Of Cats and Kids
Toxoplasmosis

We now join the journey of *Toxoplasma gondii*, of the protozoan family with a relatively simple life cycle, but with sufficient variations to provide for both wonders and woes.

First described in 1908, the genus name comes from the Greek *toxon*, meaning "arc- or bow-shaped", in reference to the unique crescent shape of the motile, trophozoite form. These are quite small, measuring 3 to 5 microns, approximately half the width of a red blood cell. We will refer to our new acquaintance simply as "Toxo".

**Tales of Wonder**

First, we must bring to center stage one of our feline friends, in particular the prized family house cat. Our tiny bow-shaped Toxo has in effect a long-term alliance with our friendly cat. As one of those wonders of nature, Toxo has exclusively selected as an ideal place to pursue its sexual desires, of all places, the epithelial cells of the feline small intestine. Where do these gametes come from?

"Nice kitty…or bad kitty?"

Most commonly, for the cat at least, from the flesh of either a mouse or a bird, that have been infected with another of Toxo's protean forms, the bradyzoites. The prefix "brady" is from a Greek word meaning "slow" or "dull". These bradyzoites represent one of Toxo's resting forms, lodged within small cysts in muscle, brain, and other tissues of a variety of mammals. Thus, when a cat gobbles up a Toxo-infected mouse or bird, the bradyzoites are released in the cat's intestine upon disintegration of the cyst wall.
With this wake up call, the bradyzoites take on a new life and transform into rapidly motile forms, called tachyzoites (“tachy” = swift, rapid, accelerated). Many of the tachyzoites penetrate through the intestinal wall and are distributed by the circulation to tissues and organs throughout the cat's body. In contrast to other members of the animal kingdom, including human beings, in whom the invasion causes infection, these tachyzoites have no observable effects on the cat, which goes merrily on its way.

Toxoplasma gondii (electron micrograph) – a protozoan parasite especially dangerous to immunocompromised hosts and infants.

The cytoplasm of the cells lining the cat intestine provide the nest within which the tachyzoites undergo sexual reproduction. Of true wonder, even in this minute fragment of nature, either "male" or "female" oriented genes are present within each individual tachyzoite. After a few days, these fully mature, sexually-oriented forms, called gametes, fuse and begin profuse proliferation, aggregating into a confined space, the oocyst. During the two to three weeks of sexual reproduction, one cat can house millions of infective forms within a host of oocysts. The numbers are staggering as each oocyst contains eight infective sporozoites.

Within four days after ingesting tissue cysts, an infected cat is capable of shedding millions of oocysts in the feces, contaminating everything within reach. Litter boxes provide a concentrated hot bed of infectivity; or, the seeds are spread to the wide-open spaces during feral escapades. Grazing herbivores, particularly sheep, and inadvertently human beings are infected through the ingestion of these oocysts. Oocysts may be hiding under the leaves of unwashed vegetables or firmly attached to fingers contaminated from the last clean-up of the litter box. Thus, as loved and tame as this cat or kitten may appear, innocently purring while being petted while lying in the lap of a loving child, underneath is an instinctual mean streak that has one eye always open for the possible trespass of a quickly moving mouse, bird, or other animal delectable.

Toxo is less selective in its proclivity to utilize a variety of host animals for replication of its sexual forms. A recent survey of 47 Illinois farms revealed the following list and percentage infected of Toxo's reservoir hosts: cats (68.3%), raccoons (67%), skunks (38.9%), opossums (22.7%), rats (6.7%) and mice (2.2%). Even though our friendly mouse was found lagging in incidence behind the rest, cats don't normally eat other cats, raccoons, skunks, or opossums; therefore, the Toxo-infected mouse, or a ground-feeding bird in the back yard still provides the main source of infection for our wily house cat.

Toxo the Insurgent

Bradyzoites remain dormant within the tissue cyst as long as the infected host has a sufficient level of immunity—as long as the "security system" is in place. If immunity begins to wane, either through advancing age, through the emergence of a secondary disease, such as AIDS, or through the administration of immune suppressive agents, (for example, as part of a post-organ transplant protocol), the bradyzoites suddenly awaken, crash through the deteriorating cyst wall, and enter the circulation as tachyzoites. Reactivation disease may thus result.

Cerebral toxoplasmosis lesions in an HIV/AIDS patient.
What barriers must tachyzoites overcome after ingestion and release in the new host intestine from a disintegrating cyst? The mucous membrane lining the intestine presents a formidable barrier. The walls of intact blood vessels and an immediate antibody response represent challenges that a recently released tachyzoite must also overcome. Insurgent tachyzoites ultimately breach these barriers, and begin to carry out their disease-producing activities, either individually, or in consort with a host of fellow provokers. Collectively they can cause considerable morbidity and even mortality. Even after gaining refuge within an infected cell, the tachyzoite must still withstand the outpouring of lysosomal enzymes as a last means of host protection.

Tales of Woe

Invading tachyzoites cause death of the parasitized cell leading to a vigorous acute inflammatory reaction in the surrounding tissue. Flu-like symptoms may follow, lymph glands either singly or collectively may enlarge, and muscle aches and pains may last for a few days to several weeks. An individual with a weakened immune system may develop progressive disseminated disease involving the lungs, heart, brain, and muscles. In chronic disease, the only symptom may be painless swelling of the lymph glands, often of a single lymph node, with or without fever. Luckily, the majority of people infected are free of immediate symptoms and death is an uncommon complication.

Congenital infections top the list of "woes". Although transplacental infections comprise only a small percentage of mothers with toxoplasmosis, severe disease may result. Once through the placental barrier, invading tachyzoites may cause spontaneous abortion, a stillborn child, or a child that is born with varying degrees of mental or physical retardation. Pregnant women are advised to minimize contact with cats, particularly with the litter box, and curtail ingestion of steak tartar or other raw or poorly cooked meat. This is good advice.

Toxo and the Psyche

Perhaps of more interest are recent accounts linking Toxo with a variety of psychological disturbances, both in humans and in animals. Individuals who are sero-positive for Toxo have a higher incidence of schizophrenia than those who test negative. Adults who have schizophrenia or bipolar disorder were found to have had a greater exposure to cats in childhood.

In one study, a significantly higher percentage of persons affected with schizophrenia had owned a house cat between early childhood and age 13, as compared to matched controls. "Adults who have schizophrenia or bipolar disorder were found to have had a greater exposure to cats in childhood."

"Whether any geographic association exists between the prevalence of toxoplasmosis and the prevalence of schizophrenia is unknown. France, with a high prevalence of Toxoplasma-infected persons, was reported to have first-admission rates for schizophrenia approximately 50% higher than those in England. Ireland also has a high rate of Toxoplasma-infected persons in rural areas, confirmed by the high rate of infection in hospital personnel in our own study. The area of our study in Ireland has also been reported to have a high prevalence of schizophrenia."

Torrey EF, Yolken RH. Toxoplasma gondii and schizophrenia. Emerg Infect Dis, Nov 2003

Also of interest are reports from a Czech scientist, Jaroslav Flegr, of Charles University in Prague. He reports that Toxo, in its extra-intestinal infective form, "makes its host animal more reckless, more aggressive, less scared of new things and less adherent to established behavioral patterns". Changes in the personality profile of young women with latent toxoplasmosis were also observed.
“Our results suggest that the personality profiles of women with latent toxoplasmosis differ in certain factors from those of women without toxoplasmosis. Toxoplasma-positive women have higher intelligence, are more prone to guilt, are more apprehensive, self-reproaching, insecure, possibly also display higher ergic tension and radicalism.”

Jaroslav Flegr and Jan Flavlicek: Changes in the personality profile of young women with latent toxoplasmosis, Folia Parasitologica, 1999, 46:

In a separate note, Flegr also further comments:
"Women infected with toxoplasma spent more money on clothes and were consistently rated as more attractive. We found they were more easy-going, more warm-hearted, had more friends and cared more about how they looked. However, they were also less trustworthy and had more relationships with men."

"By contrast, the infected men appeared to suffer from the alley cat' effect--becoming less well-groomed, undesirable loners who were more willing to fight. They were more likely to be suspicious and jealous."

In a separate study, subjects with latent toxoplasmosis were found to have significantly increased risk of traffic accidents than the non-infected subjects. Relative risk of traffic accidents decreases with the duration of infection.

"These results suggest that 'asymptomatic' acquired toxoplasmosis might in fact represent a serious and highly underestimated public health problem, as well as an economic problem."


As an accomplice to the crime, it would appear from the previous reports that cats can no longer be pictured with halos of adoration. Feral cats primarily living in the wild are even more likely to make Toxi's acquaintance.

Use caution regarding litter boxes. Empty them at least every 24 hours, since it takes at least that long for oocysts to become infective.

Oocysts within this contaminated cat mess become infective after 24 – 48 hours. They are persistently resistant to adverse environmental conditions, and in garden soil, sand boxes, etc., can remain infective for months (perhaps years in warmer climates). Yet the cat itself is lucky. These asexual stages disappear from the cat's small intestine in about two weeks, and the cat also stops producing oocysts. Thus Toxo is "out of the bag" so as to speak, and the innocent cat, in excellent health, contently and oblivious to the danger it poses, goes about its business.

More Tales of Woe

In the United States, circulating antibodies to Toxoplasma gondii have been detected in the blood of up to 40% of individuals, indicating previous exposure and infection. In France, the prevalence rates range from 42-84%, reaching close to 100% in some locales. Similar prevalence levels may be found in neighboring European countries as well. The high population of domestic cats and the common practice of ingesting home-produced meat raw or undercooked meat are to blame. Data published by the Centers for Disease Control reveal that of deaths due to food-borne pathogens, Toxoplasma gondii ranks third in prevalence (20.7%), behind Salmonella (30.6%) and Listeria monocytogenes (27.6%).

The highest risk factors predisposing to Toxo infections are ingestion of undercooked lamb, beef, or game (30 – 62%), and contact with cat-feces contaminated soil (6 – 17%). Measures for reducing chances for infection include:

- Wear gloves when gardening or performing other tasks that involve handling soil. Cats deposit their messes in gardens and sandboxes. Even though cats, in contrast to dogs, meticulously cover their messes with a thin layer of dirt, oocysts may be lurking wherever you dig.
- Cover children's sand boxes when not in use.

- Wash hands well with soap and water after outdoor activities, and before preparing food. Hands should also be washed after handling raw meat, and immediately before eating, especially if a cat is owned.

- When preparing raw meat, all cutting boards, sinks, knives, and other utensils that might have touched the raw meat should be washed thoroughly with soap and hot water before it is fully cooked.

- Eat only cooked meat. Using a meat thermometer, one should ensure that an internal temperature of 160°F is reached, maintained for a length of time sufficient to remove the pink tinge from the center cut of meat, or until the juices become colorless.

- Cats should be fed only cooked meat or commercially prepared foods. Cat feces should be removed from litter boxes on a 24-hour basis. More than 24 hours are required for gametogony and infectivity of oocysts to take place; thus, a 24-hour disposal schedule is effective.

- Pregnant women should not empty litter boxes, particularly when in the third trimester of gestation. The probability of pregnancies ending in abortion is 17% for mothers acquiring infection in the first trimester, 24% in the 2nd trimester, and 67% in the 3rd trimester.

- Do not allow cats to use animal feed bins or troughs as litter boxes.

Be kind to your well-groomed cat, and pay it due respect. Shower it with plenty of love. However, human beings must be prudent, and take well-defined precautions as mentioned before when exploring or settling in certain biospheres, or be prepared to pay the consequences.

Elmer W. Koneman, M. D.
Breckenridge, Colorado
Professor Emeritus, University of Colorado School of Medicine

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Life Cycle Summary of *Toxoplasma gondii*

The life cycle is most commonly completed when the cat eats the meat of a cyst-infected mouse. Tachyzoites, the sexual stage of *Toxoplasma gondii*, in the form of oocysts, develop within the intestine of the cat. These oocysts are released in the cat intestine, where they are released into the environment.

Humans become infected by ingestion of oocyst-contaminated fecal material, commonly from a litter box. The asexual stage may also occur in a variety of herbivores after ingestion of oocysts while foraging through contaminated soil and vegetable matter.

Humans may also become infected by eating poorly cooked meat of an herbivore harboring tissue toxoplasma cysts.