PART V

WHAT TO DO?

Knowing is not enough; we must apply.
Willing is not enough; we must do.

— Johan Wolfgang von Goethe (1749–1832)

> Thus, although predators have the most obvious role in the ongoing drama of life, the more cryptic and behind the-scenes work of infectious and parasitic diseases has clearly played the more important part in the evolution of humans, their resources, and life in general on the planet. Parasites wrote the script and direct the play; predators are simply the most visible actors. (1)
>
> Claude Combes

> The evidence indicates that there is now enough knowledge to act, firstly, to control the infection in dogs and cats and thus prevent many developing disease, and, secondly, to increase awareness of and use of diagnostic and therapeutic facilities to deal with the infection in man. (2)
>
> A.W. Woodruff's conclusion in 1970

UNDERSTANDING TAENIID AND *TOXOCARA* TRANSMISSION

Taeniids and *Toxocara* spp. are apparently very successful helminth parasites despite their somewhat complex life cycle. The transmission of eggs to grazing ungulates is maximized, as dogs prefer to leave their faeces outdoors on the grass. Strangely enough, it is not possible to teach dogs to defecate on special places designed for indoor or outdoor use, despite all of the other skills they are able to learn and exhibit.

The propensity of dogs and other canids to defecate in different places all the time increases the spread of helminth eggs maximally, and the parasite-induced trophic transmission (PITT) effect of taeniids assists canids in their predation of infected intermediate hosts. These characteristics are highly beneficial to both the canids and the taeniids. Interpreted in this way, the relationship between the adult taeniid in the canid intestine and the canid itself is an example of biological mutualism (not just commensalism) in animal biology. The canids offer the taeniids food and shelter, and the taeniids offer the canids facilitated predation. On the other hand, the relationship between the taeniid larvae and the prey animal is a typical example of biological parasitism. (3) The fact that it seems impossible to teach dogs not to defecate in different places all the time indicates that canids and Taeniidae have had an intimate relationship for their mutual benefit for millions of years of evolution.

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1. Combes C. Parasitism: the ecology and evolution of intimate interactions. The University of Chicago Press, 2001; p. 581.

2. Woodruff AW. Toxocariasis. *BMJ* 1970;3:663–9.

3. Campbell NA, Reece JB. Biology. 7th ed. Pearson, 2005.

Taeniid eggs may survive for a long time in temperate and cold climates. Eggs of *Echinococcus granulosus* and *E. multilocularis* are highly resistant to freezing temperatures and survive the winter climate of Norway. Very low temperatures of -70°C to -80°C are needed to kill these eggs. (4) The degree of resistance to freezing temperatures for other taeniid eggs is unknown, but is probably more or less similar. *Taenia multiceps* eggs can contaminate the environment and water and survive for 15 days under dry conditions, or 30 days with high levels of humidity. At high temperatures, they die within a few hours. (5) Sheep and horses will for this reason be easily infected by taeniid eggs.

The transmission of taeniid protoscolices from an infected intermediate host to a definitive host implies that infected parts of the intermediate host must be eaten by the definitive host. The PITT effect will make the infected intermediate hosts more vulnerable to predation. However, it would be hazardous for the genetic flow of *T. multiceps* spp.—which have central nervous system (CNS) tissue tropism—to be dependent on metacestodes in the brain or spinal cord to enter the canid intestine. Dissemination of protoscolices in muscles and subcutaneous tissues is also found in *T. multiceps* infection and increases the probability of successful infectious transmission tremendously.

There may be more diverse ways to transmit protoscolices to dogs than what is known today. Some of my patients told me about the propensity of dogs to eat faeces from selected cats and horses. There is no nutritional reason for dogs to eat faeces and no known reason to eat faeces only from selected animals among other animals of the same kind. A possible explanation might be that helminth larvae now and then evacuate in the gastrointestinal tract of the intermediate host and that the larvae accompanying faeces emit a smell that attracts dogs. If there are taeniid cysts in the gut wall of, for example, horses, the cyst may theoretically rupture into the intestinal lumen and evacuate protoscolices with the faeces. Another possibility is that *Toxocara* larvae move from the gut wall into the lumen and accompany the faeces. If that is the case, it would be a very effective transmission route for helminth larvae from intermediate hosts to domestic dogs.

Cats are definitive hosts of *Taenia taeniaeformis*, but may be intermediate or accidental hosts of *Taenia* larval tissue infection (LTI) as well. (6,7) In *T. solium* cysticercosis, humans may be a definitive as well as an intermediate or accidental host. *Taenia solium* cysticerci have been detected in dogs, (8) but it is unknown whether dogs may be intermediate hosts of *T. multiceps* or other taeniid spp. If they are and protoscolices

4. Eckert J, Gottstein B, Heath D, Liu F-J. Prevention of echinococcosis in humans and safety precautions. In: Eckert J, Gemmell MA, Meslin F-X, Pawlowski ZS, eds. WHO/OIE manual on echinococcosis in humans and animals: a public health problem of global concern. World Organisation of Animal Health and World Health Organization, 2001; Chapter 7, pp. 238-45. http://whqlibdoc.who.int/publications/2001/929044522X.pdf

5. Doherty ML, McAllister H, Healy A. Ultrasound as an aid to Coenurus cerebralis cyst location in a lamb. *Vet Rec* 1989;124:591.

6. Wünschman A, Garlie V, Averbeck G, Kurtz H, Hoberg EP. Cerebral cysticercosis by Taenia crassiceps in a domestic cat. *J Vet Diagn Invest* 2003;15:484-8.

7. Schwan EV, de Scally MP, van Rensburg CL, Durand DT. Cerebral cysticercosis in a cat. *J S Afr Vet Assoc* 2002;73:219-21.

8. Margono SS, Wandra T, Swasono MF, Murni S, Craig PS, Ito A. Taeniasis/cysticercosis in Papua (Iranian Jaya), Indonesia. *Parasitol Int* 2006;55:S143-8.

are excreted in faeces from an intermediate host, the genetic flow of taeniid helminths would be properly secured. Adequate preventive measures against helminth LTI will depend on a complete exploration of the transmission routes of taeniids and *Toxocara*.

Humans are thought to be accidental or dead-end hosts of dog cestodes, as they are not eaten by dogs or other canids. From the point of view of taeniids, it would be highly beneficial to establish a human-dog life cycle, as the dog is accepted as the best friend of the human being. From an evolutionary perspective, it would be more surprising if a complete life cycle of cestodes between humans and dogs did not exist than if such a possibility did exist. A theoretically possible way to transmit protoscolices from humans to dogs without ingestion of human flesh might be through ingestion of excretions from the human body or from skin eruptions. An illustration of how such transmission might occur was seen by one of the patients in this work. The patient had a cyst in her right maxillary sinus verified by MRI that was observed in varying sizes on different examinations. If this cyst was a viable metacestode, the variation in size was probably due to leakage of cyst content. Now and then, she observed evacuations from her nose that macroscopically resembled larvae. Her dog was very eager to lick her face and the inside of her mouth, and the patient had for years permitted her dog to do so.

Another possible route of transmission from a human to a dog might be by skin eruptions. Some patients complain about itching skin eruptions lasting for weeks that often reappear at the same location after a period of weeks or months. Some of these patients have noticed a conspicuous interest from dogs during secretions from these eruptions. If such skin eruptions contain helminth larvae, the dog may be infected by licking them. If there actually exists a taeniid human-dog life cycle, it would imply domestication of dog parasites and not only domestication of the wild wolf. If that is the case, it would not be the first example of domestication of parasites. A known example is the kissing bug *Triatoma infestans,* which transmits *Trypanosoma cruzi*, causing Chagas disease. (9)

PHARMACEUTICAL TREATMENT OF TAENIID AND *TOXOCARA* LTI STAGE 1–2

Treatment of active helminth LTI is mainly medical, except for treatment of echinococcosis and coenurosis, which so far has been mainly surgical. Removal of coenuri and hydatid cysts is recommended when possible. (10)

The medical treatment of choice for *Taenia solium*, *Echinococcus granulosus*, *E. multilocularis*, and *Toxocara* LTI is albendazole. Diethylcarbamazine is possibly more efficient than albendazole against *Toxocara*, but it may have more serious side effects. (11) A review about *T. solium* neurocysticercosis recommends albendazole 15 mg/kg per day for a week. (12) An albendazole trial for the treatment of subarachnoid and intraventricular cysticercosis concluded that albendazole at a dose of 30 mg/kg/day

9. Drisdelle R. Parasites: tales of humanity's most unwelcome guests. University of California Press, 2010; p. 178.

10. Centers for Disease Control and Prevention, Division of Parasitic Diseases. Parasites and health: coenurosis. http://www.dpd.cdc.gov/dpdx/html/Coenurosis.htm

11. Magnaval J-F, Glickman LT. Management and treatment options for human toxocariasis. In: Holland CV, Smith HV, eds. Toxocara: the enigmatic parasite. CABI Publishing, 2006; pp. 113–26.

12. Sinha S, Sharma BS. Neurocysticercosis: a review of current status and management. *J Clin Neurosci* 2009;16:867–76.