors) functioning together as a unit. The human body is a complex ecosystem that is host to trillions of microbes. Microbes (usually single-celled organisms) include bacteria, fungi, protozoa, and viruses.

Reachers for the Human Microbiome Project have identified more than 10,000 microbial species that occupy the human ecosystem. Microorganisms that live on and inside the body include eukaryotes, archaea, bacteria and viruses. **Bacteria** outnumber our own cells 10 to 1 but, because of their small size they only make up 1 to 3 percent of our weight.(1) While our cells are outnumbered, most of these microbes are either harmless or beneficial. Some of the benefits include helping us digest food, strengthening our immune system, and protecting us from infectious pathogens.

Our partnership with all the microbes in and on our body is called a symbiotic relationship.In biology, the word symbiosis refers to the close, long-term interaction between two different species. The relationship between the two species can be further described as mutualism, commensalism, or parasitism.

Correction was made on 7/26/2021: **Endoparasites** (live inside the body) and **Ectoparasites** (live on the body's surface - head lice, ring worm, etc.).

Terms and Definitions

The following is a very short list of terms and definitions that will help you understand the organisms covered in this manual. Additional terms are described within the manual.

Mutualism is when both organisms benefit from the relationship and there are many examples. Plant-pollinator interactions are an obvious example with the pollinator receiving food while the plant receives pollen grains for fertilization. The activities are not the result of one organism caring about the survival of the other organism. “Instead, each species pursues its own selfish interest, and any benefit incurred by the mutualist partner is an unintended consequence of the interaction”.(2)

Commensalism is when one organism benefits (the commensal) while the other organism is not harmed. Benefits may include nutrients, shelter, support, or locomotion. For example, the Cattle Egret (heron) bird feeds at the feet of grazing cattle. As the cattle move through the grass and bushes, insects are exposed and quickly eaten by the birds. The bird benefits without causing any harm.

Parasitism is when one organism benefits and causes harm to the other organism. Harmful relationship examples are found in both the animal and plant kingdoms. There are over 4,000 species of parasitic plants and they all have a unique root, called a haustorium. This slender root punctures the host and grows into the xylem or phloem to absorb nutrients. In humans, *Giardia* is a protozoan parasite that causes the diarrheal illness known as giardiasis. It is the most common parasite infection worldwide and the second most common in the United States (pinworms hold first place). Humans are hosts to approximately 300 species of parasitic worms and over 70 species of protozoa.

Pathogenic means “producing disease”, from the French pathogénique, which in turn came from the Greek word for "disease," pathos. It is considered a medical term that describes viruses, bacteria, fungi, and other organisms that can cause a disease.

The terms **microorganism**, microbe, and microscopic simply mean that the organism is so small that a person is unable see them with the naked eye and usually refers to an organism that consists of only one cell (unicellular). The study of microorganisms is called microbiology. Microorganisms include bacteria, fungi, archaea, protists and viruses, and even some algae. The image to your left is an extremely magnified view of a sharp pin head. The yellow clusters are average-sized bacteria.

The term ‘**obligate**’ or ‘**obligate parasitism**’ is used to describe any parasite that is unable reproduce without a host body, they require a host (another organism) for at least one part of their life cycle. Some are **endoparasites** (live inside the body) and others are **ectoparasites** (live on the body’s surface - head lice, ring worm, etc.). Obligate parasites include various species of viruses, bacteria, fungi, plants, and animals - all obligates are parasitic because they are dependent on another organism for survival.

Viruses are obligate intracellular parasites. **Intracellular** is a term used for when parasites grow and reproduce inside the cells of a host. A virus must gain entry into a host, survive the immune response of the host, and then enter a host's cell before viral replication (reproduction/life cycle) can occur. When the virus is able to replicate sufficiently it causes symptoms and is called an infection. Almost all of the protists known as sporozoans (spore-formers) are intracellular parasites for at least one stage of their life. Just to keep life interesting, one-celled organisms are often a host for viruses and other micro-organisms - parasites with parasites.

Free-living is a term that describes an organism that is not directly dependent on another organism for survival. Some organisms are free-living but also live as parasites. The ratio of free-living to parasitic organisms in the world is at least 60:40.

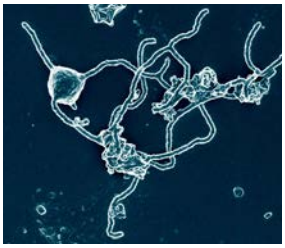
Many parasites are **species-specific**. For example*, Plasmodium gallinaceum* infects birds while *Plasmodium berghei* infects mice. *Plasmodium falciparum* and *Plasmodium vivax* are the most common cause of malaria in humans. Not all parasites have the ability infect humans.

Prokaryote vs Eukaryote

All living organisms can be broadly divided into two groups, prokaryotes and eukaryotes. Prokaryotes include bacteria, cyanobacteria, and archaea (formerly archaebacteria) and are defined by their lack of a cell nucleus or any membrane-encased organelles.

Cyanobacteria are sometimes referred to as "blue-green algae", but they are actually photosynthetic bacteria that live in the water. They are unicellular like bacteria but often grow in colonies large enough to see. They are not eukaryotes because they lack a nucleus or membrane bound organelles, like chloroplasts.

All other living organisms are eukaryotes. Eukaryotes include plants, animals, fungi, and protists. Eukaryotes are made up of cells that contain a membrane-bound nucleus holding the genetic material as well as membrane-bound organelles.



Archaea (ar-KAY-ə) are similar to bacteria in size and simplicity of structure. They both lack a cell nucleus, reproduce through fission, have plasmid DNA, and a single circular chromosome. At the cellular level archaea are entirely different than bacteria. They contain "genes and several metabolic pathways that are more closely-related to those of eukaryotes, notably the enzymes involved in transcription and translation."(3) (photo: nature.com)

Archaea are also able to release long branched filaments that reach out to nearby archaea. "Archaea possess genes and several metabolic pathways that are more closely-related to those of eukaryotes, notably the enzymes involved in transcription and translation."(3)

Some of the most extreme environments on the planet (e.g. very salty, very acidic, and very hot), including the hot springs of Yellowstone National Park are inhabited by archaea. In addition to extreme environments they also live in common soil environments. Some archaeans are aerobic, some are anaerobic, and some are capable of methanogenesis (anaerobic respiration that produces methane).

Methanobrevibacter smithii is a methane-producing archaean that lives in the human intestine. *M. smithii* helps break down complex plant sugars and extract extra energy from the food.[4] **There are three species of archaeans that have been regularly found within the human body**: *Methanobrevibacter smithii*; *Methanosphaera stadtmanae*; and *Methanobrevibacter oralis.* "*M. oralis*, the major archaeal player in the oral cavity, has long been identified in periodontal pockets. Its proportional increase with severity of disease has meanwhile been confirmed by various groups."[5]

An overgrowth of human gut methanogens has been linked to constipation predominant irritable bowel syndrome. Using the probiotic species "***Lactobacillus reuteri*** DSM 17938 (100 million CFU) 30-minutes after eating twice daily for 4-weeks significantly decreased methane gas production, as determined by a lactulose breath test. The reduction in methane production was associated with a significant increase in bowel movements and regularity."[6]

Kingdom Protista

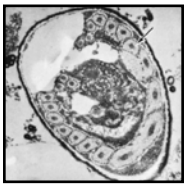
- The kingdom Protista is a massive group of eukaryotic organisms that cannot be classified as an animal, plant or fungus. **Protists include protozoans, unicellular algae, slime molds, and a few brown and red algae**. Protists can be mobile or immobile.
- While most protists are single-celled organisms (unicellular), some are multicellular. Kelp are large, multi-cellular algae seaweeds that resemble a plant but they lack tissues to carry water and food from one part to another.
- All eukaryotic organisms, and therefore all protists, have cells that contain a membrane-bound nucleus holding the genetic material as well as membrane-bound organelles. Most protists have mitochondria which produces energy for the cells to use.
- Non-photosynthetic protists (heterotrophs) use organic material as a source of food. Heterotrophic protists are further divided by how they secure their food source. Phagotrophs use their cell body to surround and engulf food (often other unicellular organisms). Osmotrophs absorb nutrients (osmosis) from the surrounding environment.
- Autotrophs are photosynthetic protists like algae which contain plastids (organelles for photosynthesis). Mixotrophs are organisms that have plastids for photosynthesis but are also able to engulf other organisms for food (phagotrophs).
- Most protists reproduce asexually through binary fission (the parent cell splits into two identical cells) or multiple fission (the parent cell splits into multiple identical cells). It has been noted that most protists probably also have some kind of sexual cycle.

Protozoa is considered to be a subkingdom in the kingdom Protista, although in the classical system they were placed in the kingdom Animalia as a phylum. A few years ago it was proposed that Protozoa should be given the classification as kingdom. Now they are saying the classification is obsolete. While the taxonomists ponder the classification and reclassification of protozoa, we will focus on how we interact with these wonderfully simple and yet complex organisms known as protozoans.

> "Modern ultrastructural, biochemical, and genetic evidence has rendered the term *protozoan* highly problematic. For example, *protozoan* historically referred to a protist that has animal-like traits, such as the ability to move through water as though "swimming" like an animal. Protozoans **traditionally were thought to be the progenitors of modern animals**, but contemporary evidence has revealed that this is not the case for most protozoans. In fact, modern science has shown that the protozoans represent a very complicated grouping of organisms **that do not necessarily share a common evolutionary history**. This unrelated, or para-phyletic, nature of the protozoans has caused scientists to abandon the term *protozoan* in formal classification schemes. Hence, the subkingdom Protozoa is now considered obsolete. Today the term *protozoan* is used informally in reference to nonfilamentous heterotrophic protists."(7)

"*Euglena spirogyra* is a species of algae. It feeds by photosynthesis in the light, but uses its flagellum to move about in search of food in the dark. Because it has characteristics of both plants and animals, German biologist Ernst Haeckel proposed in 1886 that a third kingdom, Protista, be established to accommodate microorganisms that did not fit into the plant or animal kingdom."(8) (Image: © Lebendkulturen.de | Shutterstock)

Microsporidia are a group of spore-forming intracellular parasites that were once considered protozoans but are now classified within the fungi kingdom. Microsporidia spores are found everywhere in the world and are capable of infecting any animal cell including those of insects, fish, mammals and even other parasites!



Brachiola algerae is a microsporidian that infects many mosquitos species. It is considered an emerging human pathogen and has been isolated from a human cornea, a cutaneous nodule, and deep muscle tissue. It is unknown if the infections were the result of a mosquito bite or if the spores were inhaled into the lungs or ingested.(39)

"Although the inoculation of spores during feeding cannot be excluded, we believe it is more likely that infection with *B. algerae* in this patient was a consequence of crushing an infected mosquito while it was feeding, thereby mechanically inoculating the spores into the skin-bite wound."(39)

Parasites and Humans

Parasites include viruses, bacteria, mycobacteria, fungi, protozoa, worms, etc., this manual will not cover bacteria and viruses. The main focus of this manual is to cover the most common and/or the most harmful human endoparasites (a parasite that lives inside its host) from the kingdoms Protista and Animalia in the United States.

There Are Four "Parasite Focus" Sections:
Kingdom Protista | Subkingdom Protozoa (unicellular organisms)
Kingdom Animalia | Phylum Nematoda
Kingdom Animalia | Phylum Platyhelminthes | Trematodes
Kingdom Animalia | Phylum Platyhelminthes | Cestodes

Parasite Focus: Protozaons

(a) *Balantidium coli (ciliate)*
(b) *Balamuthia mandrillaris (amoeba)*
(c) *Naegleria fowleri (amoeba)*
(d) *Entamoeba histolytica (amoeba)*
(e) *Acanthamoeba spp. (amoeba)*
(f) *Dientamoeba fragilis (amoeba)*
(g) *Giardia lamblia (flagellate)*
(h) *Trichomonas vaginalis (flagellate)*
(i) *Trypanosoma cruzi (flagellate)*
(j) *Toxoplasma gondii (sporozoa)*
(k) *Cryptosporidium parvum and C. hominis (sporozoa)*
(l) *Plasmodium malariae, P. falciparum, and P. vivaxis (sporozoa)*
(m) *Babesia microti, B. divergens, B. duncani, and B. venatorum (sporozoa)*
(n) *Brachiola algerae (sporozoa)*

Parasite Focus: Nematodes, Trematodes, and Cestodes

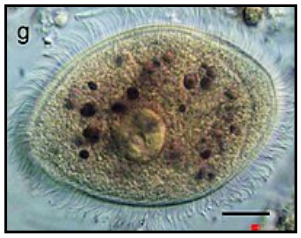
(a) *Enterobius vermicularis* (nematode/roundworm/pinworm)
(b) *Ascaris lumbricoides* and *Ascaris suum* (nematode/large roundworm)
(c) *Trichinella spiralis* (nematode/roundworm)
(d) *Toxocara canis* and *T. cati* (nematode/roundworm)
(e) *Ancylostoma duodenale* and *Necator americanus* (nematode/hookworm)
(f) *Trichuris trichiura* (nematode/whipworm)
(g) *Schistosoma spp.* (trematode/blood fluke)
(h) *Clonorchis spp.* and *Opisthorchis spp.*(trematode/liver fluke)
(i) *Fasciola hepatica* (trematode/liver fluke)
(j) *Paragonimus westermani* (trematode/lung fluke)
(k) *Fasciolopsis buski* (trematode/intestinal fluke)
(l) *Taenia solium* and *Taenia asiatica* (cestode/pork tapeworm)
(m) *Taenia saginata* (cestode/beef tapeworm)
(n) *Diphyllobothriidae* family (cestode/fish tapeworms)

Parasite Focus: Protozoans

According to the Australian Society of Parasitology, there are approximately 11,000 protozoan species that are parasitic in vertebrate and invertebrate hosts. Protozoans have been divided into six phylums. Phylum Sacromastigophora and Phylum Apicomplexa (sporozoa) encompass the most species that cause disease in humans.(9)

Virtually all humans have protozoa living in or on their body at some time, and many are infected with one or more species throughout their life. Some species are considered commensals and others are pathogens. Protozoan diseases range from asymptomatic to life-threatening.

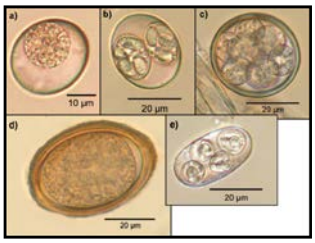
Protozoans are further categorized by how they move within and outside the host. **The main movement categories are ciliates, amoebae, flagellates, and sporozoa**.



Ciliates (ciliated protozoans) are large and the most complex, when compared to other unicellular organisms. They have numerous 'hair-like' extensions of the cell membrane called cilia. Cilia move with a smooth up-and-down motion which allows the cells to swim in fluids. There is only one known ciliate that causes disease in humans, *Balantidium coli* (*Neobalantidium coli*). photo: en.wikipedia.org/wiki/Balantidium_coli

Amoebas use pseudopodia ('false feet') to creep or crawl. Pseudopodia are temporary balloon-like extensions of the cell membrane. Protoplasm is directed into and fills the pseudopodia helping the amoeba to grip a surface and propel itself forward. Amoebae are shape shifters. Parasitic amoebae cause dysentery, meningoencephalitis and corneal lesions. photo: britannica.com/science/amoeba-order

Flagellates use long flagella (singular: flagellum) to propel the cell through liquid environments. Flagella are 'whip-like' extensions of the cell membrane. Parasitic flagellates cause enteric diseases such as giardiasis, urogenital diseases such as trichomoniasis, systemic diseases such as sleeping sickness, and tissue diseases such as Chaga's disease. photo: http://www.clpmag.com



Sporozoa ('spore-formers') have pre-spore stages that move by creating ridges in the cell membrane to produce a forward gliding motion. Sporozoans of the Phylum Apicomplexa have complex life cycles that often include both asexual and sexual reproduction. Sporozoa cause many serious diseases, including toxoplasmosis, malaria, babesiosis, and cryptosporidiosis. photo: https://www.researchgate.net

Simplified Protozoan Life Cycles

Most protozoa are able to reproduce and multiply rapidly in their host. The result is that acute symptoms may appear quickly after infection. Reproduction is limited by the host's immune response which may eliminate the parasite or it may "balance parasite reproduction" which results in a chronic infection. It only takes around 10 *Plasmodium falciparum* sporozoites (transferred from a mosquito to a human) to result in malaria if the person has no immunity. Repeated cycles of schizogony in the bloodstream can result in about 400 million parasites per milliliter of blood![10]

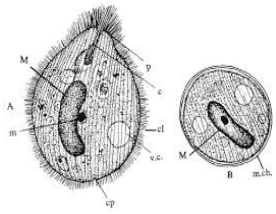
During its life cycle, a protozoan generally alternates between several stages that differ in structure and activity. Some protozoa have life cycle phases that alternate between the forms known as trophozoites and cysts. As cysts, protozoa can survive exposure to extreme temperatures, harmful chemicals, and long periods without nutrients, water, or oxygen. The cyst is also the form that allows transmission of the protozoa from one host to another. A trophozoite ('animal that feeds') is the activated feeding stage in the life cycle and is the stage usually associated with disease. Trophozoites may be found inside host cells (intracellular), body fluids, or interstitial spaces between cells (extracellular). Trophozoites, unlike cysts, do not tolerate external environmental conditions and not survive long outside of their hosts.

A variety of terms are used to describe the life-cycle stages of the diverse protozoans. For the hemoflagellates, the terms amastigote, promastigote, epimastigote, and trypomastigote describe the trophozoite stages. The terms tachyzoite and bradyzoite are used to describe the stages for *Toxoplasma gondii*. (photo: sciencesource.com)

To move from host-to-host, protozoan parasites use one of four main modes of transmission: direct, fecal-oral, vector-borne, and predator-prey transmission. An infected individual whose immune system was able to control, but not eliminate the parasites, becomes a carrier able to transmit the infection to others.

Ciliates (ciliated protozoans)

Balantidium coli is an intestinal protozoan parasite and the only member of the ciliate phylum known to be pathogenic to humans. *B. coli* is the largest protozoan and has a life cycle that includes cysts (transmission stage) and trophozoites (feeding and multiplying stage). Cysts that are passed in the stool are able to survive up to two weeks in the environment while they await a host. The trophozoites inhabit the lumen of the large intestine and have the ability to invade the wall of the colon.



Balantidiasis (balantidial dysentery) is considered a neglected zoonotic disease with pigs serving as reservoir hosts. The organism is universal and can be found wherever pigs are found. *B. coli* infects humans, rodents, sheep, monkeys, cattle, and many other animals. Porcine (swine/pig) or human fecal contamination of water sources or food is the primary route of transmission. The fecal-oral route is also a mode of transmission.

According to Frederick L. Schuster, California Department of Health, clinicians should have patients tested for balantidiasis if they have persistent diarrhea and have traveled to or from Southeast Asia, the Western Pacific islands, rural South America, or communities that have close contact with pigs.

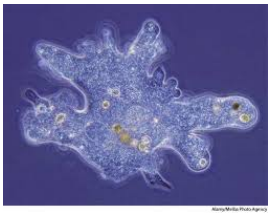
There are three levels of infection associated with balantidiasis:

- Asymptomatic infection is the most common and results in asymptomatic carries (host excretes cysts).
- Acute colitis symptoms may be mild or severe and include nausea, vomiting, diarrhea, and abdominal pain which often results in weight loss. The acute stage can cause explosive diarrhea every 20-30 minutes. Perforation of the colon may also occur in acute disease.
- Chronic Infections can can mild symptoms which include alternating diarrhea and constipation, abdominal pain, and weight loss. Severe symptoms of chronic infection include persistent diarrhea or dysentery (blood and mucus in the stool).

"There have been several reports in the literature of *Balantidium* spreading to the lungs, causing a pneumonia-like disease. Most of these infections have occurred in elderly or otherwise immunocompromised persons".(11) Severe intestinal inflammation, when combined with the organisms ability to penetrate colon mucosa and cause ulcers, creates an environment that leads to increased intestinal permeability. This may account for sporadic reports of *B. coli* found in the liver and genitourinary tract and causing peritonitis and inflammatory vaginitis. **Balantidiosis responds well to antibiotics** and there have been no reports of resistance to the drugs of choice.

Amoebae/Amoebas

An amoeba is a single-celled organism that does not have a cell wall. It has a flexible, gel-like cell membrane that surrounds a fluid called cytoplasm. Amoebae (uh·mee·buh) have the ability to move with the pseudopodia or "false feet" it creates by pushing the cytoplasm into one or more areas to accomplish a crawling-like type of movement. Some amoebas are aerobic (require oxygen) and others are anaerobic.



There are many species in the Amoeba genus and they are very difficult to tell apart. They live in lakes, ponds, streams, rivers, soil, and puddles and are even found in bottled mineral water, cooling towers, nuclear power plants, humidifiers, dental irrigation units, dialysis machines, ear wax, pulmonary secretions, eye corneas, and much more.(12)

Free-living opportunistic pathogenic amoebae such as *Acanthamoeba* spp., *Balamuthia mandrillaris*, and *Naegleria fowleri,* are found world-wide and cause infections in humans. *Sappinia diploidea* is a possible human pathogen. Most research papers and medical websites categorize amoebas as parasites however, there are pathogenic free-living amoebas that can survive without a host.(13)

Amoeba, in addition to directly causing human infections, **can also host bacteria** that are pathogenic to humans. *Legionella* bacterial species grow and multiply within amoeba and ciliate protozoans. The protozoans provide nutrients, shelter from the environment and chemicals, and a place to replicate and grow. The CDC states, “Human immune cells called alveolar macrophages look very similar to protozoa. When in human lungs, *Legionella* invades and grows within alveolar macrophages, mistaking them for their natural host and causing disease.”

Legionnaires' disease is a severe, often lethal, form of pneumonia caused by the **bacterium** *Legionella pneumophila*. Contamination of water in both potable and non-potable water systems is the most common cause of outbreaks. Once *Legionella* starts growing in a water system, it needs a way to spread. According to SafePlumbing.org, “Any source that generates aerosol or a fine mist of water has the potential to transmit *Legionella*. Large complex plumbing systems like those used in hospitals, retirement communities, and cruise ships are most often associated with Legionnaires’ disease” Each year, over 10,000 people are infected with the Legionella bacteria in the U.S. Unfortunately, this disease is also underrecognized and underdiagnosed.

In 1992 the first giant **virus of amoebas** was discovered and named *Acanthamoeba polyphaga mimivirus* (APMV). It was isolated from a water sample collected in England in an air-conditioning system, while investigating a pneumonia outbreak. In the years following, researchers identified several giant viruses that reside within amoebas. They include *A. castellanii mamavirus* that was isolated from a cooling tower in Paris, *Megavirus chiliensis* was isolated from Chilean ocean water, *Lentille* virus was found in the contact lens fluid of a patient with keratitis, and *Moumouvirus was* isolated from cooling tower water. “There are few data on APMV in animal tissues or its hypothetical role as pneumonia agent, although a recent metagenomic study found mimivirus DNA in bovine serum.” (https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0087811)

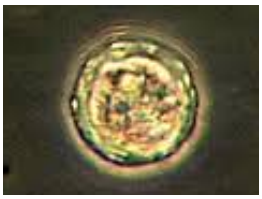
In 2013, researchers investigated whether APMV could survive adverse conditions while it was present in the amoeba *Acanthamoeba castellanii*. “It was found that when APMV is inside an amoebal cell subjected to UV irradiation, heat or exposure to different chemical biocides, it remains more stable, showing that these hosts can act like natural bunkers for APMV, increasing its resistance to the viral agents used to disinfect hospital environments.”[57] The probable importance of the *Acanthamoeba polyphaga mimivirus* as a pathogen in hospital environments has led to investigations into the ability of currently used disinfectant biocides to eliminate the amoeba and virus within.

While not an amoeba, the *Trichomonas vaginalis* is a protozoan parasite that is also a host to a virus. *T. vaginalis* infects the genitourinary tract and increases susceptibility to bacterial vaginosis, human immunodeficiency virus (HIV), and human papillomavirus (HPV). It is also responsible for reproductive complications that include infertility, pregnancy loss, and preterm delivery. “Antibiotic treatment can clear the parasite but does not prevent some of these complications…These results suggest that antibiotic treatment (metronidazole) of virus-infected *T. vaginalis* **causes an inflammatory response by liberating TVV virions or viral dsRNA from the protozoan**.” (www.virology.ws/2012/11/21/viruses-of-protozoan-parasites-may-exacerbate-human-disease)

Rare Amoebic Infections

There is no universal definition of a "**rare disease**" but the U.S. Rare Disease Act of 2002 defined a rare disease as affecting less than 200,000 people in the U.S.

Balamuthia mandrillaris, an amoeba found in soil, was isolated in 1986 from the brain tissue of a mandrill baboon. The baboon died of a neurological disease at the San Diego Zoo Wild Animal Park in California. *Balamuthia mandrillaris* is an emerging opportunistic protozoan pathogen.(14) The life cycle of *B. mandrillaris* consists of two life cycle stages, a vegetative trophozoite stage (infective stage) and a dormant cyst stage.



B. mandrillaris can infect the brain and cause granulomatous amoebic encephalitis (GAE). Infections are rare, only 94 cases reported to the CDC from 1986 to 2014, but up to 89 percent are fatal. It is possible that additional cases were misdiagnosed. Most infections in the United States have occurred in warmer regions of California, Texas, and Arizona.(15)

Balamuthia mandrillaris is found in the soil and can enter the body through a break in the skin or by breathing in contaminated dust. People with a high risk for infection include those who are immunocompromised, receiving immunosuppressive drugs, or have cancer, liver disease, diabetes, HIV/AIDS.(15) Early symptoms include headaches, nausea, and low grade fever. Symptom progression includes weight loss, difficulty speaking, and partial paralysis.

Naegleria fowleri is commonly referred to as "brain-eating amoeba". It is found in warm fresh water and has three life cycle stages: amoeba, cyst and flagellate. Amoeba-flagellates are amoebas which can transform into flagellates under certain environmental conditions. "*N. fowleri* is the only pathogenic free-living amoeba with a flagellate state".(16)

In the United States there were 145 known infections from 1962 through 2018 and only four patients survived. Most cases occurred in Florida and Texas. Symptoms included headache, stiff neck, seizures, and coma within days. Infection occurs after a person breaths in infected water through the nose (nasal inhalation). *Naegleria fowleri* attaches itself to the olfactory nerves and enters the central nervous system. It quickly causes an necrotizing infection in the brain resulting in acute Primary Amebic Meningoencephalitis (PAM). The mortality rate exceeds 98%.(17)

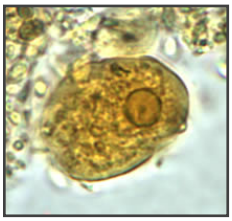
"The brain is moist and warm, just like the lakes and hot springs where the amoeba thrives. But the brain doesn't have bacteria for the amoeba to eat, so the organism attacks brain cells for nutrients. The immune system does not sit idly by, however, while the parasite eats its way through the brain. It unleashes a massive swarm of immune cells to the infected zone, which causes inflammation and brain swelling…While swimming in fresh water is the most likely source of this amoeba, this same organism and other species of amoeba can cause brain infections in people who use tap water instead of sterile water or saline when using the nasal-flushing Neti pot." (https://www.livescience.com/66083-why-brain-eating-amoeba-is-deadly.html)

Gastrointestinal Amoebiasis

Entamoeba histolytic is an anaerobic parasite that establishes itself in the intestines. Amoebiasis, also known amoebic dysentery, is an infection caused by any of the amoebae of the *Entamoeba* group. However, *Entamoeba histolytica* is the main cause of amoebiasis in the U.S.

The majority of infected individuals do not develop the classic clinical symptoms of amoebiasis (amoebic dysentery) which includes severe watery diarrhea, bloody stools, cramping, fever, and weight loss. Clinical symptoms of amebiasis occur in 15-20 percent of infected individuals. Up to 25 percent of uninfected individuals in endemic areas have anti-amoebic antibodies due to a previous infection with *E. histolytica*.

While the percentage of infections resulting in amebiasis may appear low, *E. histolytica* is ranked as one of the top three parasitic causes of death worldwide with over 100,000 deaths per year. In the United States, at least 3-4 percent of the population is infected. At least 10 percent of the asymptomatic carriers will eventually develop **invasive colitis or extraintestinal disease** (an infection outside the intestines). Extraintestinal manifestations associated with *E. histolytica* include liver abscess, pneumonia, purulent pericarditis, and cerebral amoebiasis.



Humans are the primary host, although dogs and cats may also be infected.[18][19] Ingestion of excreted cysts in water or on food are the main modes of transmission. An actively infected person can shed up to 50 million cysts per day which greatly increases the potential for fecal–oral infections. Sexually transmitted *E. histolytica* infections have also been reported, mainly from male homosexual activity.

"*E. histolytica* is classified as a category B priority biodefense pathogen by the National Institute of Allergy and Infectious Diseases because of its low infectious dose, chlorine resistance, and environmental stability, properties that can pose a threat of easy dissemination through contamination of **food and water supplies**."[20] The lack of an animal model that closely reflects the disease process of *E. histolytic*. in humans has hindered research."Currently, the only models of amebic liver abscesses involve direct injections of parasites into the liver of baby gerbils or hamsters."[22]

Definitions from mayoclinic.org

IBS: Irritable bowel syndrome is a common disorder that affects the large intestine. Signs and symptoms include cramping, abdominal pain, bloating, gas, and diarrhea or constipation, or both. The precise cause of IBS isn't known

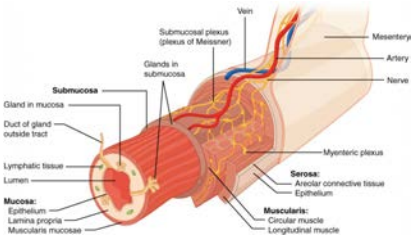
IBD: Inflammatory bowel disease is an umbrella term used to describe disorders that involve chronic inflammation of your digestive tract.

IBD symptoms include: diarrhea, fever and fatigue, abdominal pain and cramping, blood in your stool, reduced appetite, unintended weight loss.

Types of IBD include: **Ulcerative colitis -** This condition causes long-lasting inflammation and sores (ulcers) in the innermost lining of your large intestine (colon) and rectum. **Crohn's disease -** This type of IBD is characterized by inflammation of the lining of your digestive tract, which often spreads deep into affected tissues.

A diagnosis of *E. histolytic* infection is complicated by the following:

- Symptoms of amoebic colitis overlap and mimic those of IBS, Ulcerative Colitis, and IBD-Crohn's disease.
- "Stool microscopy is a relatively poor method for diagnosing intestinal amoebiasis because it is time-consuming and requires specific expertise. Culture methods are often unrewarding, with a sensitivity of only about 50%."(19)
- In the United States we tend to believe that parasites are limited to developing countries. Mayoclinic.org states that if you have IBS with diarrhea, you will be tested for celiac disease, bacterial or viral infections in the colon, and lactose intolerance. Mayo does mention at the bottom of the website page that your stool **might** be examined for parasites if you have **chronic diarrhea** and have traveled out of the country **recently.**
- "Hepatic amebiasis has been reported **over 20 years after** the last visit to an endemic area, so any travel history may be important in this diagnosis."(20)



When the cysts of *E. histolytica* enter the small intestine they release active amoebic parasites (trophozoites). The trophozoites invade the epithelial cells of the large intestines and cause flask-shaped ulcers. **Infection can then spread from the intestines to the liver, lungs, skin, eyes, joints, the brain, and other organs via the vascular system.**

At least 36 percent of patients with inflammatory bowel disease (IBD) will have at least one extraintestinal manifestation during their lifetime.(27) When a patient is misdiagnosed as having ulcerative colitis or Crohn's disease instead of an *E. histolytic* infection, "undesirable outcomes might occur from the use of steroids, including colectomy or even death. Clinicians must keep amoebiasis in mind in the differential diagnosis of patients suspected of having UC or Crohn's disease"(19). Amoebic colitis should be considered for diagnosis even in the developed countries. "Colonoscopy is not recommended as a routine diagnostic approach because intestinal amoebic ulcerations increase the likelihood of perforation during instillation of air to expand the colon."(19)

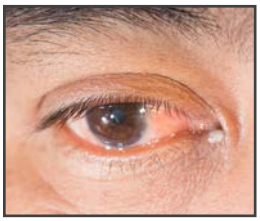
In addition to ulcerated colitis, Crohn's disease, and general IBS, chronic infection with *E. histolytica* has also been associated with **autoimmune conditions** (antibodies to colonic epithelial cells) of the intestines as well as extraintestinal autoimmune reactions. Intestinal amebiasis cases have been associated with antiphospholipid antibody syndrome with deep vein thrombosis, pulmonary embolism, and the development of symmetrical polyarthritis which is very similar to rheumatoid arthritis (RA).(21)

Recent studies have acknowledged the possibility of protozoan parasites, such as *Blastocystis hominis, Giardia intestinalis,* and *Dientamoeba fragilis*, as the cause of IBS. "It is essential that all patients with IBS undergo routine parasitological investigations in order to rule out the presence of protozoan parasites as the causative agents of the clinical signs."(23)

Acathamoeba spp.

Acanthamoeba species are commonly found in water (lakes, swimming pools, tap water, and heating and air conditioning units), soil, and the air. While several species of Acanthamoeba are able to cause disease in humans, most infections are associated with *A. culbertsoni*, *A. polyphaga* and *A. castellanii.*

A. culbertsoni causes a rare but fatal granulomatous amoebic encephalitis (GAE). *A. polyphaga* and *A. castellanii* are usually associated with ocular infections and keratitis (inflammation of the cornea). Additional *Acathamoeba* species found in ocular and CNS infections include: *A. astronyxis*, *A. divionensis*, *A. hatchetti*, *A. healyi*, and *A. rhysodes.* (Bobbi S. Pritt, Methods in Microbiology, 2015)



***Acathamoeba* keratitis** (AK) is considered rare however, the trend of increasing eye infection cases is alarming. “The most important step in *Acathamoeba* keratitis diagnosis is to think of it.”(24) It is a serious infection that requires aggressive medical and surgical treatment. *Acanthamoebae* can form cysts within the eye tissue and a single cyst surviving in the cornea can lead to reinfection.

The *Acanthamoebae* cysts are very defined and reflective, spherical structures however, the trophozoites closely resemble the the structure of leukocytes and keratocyte nuclei. The resemblance can lead to misdiagnosis.

Risk factors for *Acathamoeba* keratitis include using tap water to wet or clean contact lens (even water on your fingertips), not following proper disinfectant instructions for lens and the lens case, using lens longer than recommended (dailies used for several days, monthlies used for several months), and wearing contacts while swimming, using the hot tub, or showering.

In addition, water can cause soft contact lenses to change shape, swell, and stick to the eye. This can scratch the cornea which makes it easier for microorganisms to enter the eye and cause infection.

Soft contact lenses are a particular risk because acanthamoebae easily adhere to the hydrophilic plastic of these lenses. Soft lenses are also more difficult to clean than hard lenses. “There are currently no methods or a single drug that can eliminate both cystic and trophozoite forms, while the trophozoite form is much more readily eliminated ”(24) (photo from Ophthalmology,1984)

Acanthamoeba infections require prolonged and aggressive treatment, often because therapeutic treatment can induce encystment (resistant cyst forms). Some data indicate that povidone-iodine at high concentrations acts on both trophozoites and cysts. (Michael S Gilmore, Ocular Disease, 2010)

“In the United States, from 2005 to 2007, a multistate outbreak involving at least 170 patients was associated with use of Advanced Medical Optics Complete Moisture Plus (AMOCMP), though no specific contamination of the solution was found. After the voluntary removal of AMOCMP the number of cases declined, but not to preoutbreak levels; this new increase in baseline AK cases in the outbreak area is currently not understood.” (Anita A. Koshy, Mandell, Douglas, and Bennett's Principles and Practice of Infectious Diseases (Eighth Edition), 2015)

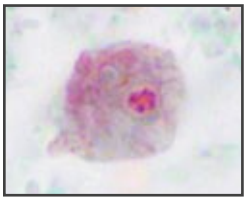
In addition to *Acanthamoeba,* there are other protozoan infections that can cause ocular diseases. “Extraintestinal manifestations of **giardiasis** are rarely reported, but in a recent study around 33% of patients affected by giardiasis showed long-term extraintestinal symptoms; hence, these symptoms are not as rare as previously assumed. Ocular complications included iridocyclitis, choroiditis, retinal hemorrhages, salt and pepper degeneration, and severe bilateral anterior uveitis. Susceptibility to ocular complications with giardiasis seems higher in smaller children.”(42) The diseases leishmaniasis, malaria, American trypanosomiasis, and toxoplasmosis may also result in ocular complications.

Keratitis isn’t limited to protozoans. Eye inflammation may be the result of infections from bacteria (*Pseudmonas aeruginosa* and *Staphylococcus aureus)*, fungi (*Fusarium*, *Apergillus*, and *Candida* species), or viruses (herpes simplex). Bacterial keratitis is one of the most common world-wide causes of irreversible blindness due to corneal infections. Herpes Simplex Virus keratitis usually heals without damaging the eye however, severe infections can lead to permanent scarring of the cornea and blindness.

Amoeba-Flagellates

Dientamoeba fragilis was originally described in 1918 but its life cycle and mode of transmission were not confirmed until recently. Until two labs in 2014 discovered *D. fragilis* cysts in stool samples, researchers believed that the organism only existed as a trophozoite. With no cyst form, the organism was thought to be fragile (hence the species name *fragilis*) and unable to survive outside the host. *Dientamoeba fragilis* trophozoites (the active life cycle stage) move by using cytoplasmic streaming of pseudopodia which is similar to how amoeba move within the body (hence the name *Dientamoeba*).

While the name *Dientamoeba fragilis* may stay the same, it is no longer considered an amoeba based on internal structures that reveal internal flagellum components within the cyst form. *Dientamoeba fragilis* is now described as a trichomonad protozoan flagellate, an intestinal trichomonad parasite. **It is not fragile and it is not an amoeba**.



The long-neglected research into the life cycle, transmission, pathogenicity, and prevalence of *Dientamoeba fragilis* has resulted in speculation and misinformation in many professional articles. The article, *Dientamoeba fragilis, one of the neglected intestinal protozoa,* was published in the Journal of Clinical Microbiology in 2016 and clarifies findings from newer studies.(25)

Dientamoeba fragilis infections are now known to cause acute or chronic diarrhea, alternating diarrhea and constipation, bloating and pain, fatigue, hair loss, failure to thrive in children, poor weight gain, and anorexia. Until recently it was hypothesized that transmission was due to a helminth vector, specifically the very common nematode (pinworm) *Enterobius vermicularis*. The theory was based on finding both pinworms and *D. fragilis* in the same stool samples from infected children. It is now known that the children were infected with more than one parasite. Infection via fecal-oral transmission is common worldwide, including in the United States.

Antiprotozoal protocols that appear to resolve *D. fragilis* infection include iodoquinol, paromomycin, and tetracycline. Metronidazole is associated with treatment failure. "*D. fragilis* is diagnosed by finding trophozoites in the stool, which can be **missed if only fresh stool specimens are examined**. Collection into various preservatives immediately on passage of stool and the preparation and careful examination of stained fecal smears will lead to higher recovery rates. Examination of multiple specimens passed on alternate days has been found useful, because the excretion of parasites may fluctuate markedly from day to day."(26)

"Eleven pediatric patients, seven of whom had peripheral eosinophilia and a history of recent travel, were diagnosed with *D. fragilis* infection and reported symptoms of **anorexia**, intermittent **vomiting**, **abdominal pain**, and **diarrhea**. Based on findings in these patients, which included **bovine protein allergy** and **eosinophilic colitis**, *D. fragilis* should be included in the differential diagnosis of chronic diarrhea and eosinophilic colitis."(25)

Protozoan Flagellates

Giardia lamblia (jee-ar-DYE-uh) is also known as *G. duodenalis* and *G. intestinalis*. It is an intestinal parasite that can infect several different hosts, including humans. In the United States, *Giardia* is the most frequently diagnosed parasitic intestinal disease (giardiasis). There were 15,223 reported cases in 2012 and most of the cases were observed in children aged 1–4 years, followed by those aged 5–9 years and then adults aged 45–49 years. Infection occurs when either a cyst or a trophozoite are ingested via contaminated water, food, or by the fecal-oral route.

The life cycle of *Giardia lamblia* includes a cyst that can survive several months in water and trophozoites that are able to move and asexually reproduce within the small intestine. Each cyst ingested will produce two trophozoites and an infected individual will excrete both cysts and trophozoites in the feces. (photo from the CDC)

Infection is primarily through the fecal-oral route. Giardiasis outbreaks in child care centers are increasingly common. If your hands become contaminated with fecal matter from an infected child while changing their diaper they must be thoroughly washed with soap and water (not hand sanitizer). Outbreaks also occur in contaminated lakes, rivers, spas, water parks and swimming pools. While less common, the house fly may also contaminate your food or drink.

As few as 10 of the microscopic cysts or trophozoites in a glass of water can cause a severe case of giardiasis. Uncooked foods that have been rinsed in contaminated water may also spread the infection. Only one third of people infected with *Giardia* exhibit symptoms, while **the majority of people remain asymptomatic**. Infected individuals who do not have symptoms can still spread it to others.

Symptoms of giardiasis usually develop one to three weeks after exposure and may include severe diarrhea and projectile vomiting. However, the infection can induce mild symptoms that include excess gas, stomach cramps and bloating, nausea, and foul-smelling diarrhea that may alternate with soft, greasy stools. Less common symptoms include allergies, itchy skin, hives, and swelling of the eye and joints. Left untreated, symptoms may last for more than 6 weeks. Sometimes the symptoms resolve but return after several days or weeks.

Chronic or prolonged infection with *Giardia* can lead to arthritis, damage to the epithelial cells of the large intestines, and other complications. Misdiagnosing a *Giardia lamblia* for IBS can delay proper treatment for years. Giardiasis can cause weight loss, malnutrition, malabsorption of sugars, fat, and vitamins A D, E, K, B12, folic acid, iron, and zinc. Lactose intolerance is commonly reported and may persist after the infection resolves. Severe giardiasis in children may slow physical and mental growth development.(29)

Multiple stool specimens, collected on separate days, are required for testing because *Giardia* cysts can be excreted intermittently. "The use of concentration methods and trichrome staining might not be sufficient to identify Giardia because variability in the concentration of organisms in the stool can make this infection difficult to diagnose. For this reason, fecal immunoassays that are more sensitive and specific should be used."(cdc.gov)(photo: ThunderHouse Instruments - Yuri)

While children are more likely to have giardiasis than adults it is not unusual for an entire family to be infected with some family members having diarrhea, some just abdominal pains, and others with few or no symptoms.

Giardia infections lead to strong immune responses and include the production of anti-parasite IgA. When an individual is reinfected the symptoms of disease are often reduced, however, the parasites are not eliminated when reinfected and they still produce cysts.(30)

"Of note, *Giardia* **specifically decreases the activity of pancreatic trypsin**, but not of chymotrypsin, which suggests that certain proteases can be hazardous for *Giardia* and may disturb a finely balanced silent infection to provoke pathogenic reactions." (www.frontiersin.org/articles/10.3389/fcimb.2017.00421/full)

Trichomonas vaginalis (trĭk'ə-mō'nās') is a sexually transmitted protozoan flagellate that can cause infection (trichomoniasis) of the urethra in men and the vagina in women. Trichomoniasis is the most common non-viral sexually transmitted disease. The CDC estimates that 3.7 million people in the U.S. have the infection (3% of women) but only 30% will develop clear symptoms. *T. vaginalis* infection in pregnant women is associated with premature rupture of membranes, preterm delivery, and low birthweight. *Trichomonas vaginalis* is one of five parasites on the CDC's neglected parasitic infections (NPIs) list.

The lifecycle of *T. vaginalis* parasite is described as consisting only of motile and symptom-causing trophozoites. However, in 2020 the Department of Biochemistry, Indian Institute of Science, challenged the assumption that the organism did not have a cyst or cyst-like structures (CLS) to survive outside the host. Their research discovered that *T. vaginalis*, in addition to trophozoites, develops cyst-like structures that allow it to survive in a variety of pH environments and in chlorinated swimming pools.(31)

The India research team's interest in chlorinated swimming pools was due to a clinical report that indicated transmission of *T. vaginalis* via swimming pool water. Test results "indicated that CLS can survive in chlorinated water. Thus, indicating environmental resistance of *T. vaginalis* CLS. We hypothesize that this could provide a possible non-sexual mode of transmission…"(31)

Trichomoniasis symptoms for women include: foul-smelling vaginal discharge which might be white, gray, yellow or green, genital redness, burning and itching, pain with urination or sexual intercourse, and vulvar and cervical lesions. Trichomoniasis rarely causes symptoms in men however, they might include: irritation inside the penis, burning with urination or after ejaculation, and a discharge from the penis. To prevent reinfection both partners should be treated.

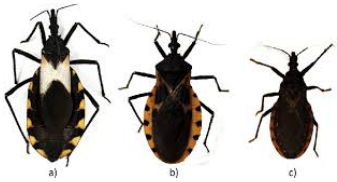


photo: reseachgate.net

Trypanosoma cruzi is a protozoan hemoflagellate that is endemic in southern N. America and S. America. The parasite infects a wide variety of wild and domestic mammals, humans, and many species of triatomine bugs (vectors). Triatomine bugs can live in cracks or holes inside of houses, between rocky structures, under cement, in rock, wood, or bark piles, in rodent nests, in outdoor dog houses or kennels, and in chicken coops. Normally they hide during the day and become active, feed on mammalian blood, at night.

Human infection is referred to as trypanosomiasis, Chagas' (CHAH-gus) disease. "The only other members of the genus *Trypanosoma* that cause disease in humans are two subspecies of African trypanosomes, *Trypanosoma brucei gambiense* and *T.b. rhodesiense*. These organisms cause West African and East African trypanosomiases, or sleeping sickness, respectively". (Louis V. Kirchhoff, in Advances in Parasitology, 2011)

Chagas disease is transmitted to humans most often through the bite of a triatomine bug (also called “kissing bugs” or cone-nosed bugs). Triatomines usually bite an exposed area of skin such as the face (hence its common name ‘kissing bug’). The bugs defecate or urinate on the skin as they feed. When the feces or urine of the bug contain the infective trypomastigotes and the person “instinctively smears the bug feces or urine into the bite wound, the eyes, the mouth, or into any skin break” the parasite enters the body and invades the cells.(32) Upon entering the cell, parasites differentiate into intracellular amastigotes. As the cells die, the amastigotes are released into the blood stream. Some will infect new cells, and some will be transformed into trypomastigotes and remain in blood.

Chagas disease listed as one of the five neglected parasitic infections (NPIs) in the U.S. “Patients with undiagnosed Chagas' cardiomyopathy go unrecognized, impeding their optimal management. The large number of undetected *T. cruzi* infections sustains the risk of transmission through **blood and organ donation** and from **mother to child**. Currently, obstetricians have limited knowledge of congenital *T. cruzi* transmission risk, and almost no screening of at-risk women is carried out.”(33)

Transmission is not limited to the bite of a triatomine bug, blood transfusions, organ transplants, and mother to child. *T. cruzi* can also be transmitted by contaminated food (the food came in contact with feces or urine of infected triatomine bug or animal).

Chagas disease has an acute phase and chronic phase. The acute phase of Chagas disease can last for weeks or months however, the acute phase of Chagas disease is usually asymptomatic (many people don't experience symptoms until the chronic stage). When acute signs and symptoms do occur, they are usually mild and may include:

- Swelling at the infection site, eyelid swelling (Nodular lesions or furuncles, usually called chagomas, may develop around bite. Chagomas occurring on the on the eyelids are commonly referred to as palpebral and periocular firm swelling.)
- Fever, fatigue, and/or rash
- Body aches, headache
- Loss of appetite.nausea, diarrhea or vomiting
- Swollen glands
- Enlargement of your liver or spleen

Treatment of Chagas disease in the United States currently focuses on **killing the parasite in acute infection** and **managing signs and symptoms in later stages**. In rare cases, the acute phase may be severe and includes cardiac or neurologic symptoms and signs. The subclinical chronic form of the disease (indeterminate form) may occur years or even decades after initial infection, or never.

Chronic infection complications include the amastiogote invasion of smooth muscle leading to irregular heartbeat, congestive heart failure, sudden cardiac arrest, difficulty swallowing due to enlarged esophagus, and abdominal pain or constipation due to enlarged colon.

Protozoan Apicomplexa|Sporozoa

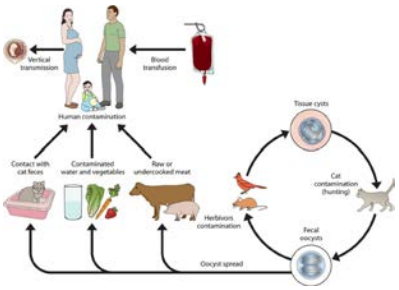
The phylum Apicomplexa (used to be called Sporozoa) consists of a large group of unicellular and obligate parasites that have a spore-forming stage in their life cycle. They all have intracellular life stages with the exception of *Cryptosporidium*, which has intracellular and extracytoplasmic stages. There are currently more than 6000 named apicomplexan species and they are well known as notorious pathogens of humans and cattle.

The Apicomplexa phylum contains five dominant groups commonly known as 'gregarines', 'haemogregarines', 'coccidia', 'malarial parasites' and 'piroplasms'. In addition to the dominant groups, there are many small transitional groups. The disease producing cryptosporidia group is one of the transitional groups

- Gregarine apicomplexans are closely related to parasites such as *Plasmodium*, *Toxoplasma*, and *Cryptosporidium* however, they have large mature extracellular (outside the cell) forms and are only known to infect invertebrates, especially annelids, arthropods and molluscs. There are approximately six hundred species.
- Haemogregarines are mainly intracellular (infect red blood cells) parasites of cold-blooded vertebrates. They are commonly found in turtles but also infect lizards, crocodiles, and fish. The life cycle of haemogregarines in aquatic hosts is transmitted by leeches or by arthropods in which the sexual part of the cycle develops.
- Coccidia are unicellular organisms that infect the intestines of a wide variety of animals, including humans, dogs, cats, birds, and cattle. Coccidia have three major stages to their life cycle: sporogony, schizogony, ametogony. Coccidia organisms are host- and tissue-specific protozoa. Cats and dogs both develop intestinal diarrheal infections from coccidia of the genus *Isospora* however*,* they their own coccidia species and cannot infect each other, nor can they infect people. Species of coccidia that can infect humans include *Toxoplasma gondii* (cats and humans) and *Cryptosporidium spp*. (humans, most cattle).
- Malarial parasites are spore-forming protozoans like the other apicomplexans and are called plasmodia, they form the genus Plasmodium. They are parasitic to reptiles, birds, and mammals. The four *Plasmodium* species well-known to cause human malaria are *P. falciparum, P. vivax, P. ovale*, and *P. malariae*. A fifth one, P. knowlesi, has been recently documented to cause human infections in many Southeast Asia countries. *Plasmodium falciparum* is the deadliest species and causes malaria in humans and is transmitted through the bite of a female *Anopheles* mosquito.
- Piroplasms divide by binary fission and as sporozoan parasites they possess sexual and asexual phases (sexual reproduction occurs in the tick gut). Piroplasms are divided into five groups but it is the *Babesia* group that has the most direct human impact. There are approximately one hundred *Babesia* species and they are closely related to *Plasmodium*, *Theileria* and *Cytauxzoon*. Piroplasms infect domestic animals, wild animals, and bird but are economically important because they cause widespread infection in cattle.

Toxoplasma gondii is a spore-forming intracellular parasite with two distinct life cycles. The sexual cycle occurs only in cats, the definitive host. The asexual cycle occurs in other mammals, which includes humans, and various bird species. The asexual cycle consists of two forms: tachyzoites (rapidly dividing form observed in the acute phase of infection) and bradyzoites (slowly growing form found in the tissue cysts). Bradyzoites in the human host are most commonly found in skeletal muscle, myocardium, brain, and the eyes. These cysts may remain throughout the life of the host.

Toxoplasmosis (tok-so-plaz-MOE-sis) is the disease caused by *Toxoplasma gondii.* It is the second leading cause of severe foodborne illness and death in the U.S. It is also on the CDC's list of neglected parasitic infections. More than 40 million men, women, and children in the U.S. are carriers of the *T. gondii* parasite. Most infections are asymptomatic because the immune system usually keeps the parasite from causing illness. Asymptomatic infections can reactivate when a person becomes immuno-compromised or is given immunosuppressive drugs. Reactivation can result in neurological damage and death.



How do humans get infected? It starts with the definitive host, the cat. During a primary infection a cat excretes millions of oocysts daily for 1-3 weeks. Oocysts are very resilient and may remain infectious for more than one year in warm humid environments. Infected animals will develop cysts in their muscles and organs of the body (brain, liver, heart, muscles), but do not develop or shed oocysts like the cat.

Food-borne transmission occurs when humans ingest raw or undercooked meat containing the parasite in their tissues (usually pork, lamb, or goat). **Pork is known to be one of the main sources of meat-borne infection.** Humans also acquire infections by eating contaminated unwashed fruits and vegetables, exposure to infected cat feces, or mother-to-child transmission during pregnancy. While considered rare, toxoplasmosis can be transmitted through an organ transplant or blood transfusion.

If you become infected **for the first time** just before or during your pregnancy, you can pass the infection to your baby (congenital toxoplasmosis), even if you don't have signs and symptoms yourself. "Congenital infection can cause pregnancy loss (miscarriage or stillbirth) or severe disease in the newborn, including developmental delays, blindness, and epilepsy. However, many newborns with congenital toxoplasmosis are asymptomatic at birth. Nevertheless, even if asymptomatic at birth, illness will develop in many infected infants later in their life, most often ocular disease, but also neurologic symptoms and developmental disabilities."(34) Congenital toxoplasmosis rates in the U.S. are approximately **1 per 1,000** newborns.

"About 15% to 25% of apparently healthy pigs in the U.S. are estimated to be exposed to *T. gondii*, as determined by antibody tests. Toxoplasma generally does not make pigs ill. The parasite can persist in the edible tissues of pigs and other food animals for years, perhaps for life." (http://www.ncagr.gov/vet/FactSheets/Toxoplasmosis.htm)

It is rare for humans to get toxoplasmosis from cats. Generally speaking, house cats that aren't allowed outside don't carry *T. gondii*. Wild cats or cats that live outside and hunt are more likely to be hosts of *T. gondii*. You may accidentally ingest the parasites if you touch your mouth after gardening, cleaning a litter box or touching anything that has come in contact with infected cat feces. **Pigs, goats, lambs, and chickens** can develop an infection when they ingest oocysts in soil, feed, water, cat feces or another animal that is infected with cysts. While rare, cattle may also become infected.

Signs and Symptoms
Toxoplasmosis may cause flu-like symptoms (body aches, swollen lymph glands, headache, fever, and fatigue) in some people but for most, the symptoms are mild and do not induce a need for a doctors visit. **However, regardless of initial symptoms, a chronic infection is established**.

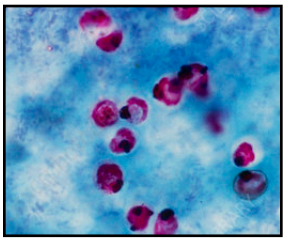
Individuals with a weakened immune system or are on immunosuppressant drugs may develop severe signs and symptoms of infection, including: headache, confusion, poor coordination seizures, lung problems that may resemble tuberculosis, and blurred vision caused by severe inflammation of your retina (ocular toxoplasmosis).

"Key to parasite prevalence is its ability to form chronic and nonimmunogenic bradyzoite cysts, which typically form in the brain and muscle cells of infected mammals, including humans. While acute clinical infection typically involves neurological and/or ocular damage, chronic infection has been more **recently linked to behavioral changes.**" (Journal of Parasitology Research Volume 2012, Article ID 589295)

"However, studies have now revealed associations between *T. gondii* antibody seropositivity (indicating infection) and the presence of various psychiatric disorders in humans (e.g., schizophrenia, bipolar illness, suicide attempts, episodes of self-directed violence, and memory impairment in elderly persons). Although these results are intriguing and potentially signal a new and compelling reason to redouble efforts to prevent toxoplasmosis, additional studies are needed to fully elucidate the relationship between *T. gondii* infection and mental illness, and how the strain and stage of *T. gondii* (oocyst versus tissue cyst) affects this relationship."(34)

"*Toxoplasma gondii* infection can be diagnosed by testing for antibodies against *Toxoplasma*, as well as by direct testing or visualization of the parasite in body tissues or fluids…Detection of IgM against *Toxoplasma* is suggestive of acute infection, but IgM can persist for months or even years after infection and false-positive IgM test results can occur in persons who are chronically infected or not infected with *T. gondii*."(34)

How do you kill *Toxoplasma gondii*? You must allow the meat to reach an internal temperature of at least 152 degrees Fahrenheit AND the temperature must be maintained for at least 10 minutes. All cutting boards, sink tops, knives, and other materials coming in contact with uncooked meat should be washed with soap and water.



Cryptosporidium *(krip·tow·spr·i·dee·uhm)* are spore-forming protozoans. There are several species that infect many different animals. Both *Cryptosporidium canis* (infects dogs) and *C. felis* (infects cats), have been associated with human infections but it is rare. The species that most commonly infect humans are *Cryptosporidium parvum* and *C. hominis* which cause the diarrheal disease Cryptosporidiosis.

Cryptosporidium parasites have a complex life cycle that includes both asexual and sexual stages.The oocyst is resistant to both prolonged environmental exposure and many commonly used disinfectants, including dilute bleach. *Cryptosporidium* infections may be zoonotic (from animal to human) or anthroponotic (human to human or human to animal transmission). *Cryptosporidium* was previously classified as coccidian parasites. As of 2012, the formerly known coccidians are classified in the subgroup Apicomplexa.

Cryptosporidium parasites only need one host to complete its life cycle. Infection occurs when an individual ingests the spore (oocyst) and it travels to the small intestine. The sporozoite that was protected and contained within the oocyst is released and burrows into the mucus layer of the the jejunum and ileum where they attach to enterocytes (intestinal absorptive cells). The infection causes watery diarrhea lasting 2-4 weeks, vomiting, nausea, and fever. While many cases are asymptomatic, signs and symptoms usually appear within a week after infection. Individuals who are asymptomatic (no symptoms) can pass on the infection to others. **Infected people, even after symptoms have subsided, can infect others for weeks.**

Cryptosporidiosis infections are primarily spread through contaminated drinking and recreational waters (pools, hot tubs, streams, etc.). Outbreaks typically occur in the summer months when there is an increase in recreational water activities. Prevention includes washing hands to prevent contamination of food (fecal-oral route) and avoiding swallowing or drinking water from swimming pools, hot tubs, lakes, and streams. Foodborne outbreaks have been associated with the consumption of raw or undercooked foods.

Severe symptoms occur most often in young children and the elderly. Diarrhea can lead to serious dehydration and weight loss. “Early childhood infection has been shown to result in **delayed growth, which may persist well beyond the period of infection**.”[(35)] Infections may not resolve in individuals with a compromised immune system or are taking immunosuppression drugs. Chronic infections can lead to **extraintestinal** infections of the liver, gallbladder, pancreas, stomach and lungs.

“Rehydration through the oral route is the most widely used intervention. Thus far, only nitazoxanide has been approved by the US Food and Drug Administration (FDA) for the treatment of *Cryptosporidium* infections in people. This product has shown to shorten the duration of diarrhea and parasite excretion, although it is not highly efficacious in the treatment of cryptosporidiosis in people with immune deficiencies.”[(43)]

***Plasmodium* species** that cause malaria in humans include *P. malariae, P. falciparum*, and *P. vivaxis*. They are spore-forming obligate parasitic protozoans of vertebrates and insects.The parasite life cycle involves two hosts, a female *Anopheles* mosquito and a human. Malaria parasites are transmitted person to person with the assistance of the mosquito.

When a mosquito bites an infected person, the blood containing the parasites enters the mosquito's gut. Within the mosquito the parasites go through complex development stages until the mature parasite eventually travels to and resides in the mosquito's salivary glands.

In humans, the malaria infection begins when the infected female *Anopheles* mosquito attaches for a blood meal. When it attaches the Plasmodium parasites, in the form of sporozoites, is injected into the individuals bloodstream. The sporozoites then travel to the liver and enter the liver cells. (photo: brittanica.com)

Within the **liver** cells, the sporozoites multiply asexually for 7 to 10 days causing symptoms of fever and chill. The next stage is the release of merozoites from the liver cells. To evade the abundant Kupffer cells (highly active liver macrophages), merozoites form merosomes (packets of hundreds of parasites surrounded by host cell membrane). Merosomes then **travel through the heart and accumulate in the lungs** where the merosomes disintegrate and release merozoites into the **bloodstream**.

In the bloodstream, the merozoites **invade red blood cells** (erythrocytes) and multiply again until the cells burst. Then they invade more erythrocytes. This cycle is repeated, causing fever each time parasites break free and invade blood cells.(36)

Is malaria a health threat in the United States?
Approximately 2,000 cases of malaria are diagnosed in the United States each year however, almost all of the cases can be traced back to travel and immigration. In the United States we have had “small and relatively isolated” outbreaks of locally transmitted malaria cases.

The latest known outbreak was in 2003 when eight cases were diagnosed in Palm Beach, Florida. Some cases are referred to as “Airport Malaria” when it is believed that a mosquito was transported to the states by aircraft, survived in the local conditions, and then infected a a local resident. **The CDC has stated that the “potential risk for the disease to re-emerge is present due to the abundance of competent vectors, especially in the southern states”**.

Sometimes the elimination of vectors comes with a hefty price. In 1947 the National Malaria Eradication Program targeted **13 southeastern states**. By the end of 1949 they had applied DDT to more than **4,650,000** rural homes. They were not just spraying the outside of homes, the **interior surfaces** or entire premises were targeted. In addition, they sprayed standing water and “occasionally” used aircrafts to cover an area

DDT was used on food crops, swimming pools, beaches, inside homes, cows, horses, creeks, and direct application to the human body. They even had DDT treated wallpaper for the children. This continued even after *Time* notified readers in 1944 that DDT's "poisoning" properties were "cumulative."

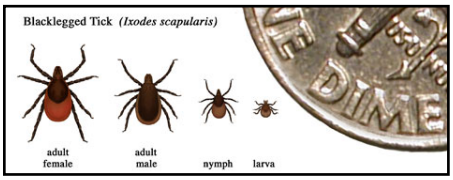
DDT is safe and effective - the science was settled!

In Rochester, NY (1946) the Health Officer, Albert D. Kaiser, published *"Treatment of Pediculus capitis in School Children with DDT Powder"*: "To simplify the treatment and control the source of contact, a preparation of **DDT powder** (10 parts DDT and 90 parts inert powdered talc) was utilized. Head inspections were made by the school nurse on all children in a grade and the infected child was treated by the school nurse. Utilizing a small atomizer, the DDT powder was sprayed on the child's hair, a paper towel being placed over the eyes to prevent any irritation. A towel or kerchief was placed over the scalp to prevent the loss of the powder and to hold the lice that came to the surface and the child was sent home with instructions to keep the head covered until bedtime. In the morning the hair was combed with a fine comb to remove the dead lice and as many eggs as possible…daily inspections until **the 7th day, when another application of DDT** powder is made, following a shampoo given the previous evening…There have been **no ill effects of any kind thus far** and the treatment has evoked no resistance on the part of the children or adults so treated. **In some instances parents have refused the treatment with the fear that DDT is dangerous.** Ultimately this fear may be overcome but at present no pressure is used to force this method of treatment on any individual."

"**All women** exposed to high levels of DDT are at **increased risk for breast cancer** through age 54, but the timing of cancer risk depends on when they were first exposed. Women exposed before 14 years of age, particularly in infancy and early childhood, were most likely to develop premenopausal breast cancer, while those who were exposed after infancy were at increased risk of developing cancer later, at 50-54 years of age."(37)

Animal studies suggest that **short-term exposure** to DDT **and metabolites in food** may have a harmful effect on **reproduction**. "In addition, we know that some breakdown products of DDT can cause harmful effects on the **adrenal gland**…Based on all of the evidence available, the Department of Health and Human Services has determined that DDT is reasonably anticipated to be a human carcinogen. Similarly, the International Agency for Research on Cancer has determined that DDT is **possibly carcinogenic** to humans. EPA has determined that DDT, DDE, and DDD are **probable human carcinogens**."(38)

Babesia microti. are spore-forming protozoan parasites that infect red blood cells (erythrocytes) and a cause malaria-like disease in humans. The parasite enters an individual when an infected blacklegged tick (*Ixodes scapularis*) attaches for a blood meal. The tick-borne disease that develops after the parasites from the tick enter the human body is called babesiosis. While more than 100 different *Babesia* species can infect animals, only a few are known to cause disease in humans. Species known to infect humans include *B. microti*, *B. divergens*, *B. duncani*, and *B. venatorum*.(40)



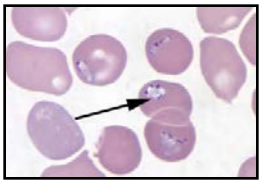
Adult blacklegged ticks ((*Ixodes scapularis*) are approximately the size of a sesame seed and nymphal ticks are approximately the size of a poppy seed. Risk of infection is greatest in the late spring and summer. (Photo: CDC)

Babesia protozoans require 2 hosts to continue its life cycle, a tick and a rodent. Specifically, the most common hosts are blacklegged ticks ((*Ixodes scapularis*) and the white-footed mouse (*Peromyscus leucopus*). A blacklegged tick has a four-stage life cycle (egg, six-legged larva, eight-legged nymph, and adult). “Each mobile tick stage (larva, nymph, and adult) requires a blood meal on a different vertebrate host. Larval and nymphal ticks leave the vertebrate host to molt between each blood meal, and adult females leave the third and final host in the fall to overwinter before oviposition in the spring. The natural hosts for larvae and nymphs are usually small mammals or birds, while the hosts for the adult ticks are larger mammals, such as deer (although humans can enter the life cycle at any stage).” (www.ncbi.nlm.nih.gov/pmc/articles/PMC5625376)

Approximately 2000 cases of babesiosis occur in the United States each year, which resulted in its announcement as a notifiable disease by CDC in 2011. Approximately 94% of reported *B. microti* infections occurred in Connecticut, Massachusetts, New Jersey, New York, Rhode Island and the Midwestern states of Wisconsin and Minnesota.

Babesiosis infections are often asymptomatic or present as mild flu-like symptoms that may include irregular fever, chills, sweats, pain, nausea, vomiting, and headache. Infection can lead to inflammation and enlargement of the spleen and an elevation of liver enzymes. In severe cases, hemolytic anemia, jaundice, shortness of breath, and hemoglobinuria (oxygen transport protein hemoglobin is found in abnormally high concentrations in the urine) have occurred. Psychiatric problems are have also been reported.

“In Europe, babesiosis is considerably rarer but more lethal; it is caused by the bovine pathogen *Babesia divergens*. The spectrum of disease is broad, ranging from an apparently silent infection to a fulminant, malaria-like disease resulting occasionally in death. Various determinants are involved in the severity of disease manifestation; among those identified are age, immunocompetence, and **coinfection** with other pathogenic agents.”(41)



Currently, *Babesia microti* is the leading cause of (RBC)-transfusion-transmitted infections in the United States. It is also the leading infectious cause of transfusion-related deaths. The FDA, as of May 2019, requires donated blood to be tested for *Babesia* species in addition to the standard questionnaire.[40]

The most common tick-borne diseases in the United States include babesiosis, Lyme disease, anaplasmosis, ehrlichiosis, relapsing fever, tularemia, and Rocky Mountain spotted fever. It is possible for one tick to transmit more than one species of parasite. While some organizations claim that up to 32 percent of patients with Lyme disease are co-infected with *Babesia*, most journals estimate that 10-23 percent of Lyme disease patients also have babesiosis. (https://academic.oup.com/qjmed/article/109/3/195/1855359)

When an individual is diagnosed with Lyme disease they are given antibiotics but they are not usually tested for common co-infections. *Babesia* is a common co-infection, and is at times the reason a patient still has symptoms after taking antibiotics for Lyme disease. Medscape: “The combination of clindamycin and quinine is used to treat *Babesia* infection. Quinine inhibits the growth of the parasite by increasing the pH within intracellular organelles and possibly by intercalating itself into the parasite’s DNA.”

The National Institute of Allergy and Infectious Diseases carried out studies with mice to determine how co-infections affect the immune response to Lyme disease. They found that a co-infection with *Ehrlichia* or *Babesia* increased the severity of Lyme disease. Interestingly, the presence of the Lyme disease causing *Borrielia burgdorferi* seemed to limit the symptoms of *Babesia*. The mice model may not transfer to humans however, it is encouraging that co-infections are receiving research attention.

Parasite Focus: Nematodes

All Nematodes Are Roundworms!

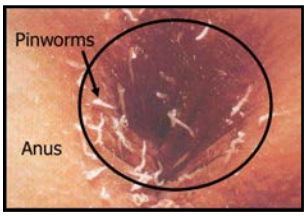
Both the nematodes and arthropods belong to the superphylum Ecdysozoa. The name is derived from the word ecdysis, which refers to the shedding, or molting, of the cuticle. The phyla in this group must be periodically shed the cuticle and replace it for them to increase in size. Depending on the source, there are an estimated 28,000 to 500,000 species of nematodes yet to be discovered and approximately 16,000 known species.

Most roundworms look very similar and have a long, thin, tube-like appearance that lacks a visually distinct head or tail. Most are microscopic but some parasitic species can reach a length of 3 feet. Parasitic nematodes come in all sizes and infect of a variety of plants and animals. The nematodes known to parasitize humans are commonly called roundworms, pinworms, whipworms, threadworms, and hookworms.

Each species is able to cause unique symptoms however, many have been implicated in the rare disease eosinophilic colitis (EC). A disease recognizable by the large number of eosinophils (a type of white blood cell) in the large intestine which leads to injury and inflammation. EC can also be caused by drugs and common food allergens such as milk, wheat, soy, fish, shellfish, peanuts, tree nuts.[28]

Enterobius vermicularis, also known as a **pinworm**, threadworm, or seatworm, is the most frequent nematode infection in the U.S. The infection is common among children 5 to 10 years of age but often spreads among family members. Humans are the only natural host for this parasite.

The worms are tiny, thread-like, and whitish with the pin-like tail located on the female worms. Infection occurs when the eggs of the pinworm are ingested, most commonly through the fecal-oral route. Transmission may also occur via contact with contaminated clothes, bedding, personal care products, and furniture. Once *E. vermicularis* eggs are ingested, they take about 1 to 2 months to develop into adult worms in the small intestine. The worms do not usually cause any symptoms while inhabiting the small intestine but when they start moving to the anus area they irritate the skin and lay eggs.



The most common symptom associated with pinworm infestation is perianal itching (itchy butt). The itch often results in squirming while sitting and hands in the pants. While the cure rate is high, re-infection is common. The eggs are microscopic but you can see the very small pinworms (about the length of a staple). Females are larger than the males.

The female adult worms and gametes migrate to the anal area mostly during the night and deposit thousands of eggs outside the anus area. The eggs hatch near the anal area causing itchy butt. Scratching the itch while sleeping is common and this leads to contamination of the fingers and results in ingestion of the eggs (autoinfection) and restarts the life cycle of the worm. While not common, infections of the liver, oral cavity, lungs, urinary tract, appendix have been reported.

Parents need to wake the child in the morning and immediately wash the child's hands with a soap and very warm water before they touch anything. They will need to shower soon after waking up but, washing their hands first will prevent them from transferring eggs to surfaces, food or their face/mouth. While it is not necessary to wash the bedding everyday they must be washed when you start an elimination remedy.

Children are not the only ones that get infected with the parasites. It is also commonly seen in adults who take care of children in day care and institutions. The CDC estimates that there are about 40 million people infected in the United States.

"*Enterobius* can be diagnosed through a cellophane tape test or pinworm paddle test where an adhesive tape-like material is applied to the perianal area and then examined under a microscope…The examination is usually done in the early morning for higher diagnostic yield. If the examination is negative for five consecutive mornings, then the diagnosis is ruled out. Stool examination is not helpful in the diagnosis of *E. vermicularis* as they are only occasionally excreted in the stool. Sometimes analysis of the stool specimen is recommended to rule out other causes…Young pinworms tend to be resistant to treatment and hence two doses of medication, two weeks apart are recommended. At the same time, all members of the infected child must be treated. If a large number of children are infected in a class, everyone should be treated twice at 2-week intervals. Follow up is vital to ensure that a cure has been obtained."(47)

Ascaris lumbricoides is a **large intestinal roundworm** that is responsible for up to one billion world-wide infections. The infection is called ascariasis (as-kuh-RIE-uh-sis) and it currently affects 25 percent of the world population. While the highest prevalence occurs in areas with inadequate sanitation and tropical/subtropical regions, it also occurs in the United States.

The number of cases in the U.S. is estimated to be 4 million. *Ascaris* is primarily transmitted in the Gulf States, southern New Mexico, and southern Arizona. Transmission occurs when an individual ingests food or water contaminated with *Ascaris* eggs. While the worms require shade and mild temperatures, the eggs are very resistant to even strong chemicals. Eggs can be found on fruits and vegetables, carried by dust and inhaled and swallowed, and can live on paper/money. Children are infected most often because they play in the dirt and put their fingers in their mouth(44)

After a fertilized egg (unfertilized eggs are not infective) is ingested, the larvae inside the egg hatches and invades the mucosa of the small intestines. Breaching the intestinal mucosa allows them to migrate to the liver and travel via the hepatic vein to the right side of the heart and into the lungs. The larvae mature within the lungs before break through the alveolar walls and travel up the bronchial tree to the throat. When they reach the throat, the individual swallows and the mature larvae is taken back down to the intestines where it will develop into an adult worm. The process takes approximately 2 to 3 months. Occasionally, larvae infect the heart or migrate to sites other than the lungs. In endemic countries such as India, ascariasis has been found to cause up to one-third of biliary and pancreatic disease.(web.stanford.edu)

The adult worm can live in a human host for 1 to 2 years and reach a length of 12-40 cm (4.7-15.7 inches). *A. lumbricoides* is the largest intestinal nematode that infects humans. Female worms can produce up to 200,000 eggs per day, which are passed with the feces. Although the majority of worms are found in the small intestine, they may be found anywhere from the esophagus to the rectum and may even wander out of the intestinal tract and into the biliary and pancreatic ducts. The good news is that adult worms do not multiply in a human host. The number of adult worms infecting an individual depends on the number of fertile eggs have been ingested over time.(45)(photo: parasiteswithoutborders.com)

Individuals infected with *Ascaris* often show no symptoms (asymptomatic). When symptoms do occur they are usually mild and include a cough when the larvae migrate to the lungs, nausea, abdominal bloating and pain. Symptoms depend on the number of worms within the intestines. Heavy infestations can cause intestinal blockage and impair growth in children. Although ascariasis occurs at all ages, it is most common in children 2 to15 years old. Damage to the intestinal villi by *A. lumbricoides* can impair the absorption of fats, vitamin A and iodine, and cause lactose intolerance. In addition to intestinal symptoms, infection can lead to an allergic reaction to worm waste and result in skin rashes, eye pain, asthma, insomnia, and restlessness. Skin reactions that may result from ascariasis include chronic dermatitis and childhood atopic dermatitis.(46)

Ascaris suum is a **pig roundworm** that can infect humans. It is indistinguishable from the human roundworm *Ascaris lumbricoides*. *Ascaris suum* eggs are extremely resistant to heat and cold and can survive for up to 10 years in the soil. “It is virtually impossible to completely remove *Ascaris suum* eggs from the environment where an infected pig has been present” (CDC)

Fourteen cases of ascariasis occurred in Maine from 2010 to 2013. All of the infected individuals had contact with pigs. “Ascariasis and other soil-transmitted helminth infections were highly prevalent in the southern United States and Appalachia as recently as the 1980s…Less is known about ascariasis prevalence elsewhere in the United States, including the Northeast, but infection has been presumed to be uncommon. ” (https://wwwnc.cdc.gov/eid/article/21/2/14-0048_article)

China provides almost 50% of the world’s total pork production each year. A study published in February of 2020 concluded that the overall seroprevalence of anti-*Ascaris* antibody was >60%. Screening included 512 individual serum samples from fattening pigs from 13 farms across seven distinct locations of the Sichuan Province in China. “There was no significant difference in seroprevalence between the intensive and extensive farms.”(48)

In September 2010, three heifers died in Missouri with symptoms of respiratory distress, coughing, tachypnea, and general weakness. There were only 15 cows on the farm and all of them had similar symptoms for 2–3 weeks. The Veterinary Medical Diagnostic Laboratory in Columbia. MO provided a postmortem examination and determined they died from a roundworm infection.

“Further investigation indicated that the source of infection was a pair of young-adult, free-range pigs living alongside the affected cattle. The cattle had been fed a round bale of hay to which the pigs had access. Parasitologic examination of the hay bale showed contamination with *A. suum* nematode eggs, indicating that the hay bale was probably exposed to pig feces. The hay bale was removed from the remaining cattle, and clinical signs gradually resolved without additional loss” (www.ncbi.nlm.nih.gov/pmc/articles/PMC4734507/)

Trichinella spiralis is an intestinal roundworm that **infects the muscles** (cyst form). The infection is commonly called trichinosis (trik-ih-NO-sis), sometimes it called trichinellosis (trik-ih-nuh-LOW-sis). Rates of trichinosis in the United States have decreased from about 400 cases per year in the 1940s to about 20 per year in the 2000s. Diagnosis is usually made based on symptoms and is confirmed by a blood test. Identification of encysted or non-encysted larvae require a biopsy.

The parasite’s life cycle begins when the under-cooked muscle/meat containing the cyst is ingested. Digestion of the meat also breaks down the *Trichinella* cyst wall and releases the larvae. Within four days the larvae will reach maturity within the intestines and the worms will mate. The female worms, after mating, will perforate the intestinal mucosa and release the newly formed larvae. The larvae will then migrate through the blood system and enter a skeletal muscle (usually) and enter a cyst stage. The larvae may also invade other tissues such as the heart, lungs and brain. The cysts remain alive for years but the adult female worm in the small intestine is eventually expelled.

Initial symptoms of trichinosis include the flu-like symptoms of diarrhea, abdominal pain, fatigue, nausea, and vomiting. These symptoms are the result of the larvae penetrating the wall of the small intestine and your immune response. About a week after the infection, the female worms will release the larvae and they will travel to and penetrate muscle or other tissues. The invasion of the tissue may result in symptoms that include a high fever, muscle pain, swelling of the face or eyelids, pink eye, headache, and sensitivity to light

Many different wild and domestic animals can carry infective *Trichinella* cysts in their muscle/meat, including swine/pigs, wild boars, bears, moose, walruses, rodents, and even crocodiles. The prevalence of *Trichinella* in the U.S. swine population is very low, 0.007% in 2000, and regulations are in place for processing pork (making ready to eat products) to further minimize and human infections. “Irradiation of pork and other meats was legalized in 1988 and now is providing additional protection”.(56)

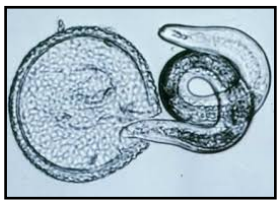
To destroy any cysts in pork, the meat must be frozen and/or cooked thoroughly. Freezing meat from wild animals doesn’t appear to kill the larvae. “Antiparasitic drugs such as albendazole can eliminate the worms from the intestine but not larvae in muscles, and analgesics are needed to relieve muscle pain.” (Merck Manuals)

The best way to prevent trichinellosis from pork is to cook the meat to a temperature that will kill the cysts. Pork should reach an internal temperature of at least160°F (71°C) and it needs to sit for 3 minutes after removing from heat. Canada still recommends that pork should be heated to at least 160°F but, the U.S. lowered the safe temperature requirement in 2011 (below). Freezing pork that is less than 6 inches thick for 20 days at 5°F (-15°C) will kill any larvae. Irradiation of course will kill the trichinella. Smoking and pickling meat does not kill trichinella parasites in infected meat.

Disturbing: May 24, 2011 “New cooking guidelines from the nation’s food-safety agency confirm Pork Checkoff research that shows pork can be consumed safely when cooked to an internal temperature of 145 degrees Fahrenheit, followed by a three-minute rest time. The guidelines were announced today by the U.S. Department of Agriculture’s Food Safety Inspection Service (FSIS)…The revised recommendation applies to pork whole-muscle cuts, such as loin, chops and roasts. **Ground pork, like all ground meat, should be cooked to 160 degrees Fahrenheit**…The new recommendation evolved from a 2007 Pork Checkoff-funded research project conducted by Ohio State University to measure consumer eating preferences. As part of that project the university researchers tested how various end-cooking temperatures affected eating preferences. But the researchers needed to know if temperatures below 160 degrees would be safe if that turned out to be consumers’ preference.” (pork.org)

For information on the irradiation of food (meat, fruits, vegetables, eggs, sprouting seeds…) visit: https://www.fda.gov/food/irradiation-food-packaging/overview-irradiation-food-and-packaging

Toxocara canis infects dogs and ***Toxocara catis*** infects cats. When the eggs are transmitted to humans and cause an i**ntestinal roundworm** infection it is called Toxocariasis. Humans become infected when they have contact with the eggs and accidentally ingest them. Children are affected most often because they are more likely to play in the dirt, on playgrounds, and in sandboxes. Contaminated garden soil, unwashed vegetables, and the hair of infected pet dogs and cats can also lead to transmission. Soil sample testing for *Toxocara* eggs in public parks and sandboxes had positive rates ranging from 0.3% to 39%.



Puppies usually contract the parasite from their mother before birth or from her milk. The larvae mature in the puppies intestines within 4 weeks and start producing eggs. After the eggs are expelled with the feces, it takes about 2 to 4 weeks for infective larvae to develop in the eggs. If an individual ingests one of these infective eggs they can become infected with toxocariasis. (photo: CDC)

Serious *Toxocara* infections include visceral toxocariasis (VLM) and ocular toxocariasis (OLM). Visceral toxocariasis occurs when the larvae migrate to various body organs, such as the kidneys, muscle, lungs, liver, or brain/central nervous system. Only *T. canis* (not *T. cati*) is capable of invading the central nervous system. Ocular toxocariasis is when the larvae migrate to the eyes or optic nerve. The infection usually presents as retinal granuloma, a yellowish or whitish inflammatory mass that can cause macular edema and retinal detachment.

According to the CDC, most cases of toxocariasis are not serious. However, recent research has discovered that both children and adults can manifest a wide range of **inflammation-related symptoms** and diseases when infected with *Toxocara,* including asthma, allergies, pneumonia, endomyocarditis, meningoencephalitis, granulomatous hepatitis, lymphadenopathy, and skin disorders. The manifestation of symptoms and disease depends on the quantity of infectious larvae, host immune responses, age-related factors, and the organs involved.(50)

Researchers at the University of Bergen Norway were surprised to find a connection between allergy and **asthma** risk in humans and *Toxocara canis* infections. Their results showed that young people who test positive for *T. canis*, have a 4 times higher risk of developing asthma and allergies. "Usually, we consider a 50% higher risk as being high, but here we see a 400% higher risk."(www.sciencedaily.com/releases/2017/12/171204091811.htm).

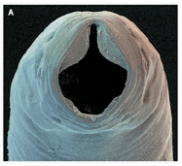
“Substantial studies have indicated that people with *T. gondii* infection may be highly susceptible to schizophrenia development. Since infection with *T. canis* would increase the risk for *T. gondii* infection and vice versa, we cannot completely exclude the possibility that schizophrenia syndrome in *T. canis*-seropositive patients is truly triggered by *T. gondii* rather than *T. canis* infection. However, this is still unclear, since the studies mentioned above did not reveal the status of *T. gondii* infection among schizophrenia patients. Clearly, further research on the possible mechanistic relationship between *Toxocara* **brain involvement and schizophrenia, depressive, and cognitive disorders** is required.”(50)

Toxocariasis is listed as a neglected tropical disease but it also a neglected disease in the United States. Toxocariasis is not a nationally reportable disease and no surveillance systems are currently in place to track cases."[49] Depending on the source, the prevalence of past and present toxocariasis infections in the U.S. is 15%-25% of the population (tens of millions).

A study from Japan, based on 911 cases diagnosed during 2001 and 2015 revealed that it was the adults, not the children as found in the the U.S., that were primarily infected. "This difference in the epidemiology appears to be associated with food preference among Japanese people. They are definitely **'sashimi lovers'** who have been enjoying sushi and sashimi of fish for a long time. People in Japan have a basic feeling that sashimi is the best way to enjoy natural delicacies… Amazingly or unfortunately, Japanese people have now extended their foodstuff territory for sashimi and sushi to animal meat, farmed as well as game meat. The fact that 67.9% of the present patients had a history or habit of **ingesting raw or undercooked animal meat** and/or liver seems to suggest that they acquired infection by eating paratenic host meat."[52]

Ancylostoma duodenale and Necator americanus are the two major species of **hookworm** that infect humans. *Ancylostoma duodenale* is found primarily in Mediterranean countries and *Necator americanus* is found in North and South America, Africa, Indonesia, China, India, as well as other countries. *Ancylostoma ceylanicum* is an emerging hookworm that is common in dogs and cats throughout Asia and an emerging public health risk in tropical northern Australia.

Hookworm larvae live in soil and typically enter humans through the soles of their feet. The larvae travel through the bloodstream and into the host's lungs and throat before latching on to the small intestine. Hookworm eggs are expelled with the feces of the host. Symptoms often include stunted growth, anemia, digestive problems and bloating, and desire to eat dirt. While extensive control efforts reduced the prevalence of hookworms within the U.S. regions in the south east that have poor sanitation are still known to have hookworm outbreaks.



Nector americanus is a common hookworm in many parts of the world but infection is currently very rare in the U.S. Occasional small outbreaks still occur but It was widespread in the southeastern U.S. until the early 20th century.

Ancylostoma caninum**,** a hookworm that infects dogs, was responsible for a recent case of eosinophilic enteritis in Louisiana.

Ancylostoma braziliense infects both cats and dogs and causes cutaneous larva migrans (skin infection). It is found in the tropics/ subtropics, including the Gulf Coast of the U.S. It also common on Caribbean tropical beach resorts. *Ancylostoma* can be transmitted orally, through the penetration of the skin (broken or unbroken skin)and probably transplacentally. (Peter J. Hotez, *Tropical Infectious Diseases,*3rd Ed., 2011) (skin infection photo: pathologyoutlines.com) (photos *Nector* and *Ancylostoma:* stanford.edu website)

Entry through skin: Before the hookworms can adhere to the small intestines they must gain entry to the body. The most common area of the skin penetrated by hookworm larvae is the feet (bare feet). Many individuals will have an allergic reaction at the site of entry. The reaction is called ground-itch and it is common in individuals infected with *N. americanus.* Additionally, a cough and inflammation in the lungs (pneumonitis) may occur as the larvae breach the alveoli within the lungs and travel up the trachea. The larvae are swallowed when they reach the throat. Once the larvae reach the small intestine of the host they begin to mature into adults. While most adult worms are eliminated by the host body within 1-2 years, they may live for several years. The larvae of some *A. duodenale* may become dormant within the intestines or a muscle and reactivate long after the individual thought the infection was cleared.

Oral Entry: When *A. duodenale* is transmitted orally, the early reaction to the larvae may cause nausea, vomiting, sore throat, a cough, difficulty breathing, and hoarseness. These symptoms, when caused by *A. duodenale,* are called Wakana disease. Eosinophilic enteritis has been associated with *A. caninum* following oral ingestion of larvae. The CDC has stated it may be possible to transmit the *A. duodenale* infection from mother to child via the transmammary route. Recent research with animals has confirmed that the infective larval stages of helminths, especially nematodes, are transmitted via the mammary glands and it is more common than suspected.(53)

"Recently, more attention has been given to other important outcomes of hookworm infection that play a large role in public health. It is now widely accepted that children who suffer from chronic hookworm infection can suffer from **growth retardation as well as intellectual and cognitive impairments**. Additionally, recent research has focused on the potential of adverse maternal-fetal outcomes when the mother is infected with hookworm during pregnancy".(54)

Chronic, heavy-infestation of adult hookworms in the small intestine is associated with intestinal blood loss, iron deficiency, protein malnutrition, diarrhea, and intestinal pain or discomfort. "Malnutrition is common to all soil-transmitted helminth (STH) infections although particular species are associated with specific nutrient deficiencies. For example, **hookworm is strongly associated with anemia caused by iron deficiency** because hookworms suck blood from the intestinal mucosa and secrete anticoagulants to prevent clotting". (Martin Walker, María-Gloria Basáñez, Ascaris: The Neglected Parasite, 2013)

Hookworm infections are diagnosed by identifying the eggs from a stool sample. The egg is unsegmented or in an early segmentation stage when passed with the feces. It is rare to find free larvae in the stool. Eosinophilia (elevated eosinophils) is a common immune reaction when an individual is infected with hookworms. Eosinophils are disease-fighting white blood cells and when they are elevated it most often indicates a parasitic infection, allergic reaction, or cancer.

NOT ALL hookworm infections go beyond the skin. Cutaneous larva migrans is a parasitic skin infection caused by hookworm larvae that usually infect cats and dogs. Humans can be infected with the larvae by walking barefoot on sandy beaches or soil contaminated with animal feces.

Trichuris trichiura, is called a **whipworm** because of its shape. The anus end is wide and the “mouth” end is slender. The size of the whipworm varies from 3 to 5 cm (1 to 2 inches) and the female is usually larger than the male. Infection (trichuriasis) is primarily acquired through fecal-oral transmission and may involve the cecum, appendix, colon and rectum.

Humans become infected via the fecal-oral route, by ingesting contaminated soil, food or water containing Humans are the only known hosts of *T. trichiura* and their eggs are released in human feces. The amount of eggs that enter the body through the mouth determine the worm burden in an individual. As with most soil-transmitted helminth infections, children aged 3 to 9 years are the most vulnerable. In the United States and Europe, mentally handicapped children in institutions have a high risk of infection.

Female worms typically reside in the cecum (the small pouch between the small and large intestines) and lay over 3,000 eggs per day (up to 20,000 per day). The eggs hatch in the small intestine releasing the larvae that will mature and inhabit the cecum and ascending colon. The whipworms establish themselves by latching onto the intestinal mucosa which can lead to rectal bleeding and abdominal pain. The host’s immune response includes the release of eosinophils, lymphocytes and plasma cells.

Following excretion, fertilized *Trichuris* eggs will mature into an embryonated infective stage, which, if consumed by a susceptible person will establish a new cycle of infection. Excreted eggs that were not fertilized before elimination with the feces are are not infective. It has been estimated that 600–800 million individuals are infected. Only 10% of infected individuals clear parasitic symptoms so the estimate is likely much higher.

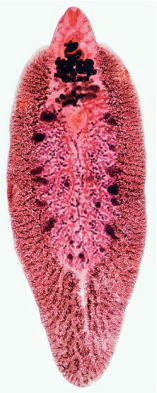
Trichuriasis is considered a neglected tropical disease by the World Health Organization and the Centers for Disease Control and Prevention (CDC). In parts of Asia and Africa where sanitation conditions are lacking, the prevalence of whipworm is very high. In the United States, whipworms thrive in the warm and moist environment of the southern Appalachian Mountains and in rural Louisiana. Individuals are also at risk when they travel to Brazil, Costa Rica, and other popular vacation areas in the tropics and subtropics.

“The whipworm tends to be more resistant to treatment than other helminths, with some studies listing **cure rates as low as 28% to 36%**. Whipworms can still be present after treatment however it is thought that a low worm count leads to no significant disease burden. While the worm is not fatal, it can cause anemia and nocturnal stooling. Many patients develop **colitis and malabsorption**. Deficiencies of fat soluble vitamins are not uncommon. Children may have growth retardation and rectal prolapse.”(55)

Parasite Focus: Trematodes

Also known as flukes, trematodes are a group of parasitic flatworms. S*chistosoma* species consist of male and female flatworms that infect humans by penetrating the skin. The other species of flatworms are hermaphrodites and infect humans when their eggs/larvae are ingested.

Tremotodes belong to the phylum Platyhelminthes. Platyhelminthes literally means “flatworms”. As a group, trematodes are found worldwide but the highest prevalence is in Asia. Approximately 70 trematode species have been known to infect the human intestinal tract. Trematodes have prominent oral and ventral suckers to help maintain their position in the intestines.



“Free-swimming larvae (cercariae) are given off by infected snails. These either penetrate the skin of the human definitive host (**schistosomes**) or are ingested after encysting as metacercariae in or on various edible plants or animals (**all other trematodes**). After entering a human the larvae develop into adult males and females (**schistosomes**) or hermaphrodites (**other flukes**), which produce eggs that pass out of the host in excreta. These eggs hatch in fresh water into miracidia which infect snails…The distribution of flukes is limited by the distribution of their snail intermediate host. Larvae from snails infect a human by penetrating the skin (**schistosomes**) or by being eaten (**encysted larvae of other trematodes**).”(58)

Human’s acquire trematode infections primarily from raw or under-cooked infected fish, crayfish, crabs, shrimp, lobsters, and aquatic plants contaminated with the larval stages of the parasite. Although most trematodes cause mild infections, severe human disease can occur when infected with species from the genera S*chistosoma, Fasciola, Clonorchis, Opisthorchis*, *Fasciolopsis,* and *Paragonimus*.

Schistosoma (blood flukes)

Schistosomiasis (shi·stuh·sow·mai·uh·suhs) is a parasitic disease caused by blood flukes from the genus *Schistosoma*. There are five species that can infect humans but the three most common are *S. japonicum, S. mansoni,* and *S. haematobium*. Common names for the infections include Bilharzia; Katayama fever; Swimmer's itch; Blood fluke; Snail fever

Schistosoma japonicum worms and eggs have been found in many different animals such as cattle, dogs, cats, rodents, pigs, horses, and goats. The distribution of *S. japonicum* includes the tropical and subtropical regions China, Taiwan, the Philippines, and Asia. It is estimated that at least 90% of those requiring treatment for schisto-somiasis live in Africa however, schistosomiasis is a major public health problem in 52 endemic countries. ***Schistosoma mansoni*** is primarily a human parasite but in endemic areas wild primates may become infected. The distribution of *S. mansoni* is Africa, the Middle East, the Caribbean, Brazil, and Venezuela.

Schistosoma mansoni and *Schistosoma japonicum* must have a freshwater snail (not all species of snails) and a vertebrate host to survive. Freshwater snails live in lakes, streams, ponds, and ditches. Snails are not natural reservoirs for trematodes and the infection has negative consequences. Infection is transmitted to snails when *Schistosoma* eggs from feces contaminate the water. When the egg hatches in the water a miracidium, covered in cilia and able to swim, is released. The miracidium penetrates the snail and reproduces asexually. The offspring are called cercaria which look like tiny (200 micrometers long) flatworms with a tail. They leave the snail in search of a new host.

Humans are infected when they enter the contaminated water and the cercaria penetrates their skin and travels through the bloodstream to the mesenteric venules that surround the intestines. Within the venules, they will feed, mature, and produce eggs. A mature worm is about 15 mm (1/2 inch) in length and each worm pair will produce over 300 eggs per day. *Schistosoma* eggs must then migrate from the mesenteric vessels, across the intestinal wall and into the feces.(59) Eggs that become trapped in body tissues cause immune reactions and damage to organs. Symptoms are not caused by the worms. Symptoms are the result of the body's immune response to the eggs.

Fever, cough, eosinophilia, abdominal pain, diarrhea, and blood in the stool are associated with acute and chronic symptoms. Heavy infestations and/or chronic infections may lead liver, spleen, brain and spinal cord granuloma lesions. A granuloma is a group of macrophages (immune cells) that form "a wall" around a foreign substance or organism that it is unable to eliminate.

An estimated 120 million people worldwide have symptomatic schistosomiasis, 20 million have a severe clinical infection. There are more than 200,000 deaths per year just in sub-Saharan Africa. Many infections are asymptomatic when the worm/egg load is light.

Africa, the Middle East, Corsica (France) are areas where outbreaks of ***Schistosoma haematobium*** occur the most often. *S. haematobium* do not use snails as a host for part of their life cycle, **humans are the only host needed for them to survive.** Human feces containing the eggs contaminate water and continue the cycle. *S. haematobium* have an affinity for vesical venules, the venous network around the bladder, and infection may result in fibrosis or cancer of the bladder. Women may develop genital lesions, vaginal bleeding, and vulva nodules and men may develop various diseases of the seminal vesicles and prostate. Other organs that may be affected include the rectum, intestines, kidneys, liver, heart, and lungs. Fever, chills, swollen lymph glands, "swimmer's itch" where the parasite entered the body, diarrhea, painful urination, and blood in the urine are all possible symptoms.

Schistosomiasis is not usually seen in the U.S. Cases typically involve travelers returning home or when an infected person migrates to the U.S. "With the rise in eco-tourism and travel "off the beaten track", increasing numbers of tourists are contracting schistosomiasis. At times, tourists present severe acute infection and unusual problems including paralysis." (World Health Organization)

Liver Flukes

There are three major types of liver flukes that infect humans: *Clonorchis sinensis*, various *Opisthorchis* species, and the *Fasciola* species *hepatica* and *gigantica*.

Clonorchis sinensis and ***Opisthorchis spp.*** have similar life cycles that require three different hosts: a mammal, a snail, and a fish or crustacean (lobster, crab, shrimp, etc.) In humans, the adult worm resides in the biliary tree (liver, gallbladder, and bile ducts) where they produce up to 2500 eggs per day. The eggs exit the body with the feces and when they contaminate a fresh water source, freshwater snails will ingest them. Inside the snail the eggs hatch and go through various growth stages until they are cercaria. Cercaria are able to "swim" and penetrate the skin of a fish (or crustacean) and migrate to the muscles/meat. After the cercaria reach the fish muscle/meat they will encyst and are able to survive in that state for at least one year. When the infected raw or under-cooked freshwater or brackish-water fish are eaten by a human the cycle restarts.

Individuals infected with only a few of the flatworms are usually asymptomatic. Infection with several flatworms can result in skin rashes, pain in the liver area (upper right abdominal area), a high fever, lymphatic swelling, and muscle pain may develop. A heavy infestation may obstruct the liver and cause jaundice, cirrhosis of the liver, and cholangiocellular carcinoma.(60) Chronic infection symptoms include abdominal pain, enlargement of the liver, and weight loss.

Occasional cases in the U.S. occur due to consumption of imported fish. *C. sinensis* is widely distributed in Thailand, China, Korea, and other surrounding areas. Japan was a heavily infected area until the 1960s. (photo: Anisakis worm in fresh salmon)

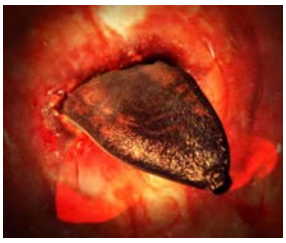
Fasciola hepatica is another liver fluke but it not transmitted to humans through undercooked fish and crustaceans. The lifecycle of of *F. hepatica* is similar to *Clonorchis* and *Opisthorchis* but instead of a fish or crustacean host the cysts attach to aquatic plants. Infection occurs when an individual consumes an infected aquatic plant such as watercress or parsley. Infection is also possible if a person drinks contaminated water or uses it for irrigation and does not wash the produce. *F. hepatica* also infects animals like cows and sheep.

While the acute phase of infection is usually asymptomatic, within a few weeks the larvae will migrate through the liver and my cause abdominal pain, a cough, skin rashes, and fever. Chronic infections can last for several years with abdominal pain, fatty food intolerance, nausea, jaundice, itching, and intestinal discomfort symptoms.

Some cases of fascioliasis have been documented in Hawaii, California, and Florida. However, most reported cases in the United States have been in immigrants and those who have traveled to countries where fascioliasis is common.

Lung Flukes

Paragonimusare westermani is the most common lung fluke out of the eight parasitic lung flukes within the genus of *Paragonimusare*. The lung flukes are endemic to China, Korea, Japan, Siberia, Mongolia, Taiwan, and the surrounding areas. Infection occurs when an individual consumes **raw or pickled crabs and crayfish**.



Lung flukes inhabit the cystic cavities in the human lung and produces eggs. The eggs come up with the sputum when a person coughs or are passed with the feces. When the eggs reach fresh water they will hatch and invade a suitable snail host. Like the liver flukes, the lung flukes will exit the snail and search for the next host. *P. westermani* will search for a crustacean of the crab or crayfish family and encyst inside their muscle/meat.

Symptoms of infection include a chronic cough, coughing up blood, and the production of brown sputum. Chest pain and shortness of breath are common. Pulmonary paragonimiasis is often misdiagnosed as pneumonia, tuberculosis, or lung cancer.(61) Acute infections are often asymptomatic but may include abdominal pain, diarrhea and a skin rash. The lung fluke has demonstrated extrapulmonary migration by moving to the central nervous system but it is rare.

Intestinal Flukes

Worldwide there are approximately 70 species of intestinal flukes that are known to infect humans. Two trematode families, the *Heterophyidae* and the *Echinostomatidae,* contain over half of species that infect humans and are well-known as fishborne/ foodborne parasites in many parts of Asia and India. *Fasciolopsis buski* belongs to the *Echinostomatidae* family and is commonly called the giant intestinal fluke.

Most intestinal flukes are found in raw fish but, *Fasciolopsis* cysts latch onto aquatic plants. Humans (and pigs) become infected when they eat raw aquatic plants that have *Fasciolopsis* cysts attached to them.

Fasciolopsis buski infection occurs after the individual consumes the contaminated vegetation and the cysts release the larvae within the intestines. The larvae will migrate and attach to the mucosa of the small intestine and mature. *Fasciolopsis* adult worms are 20 to 75 mm long (approximately 1-3 inches) and produce over 25,000 eggs every day. When an individual has a heavy infestation the worms may be found in the stomach and lower intestines in addition to the preferred area of the small intestine.

Heavy infestations may cause alternating diarrhea and constipation, epigastric pain (pain just below your ribs), nausea, vomiting, intestinal obstruction, and mucosal injury. The metabolites produced *F. buski* are absorbed in the intestines and can cause generalized edema, especially in the face. The duodenum and jejunum of the small intestine are severely affected from the worms attaching to the mucosa. Extreme inflammation of the mucosa can lead to ulceration and abscess formation. Leukocytosis and peripheral eosinophilia are also frequently associated with fasciolopsiasis.

(Gregory Lauwers, Richard L. Kradin, in Diagnostic Pathology of Infectious Disease, 2010)

FDA: Parasites (https://www.fda.gov/media/80777/download)

"Parasites (in the larval stage) consumed in uncooked or undercooked seafood can present a human health hazard. Among parasites, the nematodes or roundworms (*Anisakis spp., Pseudoterranova spp., Eustrongylides spp.,* and *Gnathostoma spp*.), cestodes or tapeworms (*Diphyllobothrium spp*.), and trematodes or flukes (*Chlonorchis sinensis, Opisthorchis spp., Heterophyes spp., Metagonimus spp., Nanophyetes salmincola,* and *Paragonimus spp.*) **are of most concern in seafood**.
Most of these parasites cause mild-to-moderate illness, but severe symptoms can occur…Some products that have been implicated in human parasite infection are the following: ceviche (fish and spices marinated in lime juice); lomi lomi (salmon marinated in lemon juice, onion, and tomato); poisson cru (fish marinated in citrus juice, onion, tomato, and coconut milk); herring roe; sashimi (slices of raw fish); sushi (pieces of raw fish with rice and other ingredients); green herring (lightly brined herring); drunken crabs (crabs marinated in wine and pepper); cold-smoked fish; and, undercooked grilled fish.
A survey of U.S. gastroenterologists confirmed that seafood-borne parasitic infections **occur in the United States with sufficient frequency to recommend preventive controls** during the processing of parasite-containing species of fish that are intended for raw consumption."

Parasite Focus: Cestodes

Cestodes are hermaphroditic and commonly known as parasitic tapeworms.They cycle through three life stages: eggs, larvae, and adults. The adult tapeworms inhabit the intestines of definitive hosts, mammalian carnivores. The intermediate hosts for tapeworms that primarily affect humans are fish, cattle, and swine.

Tapeworms are well known for the enormous lengths they can reach. The whale tapeworm can grow to 130 ft in length with as many as 45,000 segments. During their normal life cycle, tapeworms shed large parts of their body and then regenerate to maintain a certain length.It is unknown how they accomplish regeneration.Adult tapeworms are multi-segmented flat worms that lack a digestive tract and absorb nutrients directly from the host's small intestine.

Tapeworms have 3 recognizable segments:

- The scolex (head) is an anchoring organ that attaches to intestinal mucosa.
- The neck is an unsegmented region with regenerative capacity. If treatment does not eliminate the neck and head, the entire worm may regenerate.
- The rest of the worm consists of numerous segments called proglottids. Some proglottids can develop hermaphroditic sex organs and others contain eggs in a uterus.

The most common tapeworms include:

- Fish tapeworms from the *Diphyllobothriidae* family
- Pork tapeworm *Taenia solium*
- Asian tapeworm *Taenia asiatica* (pork tapeworm)
- Beef tapeworm *Taenia saginata*

There are two types of infections that can develop from tapeworms depending on the route of infection. The two routes of infection are:

- The ingestion of eggs from an adult tapeworm (expelled in feces)
- The ingestion of cysticerci (eating under-cooked meat from an infected animal).

Ingesting the **eggs** from an adult worm (expelled in animal or human feces) results in developing cysticerci (larval stage) within the animal or human tissues. This is known as **cysticercosis**. If these cysticerci migrate to and develop in the central nervous system, its is called neurocysticercosis.

Ingesting the **cysticerci** themselves, from under-cooked infected meat, results in the growth of an adult tapeworm within the upper small intestine. The infection is called **taeniasis** if from the *Taenia* family of pork parasites or **diphyllobothriasis** if infected by *Diphyllobothrium fish parasites.*

Adult pork and beef tapeworms residing in the small intestine do not provoke a strong immune system response. The result is primarily mild non-clinical symptoms in adults. Children tend to develop more severe, or noticeable symptoms. When *Taenia* species attach to the mucosa of the upper small intestine using their suckers and hooks, it only causes mild inflammation and very little damage to the intestine.(62)

Diphyllobothriasis is an intestinal infection caused by the fish tapeworm *D. latum*. The infective larvae, plerocercoid, reside in the muscles/meat of trout, perch, burbot, salmon, pike, whitefish, and sea bass. When an individual ingests the infected and under-cooked fish, the larvae attach to the mucosa of the small intestine. Within about 6 weeks the larvae will have developed into an egg laying adult . Adult *D. latum* worms can grow to a length of 32 feet!. While not all of them will grow to that length, they are the largest tapeworms that can infect people. Despite its size, *Diphyllobothrium* infections are often asymptomatic or mild. “One in five infections may have diarrhea, abdominal pain, fatigue, constipation, pernicious anemia (B12 deficiency), and less commonly headache and allergic reactions.”(63).

“Diphyllobothriasis is regularly observed in cold climate areas, such as northern Europe and northern America. In Japan, salmon and trout have been commonly served as sushi and sashimi, and >100 cases are now recorded annually in the northern part of the country. Together with the development of a chilled transportation system, this disease is spreading all over Japan”.(63) In Japan, *Diphyllobothrium nihonkaiense*, is responsible for most of the fish tapeworm infections. The diagnosis is mainly based on the detection of ova or proglottids in the feces.(64)

Humans infected with the *Diphyllobothrium* tapeworm will excrete eggs with their feces. When the eggs in the feces are allowed to contaminate water (poor hygiene or lack of appropriate sanitation), they will hatch. The larvae are consumed by small crustaceans and then the crustacean is ingested by the fish. *Diphyllobothrium* may live for 20 years in the human host and continue to pass eggs through their lifetime. The species typically prefers the cold water and infections are mostly reported in Asia, Europe, Russia, and North America.

The reproductive cycle of *Taenia* species are similar to *D. latum*. Eggs are expelled in animal or human feces and contaminate the water and vegetation that cattle or swine ingest. When eggs, or worm segments, are ingested by a cow or pig they will penetrate the intestinal wall and migrate to various muscles or other tissue and develop into cysticerci. If an individual ingests under-cooked pork infected with *T. solium* cysticerci or beef infected with *T. saginata* cysticerci, it will result in an adult egg-laying tapeworm in the intestines.

Ingestion of cysticerci only causes taeniasis, an intestinal adult tapeworm. Infection with the adult tapeworm is most commonly asymptomatic however, many report anal pruritus (itching) from the escaping worm segments and mild abdominal pain. “Most patients become acutely aware of the infection by noting the passage of proglottids in their feces”.(63)

Ingestion of the eggs causes cysticercosis (fecal-oral route, autoinfection). *Taenia* eggs hatch in the small intestine and the larvae migrate to various tissues in body. The preferred destination is striated muscles but they may also migrate to eyes and central nervous system/brain. Cysticercosis symptoms are usually mild when the cysts are residing in muscle tissue but they may cause subcutaneous nodules (picture).If the larvae migrate to the central nervous system/brain the infection is called neurocysticercosis.

Neurocysticercosis symptoms depend on the location of the brain lesions and can mimic many neurological disorders. Symptoms may include cognitive decline, seizures, speech, hearing, and speech, intracranial hypertension, involuntary movements, and mini-stroke symptoms. Neurocysticercosis is not an infectious disease. “Only the tapeworm carriers and the infected pigs are important in terms of transmission. Individuals with neurocysticercosis are a health concern; but unless they also carry an intestinal tapeworm, they do not pose a public-health risk.”(62) Due to diagnostic limitations, the prevalence of neurocysticercosis is likely under-diagnosed.

”Neurocysticercosis (NCC) is typically considered a disease of the developing world. Nonetheless, NCC is also diagnosed in the developed world. The rise in the number of cases of NCC in developed countries, especially in the United States of America, has largely been driven by the influx of immigrants from endemic to non-endemic regions and the widespread access to neuroimaging. Cases of local transmission have also been documented particularly in the setting of a tapeworm carrier present in the household, which highlights the relevance of NCC as a public health problem in the USA.”(65)

Except for *Taenia asiatica,* the pork tapeworm commonly called the Asian tapeworm, the *Taenia* species have a worldwide distribution. *Taenia solium* has been "effectively controlled" in most of Europe, North America, and Australia while the highest prevalence is found in Africa, Asia, Latin America, East Europe, China, Pakistan, and India.(63) Effective control of the infection relies on education measures that include personal hygiene and proper santiation (washing hands, not defecating in fields or areas where cattle or pigs eat or around produce, appropriate care of feed lots, etc.). Worldwide there are hundreds of millions of human infections.

"Taeniasis due to *T. saginata* is rare in the United States, except in places where cattle and people are concentrated and sanitation is poor, such as around feed lots where cattle can be exposed to human feces. Tapeworm infections due to T. solium are more prevalent in under-developed communities with poor sanitation and where people eat raw or undercooked pork." (CDC.gov) Southern and Eastern Africa have the highest prevalence *T. saginata* infections.

Transmission of *Taenia* parasties occurs mainly in rural areas where pigs are exposed to untreated human sewage/feces. In the U.S., controlled domestic pig farms and sanitation requirements have eliminated or greatly reduced most parasitic issues in pigs. While huge pig-farm operations do have many drawbacks, they have successfully reduced parasites within the swine population.

Herbal Formulas and Homeopathics for Parasites

There are several herbs known to expel and/or kill parasites of all forms. A quick internet search or look through our herbal books brings up several common and long-used remedies: Black Walnut hulls, Pumpkin Seeds, Wormwood (Artemisia absinthium), Wormseed, Garlic, Rue, Peach Leaves, Clove Oil, Spigelia marilandica (pink root), Santonica buds (Artemisia santonica), Thyme, Oil of Oregano, Berbine herbs (Barberry, Goldenseal, Oregon Grape), Pau D Arco, and more.

I know very few natural health professionals who make their own formulas - including myself. Professionals have also had enough real-life experience to know that using only one herb, regardless of its reputation, is just not good enough. Another misconception is that probiotics can kill off intestinal and systemic parasites. You will need a well-rounded formula to address the massive variety of parasites and their various lifecycle forms.

My preference for a parasite program is the use of a parasite herbal formula paired with a homeopathic nosode formula - I called it the **Crossfire** and it works. This is not always appropriate for children, elderly, or those who are very weak or sensitive. I also use liquid herbal formulations for better digestion and assimilation - the bowels are not in peak condition!

Very few parasites cause bowel-related symptoms. The goal is not to eliminate every parasite. The goal is to re-establish balance when there are health issues or as prevention. There are many great companies and formulas but, I can only speak for the ones I have used personally. Below are some products and what they contain so you are able to at least compare formulas if using a company that is not on this list.

Herbal Formulas For Results Include:

Core Artemisia Blend by Energetix: Black walnut hulls, wormwood aerial parts (artemisia absinthium), papaya leaf, pumpkin seed, clove bud oil, garlic clove, senna leaf, turmeric root (curcuma longa), pomegranate fruit, tansy aerial parts. *Strong, for overgrowths of all kinds. I do not recommend this for young children or weak, sensitive adults.

Para A by Marco Pharma: Black walnut hull, Wormwood aerial portion, Clove fruit, Olive leaf, Fennel seed, Citrus seed extract. *Dr. Andreas Marx of Marco Pharma used laboratory testing when developing this proven herbal formula.

Parasite Complex by DesBio: Betel nut, Fennel, Black Walnut, Pink Root, Pumpkin Seed, Senna, Wormwood, Grapeseed Extract. Other ingredients; natural licorice flavoring, glycerine. *Worked best when paired with their VER homeopathic formula.

Para-Mac for intestinal parasites by InnoVita: Cayenne Pepper, Garlic, Dog Rose, Iceland Moss, Lotus (Root), Pau D'Arco (Inner Bark) Purslane, Asafoetida (Resin), Hibiscus (Flower), Mugwart (Above Ground), Senna, Thalamus FormCodeTM, Bromelain, Mexican Tea, Betel (Nut) *I found this formula to be "gentle" and effective for the youngest and oldest and weakest clients. Also a great choice for pinworms.

Micro-Site for unicellular circulatory parasites by InnoVita: Barberry (Root Bark), Quassia (Inner Bark), Cat's Claw (Inner Bark), Pippali (Fruit), Lotus (Root), Magnolia (Bark), Senna (Leaves), Mulberry (Root Bark), Tansy (Flower), Papaya (Fruit), Thalamus FormCodeTM, Pancreas FormCodeTM, Liver FormCodeTM - this is not a stand alone formulation. Use it with an intestinal formula like the Para-Mac, Para-A, etc.

CXVRM#1 for large parasites (worms) - by Systemic Formulas: Clinical Dose of Wormseed oil and Black Walnut leaves in an herbal support blend of garlic, pau d'arco, rose hips, zapilopatle beans, jalapa, hops, bromelain, valerian, and clay. - CX stands for the very concentrated liquid form. It seems expensive but it is equivalent to 3-4 bottles of the capsules. When eliminating organisms with life cycles it is best to take this formula for 10 days and then stop for 5 days and start over until the bottle is gone (a person needs to finish 3 to 4 ten day cycles).

CHOOSE AN APPROPRIATE HOMEOPATHIC TO CREATE A CROSSFIRE.

Homeopathic Formulas For Results Include:

VER by DesBio: a nosode combination for roundworms, protozoans, hookworms, liver fluke, blood fluke, fish tapeworm, common tapeworm, whipworm, trichomonas, and trichinella. *This formula tested best for those who had liver or gallbladder issues and for those who ate pork roasts and other parts on a regular basis. It pairs perfectly with the DesBio Parasite Complex, CXVRM#1 by Systemic Formulas, Para A by Marco Pharma, and Para-Mac by InnoVita.

Bowel Pathogens by Professional Formulas: Acanthocephala worms, Amoeba, Annelida worms, Ascarides, Botulinum, Campylobacter, Citrobacter, Clostridium perfringens, Cryptosporidium, Diphtheria coccinum, Enterococcinum, Escherichia coli, Giardia lamblia, Nemathelminthes worms, Platyhelminthes worms, Blastocystis hominis. *This formula tested best for those who had bowel issues of any kind, several antibiotics in their lifetime, struggled with candida, or have traveled outside the country. It pairs very well with Core Artemisia Blend by Energetix, Para A by Marco Pharma**,** and Micro-Site by InnoVita.

Parasite/Amoeba/Protozoan Nosode Combination by Professional Formulas: Amoeba, Toxoplasmosis, Malaria, Eucalyptus, Belladonna, Eupatorium Echinacea. *This formula tested best with those who owned cats, went swimming in lakes…a lot of children tested for this formula and I paired it with a "gentle" herbal mixture to counter bacteria and yeasts/molds (Barberry 1/4, Dandelion 1/4, Pau D arco 1/4, Peppermint 1/4). With adults this homeopathic paired well with Micro-Site by InnoVita and DesBio Parasite Complex

Pinworms combination: Nematodes homeopathic by Professional Formulas paired with Para-Mac by InnoVita.

Note: Everyone in the family should do a parasite program when worms are present in one member.

OTHER CONSIDERATIONS

* **Support should always include herbs for liver (milk thistle), blood (burdock), lymphatic (poke root) cleansing and immune system (vitamins, minerals, echinacea, astragalus..).**
* Probiotics should be used during and after the parasite formulas (multi-species formulas)
* Mineral and vitamin deficiencies should be corrected before using parasite formulas if possible.
* Digestive and Systemic enzymes will help break down the proteins and other materials from the die off. Marcozyme by MarcoPharma is an excellent systemic enzyme formula (empty stomach) and could also be used with food as a digestive.
* For best results a person should eliminate sugar, gluten, dairy.
* Absolutely NO pork products during an antiparasite program.
* Drink clean water (not tap or well water - well water is sometimes the culprit with reinfections) - Reverse osmosis installed or a water machine/delivered water.

After a parasite "cleansing" program a person still needs to heal the damage done to the intestinal walls, reduce the systemic inflammation from the immune action in the body, and address bacteria, viruses, mycoplasmas, yeasts/molds…co-infections.

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