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Toxoplasma gondii:

What are the implications on society of recent studies?

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Abstract: The implications of the results found by recent studies and experiments done on the parasite Toxoplasma gondii are possibly groundbreaking, large stepping stones into the study of the human brain and biological adaptations to modify its function. If this process was completely understood it could possibly bring us new technology advances (e.g., nanotechnologies) and possible cures to poorly understood mood disorders and neuropathologies.

Thesis:

This paper is a synthesis style review of several peer-reviewed articles discussing the topics of transmission, biological effects and psychological effects; specifically this paper is attempting to address the implications of the research done on Toxoplasma gondii (*T. gondii*) and *T. gondii's* implications on human culture and society. *T. gondii 's* ability to manipulate human behavior in both men and women makes it a significant topic of research because we don't know many biological organisms that can alter behavior.

Background:

A fascinating phenomenon in behavioral biology is the ability of parasites to manipulate host behavior for their own benefit. A handful of examples are noted for insect and crustacea hosts, but rarely so in mammals. The extraordinary effectiveness of the mammalian blood brain barrier denies most pathogens access to the privileged central nervous system, the seat of will [2].

T. gondii is able to infect all warm-blooded animals and it is estimated that a third of all humans have been infected. In humans and other animals, infection is frequently associated with congenital infection and abortion. "*T. gondii* is an opportunistic pathogen that is associated with encephalitis in immunocompromised hosts, such as individuals with AIDS." [1]

Mode of Transfer:

T. gondii is a "coccidian parasite" [1] and has several life stages, including a rapidly growing tachyzoite stage (responsible for dissemination during acute infection), a slow-growing bradyzoite stage (which forms tissue cysts and is responsible for transmission by carnivorism), and the sexual lifecycle oocyst stage that develops in felids, responsible for its transmission by water or food. As illustrated by an outbreak in Victoria, Canada and a better understanding of the epidemiology of toxoplasmosis in South America, oocysts transmitted via water or other environmental sources are a significant source of *T. gondii* infection. The association of *T. gondii* with waterborne outbreaks has led to its classification as a National Institute of Allergy and Infectious Diseases (NIAID) Category B priority agent [1]. Humans can

become infected with *T. gondii* through soil contact, or by eating infected meat. People with cats or who work with soil are more susceptible [3].

T. gondii is an "obligate, single-celled protozoan parasite capable of crossing into the central nervous system of any warm-blooded vertebrate." [2] *T. gondii* requires the cat intestine to reproduce sexually, is shed in cat feces, and must make its way from the ground to another cat host. It infects ground-dwelling rats who, remarkably, begin selectively preferring areas with cat urine; likely an adaptive manipulation by *T. gondii*, increasing infected rat predation rates and facilitating *T. gondii* transmission to the cat [2].

Biological Processes and Effects:

The biological processes of *T. gondii* can be summarized by stating that *T. gondii's* membranes and organelle are highly differentiated to interact, in an inhibitory manner, with several specific structures including immunologic proteins and all the host cells' organelle, "resulting in extensive modification of host gene expression and signaling pathways." [1]

Biological structures are discussed extensively in hopes of understanding function. Here is a quote that summarizes that aspect of this large article: "many molecules in the cytoplasm interact with organelle proteomes and may be associated with … proteins, although not strictly derived from the organelle itself." [1]

The parasite causes production and release of many times the normal amount of dopamine in infected brain cells. Through investigation it seems "most infected humans initially suffer from mild flu-like symptoms; soon parasites become dormant in the brain and in other tissues." [3] Experiments show that by two weeks post infection, *T. gondii* has settled throughout the host's brain (rat) in "spherical cysts approximately 50–70 micrometers in diameter." [2]

Psychological effects:

Intriguingly, cysts formed from *T. gondii* show a slight preference for limbic system regions responsive to both "predator stimuli and sexual stimuli, regions responsible for gating innate approach and avoidance

behaviors." [2] This is shown in rats of an experiment in which "*T. gondii* infected rats are biasing the processing of the cat urine toward the sexual, 'reproductive' pathway. Plausibly, this shift is altering the salience of the cat urine stimuli and mitigating the defensive response by creating, in its stead, a competing attraction to the cat urine." [2]

People that are infected experience a variety of long-term personality & behavioral changes due to altered levels of cytokine which influence the level of neuromodulators (which moderate the level of neurotransmitters such as dopamine) in an infected brain. In infected women personality traits affected were: kindness, warm heartedness, exhibiting an outgoing personality, also a sense of conformity and a rule-bound moral. In infected men the personality traits appeared to be rigid, slow-tempered, and insecure or guilt prone. *T. gondii* infected men are also prone to take more risks. Infected women become more attractive to infected men. Entire cultures are changed by the rate of infection and the long term effects of the change on personality [3].

Studies have shown that some psychological disorders and brain pathologies can be more likely eminent due to the parasite including recent studies that "find infection increases risk for schizophrenia and obsessive compulsive disorder diseases noted for elevated dopamine levels and disturbed amygdala function." [2]

Reasoning for Psychological Effects:

It is an obligate intracellular parasite; it must "successfully invade host cells and create a hospitable environment in which it can acquire nutrients, yet, avoid killing by its host cell." [1] This can be explained by a particular study on the effect of the odor of cat urine to T. gondii infected feline. Feasibly, this shift is altering the salience of the cat urine stimuli and mitigating the defensive response by creating, in its place, a competing attraction to the cat urine [2]. It is thought to be that these adaptations are used by the protozoan to better its chances at survival throughout generations; each of these behaviors helps the parasite in some way [3].

Conclusion:

As evidence is seems to show, entire cultures are changed by the rate of infection and the long term effects of the change on personality. These changes are thought to be adaptations used by the protozoan to better its chances at survival throughout generations [3]; each of these behaviors helps the parasite in some. This, in my mind, implies that there is a possibility to biologically reverse-engineer this parasite's DNA and to find what makes it possible for the parasite to read and alter the correct brain functionality and patterns that allow it to reap the benefits of its actions and to further its species survival rate and growth rate. This could give us the advantage needed, or the push off the edge that humans need to master what we still don't understand about curing neuropathologies and certain mood disorders, possibly even some genetic diseases. This knowledge could also give us an edge on furthering technology, possibly taking us to the integration of nanotechnologies in medicine. Although these possibilities seem to have been shown to exist, it appears from research that they are still years if not decades away from a true understanding. Scientists seem to still be in the thesis forming stage, as opposed to even the testing phase.

Sources:

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[2] Astrid M Tenter, Anja R Heckeroth, Louis M Weiss. "*T. gondii gondii*: from animals to humans" [Int. J. Parasitol. 30 (2000) 1217–1258] *International Journal for Parasitology*, *Volume 31, Issue 2*, *February 2001*, *Pages 217-220*

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