

Description of the microbe

Toxoplasma Gondii is a single-celled parasitic protozoan that belongs to the phylum Apicomplexa and is the only species in the *Toxoplasma* genus. It was not until 1970 that this protozoan's life cycle was discovered. This parasite has a complex life cycle as it contains both asexual and sexual phases and requires two different hosts in order to complete its full development. The two different types of hosts are defined as "definitive" or "intermediate." Definitive hosts are where the parasite will reproduce and form eggs known as oocysts. Intermediate hosts are where the parasite will replicate and cluster inside of cysts. The primary definitive host for the sexual reproduction phase is typically a member of the Felidae family. When a cat eats prey that has been infected with these cysts, the parasites will be released into the feline's digestive tract where it will then create the oocysts. These oocysts are excreted along with the feces and can survive in the environment for over a year. However, these passed oocysts are not immediately infectious as they must first undergo sporulation which can take 1-5 days. Once an intermediate host consumes a sporulated oocyst, the infection presents itself as the formation of tissue cysts all over the body. These tissue cysts will then remain in the body of the intermediate host for the rest of its life.

Metabolic capabilities

Toxoplasma gondii can infect any warm-blooded animal which highlights how adaptable this protozoan is in its metabolism and ability to acquire the nutrients necessary for survival. There is currently no experimental approach in existence that would help us fully understand the necessary substrates present in a host cell needed for replication. However, the experiments that are currently available have shown that *T. gondii* has the capability of making several important biomass precursors such as certain nucleotides, fatty acids, and about half of its necessary amino acids. When provided with the materials needed to make the rest of the

biomass constituents, it was still unable to fully produce them on its own. (Tymoshenko et al., 2015) This suggests that the parasite relies on the host for the rest of these products.

Evolutionary history

Although toxoplasmosis is found all over the world, South America has a high amount of cases in comparison. The true geographical origin of this pathogen is still unknown, but phylogenies were created as a way to develop an estimate of the most recent common ancestor and create an inference of this protozoan's origin. A world wide sample of *T. gondii* was isolated and based on its genes, it is believed that around 1.5 million years ago this strain had evolved from a South American ancestor. This is a lot earlier than the emergence of an ancestral strain of *T. gondii* which is believed to have emerged around 11 million years ago and quickly follows the arrival of felines in this part of the world. As the cats began to adapt to eating meat in this area, it allowed the new strain to outcompete the old strain and undergo a worldwide spread. (Bertranpetit et al., 2017)

Discussion of infection mechanisms

When a human is infected by an oocyst, they can develop toxoplasmosis. There is typically a higher rate of infection in areas with hot and humid climates as this is a preferred environment for the toxoplasma parasite. Toxoplasmosis can only be transmitted from one person to another in the case of mother to unborn child, blood transfusion, or during an organ transplant. (Galal et al., 2019)

The typical mode of transmission for this parasite is food borne. Consuming contaminated undercooked meat such as pork, lamb, or shellfish or failing to wash your hands after handling the contaminated meat can cause you to become infected. Toxoplasma cannot be absorbed through intact skin, so the contaminant must be consumed in order to cause harm.

Another mode of transmission for this parasite is zoonotic, which is the transmission from animal to human. As previously stated, cats play a crucial role in the reproduction of *Toxoplasma Gondii*, but they can also play a part in the spread of the parasite. The oocysts that develop in the cat's intestinal tract are microscopic and can not be seen by the naked eye. These oocysts are then shed by the millions in their feces. If an outdoor cat were to defecate in a vegetable garden, a water source, or if the owner did not properly wash their hands after cleaning the litter box, then the shed oocysts can accidentally be consumed.

Symptoms

Everyone has the same chance of being infected with Toxoplasmosis, however those with healthy immune systems are more likely to be asymptomatic. Those who are immunocompromised are more at risk and are more likely to show symptoms which can range in severity. (Wang, Huang 2015) The typical symptoms of toxoplasmosis include swollen lymph nodes, muscle aches, and other flu-like symptoms. However, severe toxoplasmosis can cause lasting damage to the eye, brain, and other organs. If the toxoplasma parasites infect the tissue of the inner eye, then it is referred to as ocular toxoplasmosis. Symptoms of ocular toxoplasmosis can include pain in the eye, blurred vision, and floaters. Floaters are little specks or clumps that can appear in your vision. If this were to go untreated, then it can ultimately lead to blindness. If the parasites infect neural tissue, then this can cause swelling of the brain, referred to as encephalitis. Symptoms of this can include: confusion, weakness of the muscles, poor alertness, and even seizures.

Congenital toxoplasmosis is when toxoplasmosis is passed on from the mother to the fetus during her pregnancy. The disease is typically more severe if the infection occurs during the first trimester. Medical issues that may be present at birth include: hydrocephalus, severe infection of the eye, abnormal brain tissue, and an enlarged liver. More severe symptoms can include motor skill issues, issues with vision or hearing, heart disorders, or jaundice. If a baby is

infected with toxoplasmosis, it is also possible for them to not show any symptoms at birth, but develop medical issues later in childhood. Eye infections can return, hearing loss can develop, growth can be slowed, and this could even result in early onset puberty. (Mosawi et al., 2019)

When the protozoan infects a rat and creates cysts in the brain, the parasite will latently live in this host for the remainder of the host's life. It has been observed that the cysts tend to be more abundant in the amygdalar structures than in other regions of the brain. (Wana et al., 2023) The amygdala of the brain is responsible for processing emotions and triggering the "fight or flight" survival reaction. When these cysts form, they are able to alter the rat's behavior and change their innate aversion to the smell of cat urine to an attraction. The infected rats also displayed reduced anxiety and increased expression of Indoleamine 2,3-Dioxygenase, or IDO. IDO is responsible for ensuring the immune system does not over respond to threats by breaking down Tryptophan. Increased expression of this gene could be linked to the parasite's survival as it suppresses the immune system. The studies done in the rats implies that infection in humans would have the same effect. (Wana et al., 2023)

Epidemiology

According to the CDC, about 11% of Americans over the age of 6 years old, have had a *Toxoplasma* infection. In many other places around the world, this number is much higher, especially in places with less stringent sanitation and food safety practices. *Toxoplasma Gondii* is considered to be the most common protozoan parasite in developed countries and can be found worldwide, except for Antarctica. While it is not yet fully understood, there are different strains of *Toxoplasma Gondii* that vary depending on where you look in the world. (Gala et al., 2019) Since *Toxoplasma Gondii* can infect any warm-blooded animal species, this provides the protozoan with a multitude of ecological niches in wildlife. This large amount of host diversity exposes the parasite to different selection pressures which results in significant genetic diversification.

Treatment

Once a person is infected by the *Toxoplasma* protozoan, there is no way to completely eliminate the infection from the body. Active infection is characterized by tachyzoites, which are the asexual forms of the parasite that invade the host cells, while latent infections are characterized by cysts in the tissue. There are very few reviews published on the treatment of *Toxoplasma* in both humans and in vivo models. Current treatments for Toxoplasmosis target the active stage of infection as there is no treatment for the latent stage. The most effective therapy involves the combination of the two antimicrobials, pyrimethamine and sulfadiazine, but there are still high failure rates. In September of 2015, the price of pyrimethamine increased by over 5,000% by the sole manufacturer for the United States. In other areas of the world, the price of one pill is still less than \$1. (Dunay et al., 2018) This demonstrates the unethical monopoly that pharmaceutical companies can have in the United States.

Prevention of infection

There are several ways in which you can prevent infection of this protozoan. You can wear gloves when you garden and thoroughly wash your hands after working with the soil. You can thoroughly wash your kitchen utensils, fruits and vegetables before consumption. Stay away from eating raw or undercooked meat, unpasteurized goat milk, and untreated water. If there is a sandbox in your home, be sure to keep it covered when it is not in use as a stray cat may use it as a litter box. If you are a pregnant woman, then it is in your best interest to stay away from changing the litter in the litterbox.

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