The Consequences of Parasitic Infection for the Behavior of the Mammalian Host

by Peter J. Donovick* and Richard G. Burright*

As many as one billion people may be infected with animal parasites. The behavioral consequences of such infection, or of illness in general, is poorly understood. This issue is discussed using as an example infection of mice with Toxocara canis, the common roundworm of dogs. Current literature suggests that two-thirds of all dogs have been infected with this parasite, and 7% of all humans have antibodies to T. canis.

T. canis completes its life cycle in dogs, but when it infects aberrant mammalian hosts (e.g., humans or mice), larvae migrate through various organ systems including the brain, where they can remain viable and mobile for extended periods of time. Changes in motor activity, sensory reactivity, and learning of mice infected with T. canis have been observed. The pattern of behavioral changes is influenced by the infection regime and exposure to other toxicants such as lead.

Scope of the Problem

The clinical manifestation of many diseases are dependent on factors such as the genetic constitution and environmental history of both the host and the infectious agent. The concept of zoonosis, the transmission of a disease from its animal host to humans, recognizes the complexity of the flow of disease or infectious agents among different hosts; some hosts may be better able to compensate for infection and thus are seen without symptoms, while others more clearly express the pathology. Variability in the reaction to parasitic infection is determined partly by genetic constitution of the parasite itself and the host (1), resulting in variable expressivity of the infection (2). "Parasites, with their bizarre pathology, often cause confusion in diagnosis, especially in countries where they are uncommon" (3).

Part of the problem may lie in the fact that many of the pathological changes found associated with parasitic infection may be caused by inflammation or immunopathological reactions, with eosinophilia as a characteristic accompaniment (3–5).

Although perhaps more than 500 million humans are infected with animal parasites (6), little is known concerning the behavioral effects of parasitism in mammalian hosts. It is not commonly recognized, even in industrialized nations, that most people are exposed to, or infected with, one of a variety of parasites (e.g., Toxoplasma, an intracellular parasite, in the reticuloendothelial system, or trichomonads in the genital tract) (3). Commonly, people are unaware that they are infected, and accurate diagnosis of parasitic infection may not be made, even when symptoms are exhibited. The relationship between parasite and host is complex and may change over time. For instance, the parasite may stimulate the immune system, allowing the host both to respond minimally to subsequent re-exposures to the same parasite and to reject more pathogenic organisms. At the same time, the sick or infected organism may be particularly vulnerable to further environmental challenges. Furthermore, whereas some parasites were once relatively restricted to third world communities, increased international travel has increased the global spread of infection by such organisms.

T. canis: Brain and Behavior

We have examined the impact of Toxocara canis, the common roundworm of dogs, on the behavior of mice. In aberrant hosts such as humans or mice, as shown in Figure 1, the second stage larvae of this parasite migrate through various organs (liver, spleen, lung, brain, and eye) where they can remain viable for many years (7). In the dog, the natural host of T. canis, the adult stage of the parasite is normally found in the intestinal tract. However, in the aberrant host the parasite fails to reach maturity. Thus, there are no eggs passed in the feces, and only indirect diagnostic assays such as serological tests are available to suggest the presence of T. canis (8). The dimension of the problem is apparent when one takes into account: (a) a survey cited by Jacobs (9) that suggests that 38% of all American households in 1973 had dogs; (b) the high prevalence of infection of dogs by this parasite worldwide (9–12); (c) the high prevalence and long-term viability of T. canis eggs in

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that pact to other contaminants. Brain, where, during somatic migration; through liver, remains sequestered, they suggest (18-20).

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neuropathology observed using light microscopic techniques was confined primarily to large myelinated fiber tracts, but was not different between animals exposed to parasite alone or in combination with lead (5). These data suggest that evidence for both the pattern of specific behavioral deficits and instances of resistance may occur depending on the regime of infection and exposure to other environmental toxins.

Humans and other aberrant hosts most likely experience repeated exposures to parasites. Recently we examined the impact of single versus multiple exposures to T. canis (4). In this situation, we anticipated a more heightened and sustained host immune reaction to secondary and subsequent infections of the parasite (44–50). Prior work had noted that the pattern of larval distribution in various organ systems is different in rodents given single versus multiple doses of T. canis (51–52). Our data supported the notion that prior exposure could indeed protect the organisms against subsequent exposures to T. canis. Both the pathological changes observed and the pattern of behaviors exhibited by the mice were influenced by the infection regime. However, the results also indicated the complexity of the interaction(s) between the parasite and its host. Thus, factors such as the specific “dose” (28), the time of measurement since infection (32), exposure to other toxins (18–20), or the pattern of repeated infections (4) all may alter the nature and extent of changes in the observed behavior of the organism.

Conclusions

It is surprising that this area of research has generated so little interest given the obvious impact of parasitic infection on several critical aspects of the behavior of the host ranging from sensory/motor processing (19,29,53–56) and aggression (57) to learning (18,31,34,58). Indeed, investigations of the role of physical health or disease (59–61) on psychological processes in general are relatively rare. Thus, although several aspects of behavioral toxicology have become popular areas of research (e.g., the consequences of exposure to lead), many domains of research remain virtually unexplored. It is our belief that such lines of research will be critical before we can understand the etiology of a number of behaviorally significant disorders. Indeed, disease is an orphan in most psychobiological research, and the dualistic view that behavior is either organic or psychological remains common. However, to truly understand behavior, attention will have to be paid to the exquisitely complex interactive networks of adaptive processes which define any individual living organism.

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