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■ ■FURTHER READING Bourli P et al: Waterborne transmission of protozoan parasites: A review of worldwide outbreaks–an update 2017–2022. J Water Health 21:1421, 2023. Buret AG et al: Update on Giardia: Highlights from the Seventh Inter national Giardia and Cryptosporidim Conference. Parasite 27:49, 2020. Carter BL et al: Health sequelae of human cryptosporidiosis in indus trialized countries: A systematic review. Parasit Vectors 13:443, 2020. Coffey CM et al: Evolving epidemiology of reported giardiasis cases in the United States, 1995–2016. Clin Infect Dis 72:764, 2021. Fitri LE et al: Diagnostic methods of common intestinal protozoa: Current and future immunological and molecular methods. Trop Med Infect Dis 7:253, 2022. Hemphill A et al: Comparative pathobiology of the intestinal protozoan parasites Giardia lamblia, Entamoeba histolytica and Cryptosporidium parvum. Pathogens 8:116, 2019. Mathison BA, Pritt BS: Cyclosporiasis—updates on clinical presen tation, pathology, clinical diagnosis, and treatment. Microorganisms 9:1863, 2021. Ramanan P, Pritt BS: Extraintestinal microsporidiosis. J Clin Microbiol 52:3839, 2014. Van Den Broucke S et al: Microscopic detection of intestinal Sarcocystis infection diagnosed in international travelers at the Institute of Tropical Medicine, Antwerp, Belgium, from 2001 to 2020. Am J Trop Med Hyg 109:327, 2023. Van German TO, Muzny CA: Recent advances in the epidemiology, diagnosis, and management of Trichomonas vaginalis infection. F1000Res 8:1666, 2019. Van Gerwen OT et al: Trichomoniasis. Infect Dis Clin North Am 37: 245, 2023. Van Gestel RSFE et al: A clinical guideline on Dientamoeba fragilis infections. Parasitology 146:1131, 2018. Widmer G et al: Update on Cryptosporidium spp: Highlights from the Seventh International Giardia and Cryptosporidim Conference. Parasite 27:14, 2020. Section 19 Helminthic Infections Peter F. Weller, Edward T. Ryan

Introduction to

Helminthic Infections The word helminth is derived from the Greek helmins (“parasitic worm”). Helminthic worms are highly prevalent and, depending on the species, may exist as free-living organisms or as parasites of plant or animal hosts. The parasitic helminths have co-evolved with specific mammalian and other host species. Accordingly, most helminthic infections are restricted to nonhuman hosts, and only rarely do these zoonotic helminths accidentally cause human infections. Helminthic parasites of humans belong to two phyla: Nemathel minthes, which includes nematodes (roundworms), and Platyhelmin thes, which includes cestodes (tapeworms) and trematodes (flukes). Helminthic parasites of humans reside within the human body and hence are

the cause of true infections. In contrast, parasites of other genera that reside only on mucocutaneous surfaces of humans (e.g., the parasites causing myiasis and scabies) are considered to represent infestations rather than infections. Helminthic parasites differ substantially from protozoan parasites in several respects. First, protozoan parasites are unicellular organ isms, whereas helminthic parasites are multicellular worms that possess

differentiated organ systems. Second, helminthic parasites have complex life cycles that require sequential stages of development outside the human host. Thus, most helminths do not complete their replication within the human host; rather, they develop to a certain stage within the mammalian host and, as part of their obligatory life cycle, must mature further outside that host. During the “extra-human” stages of their life cycle, helminths exist either as free-living organisms or as parasites within another host species and thereafter mature into new developmen tal stages capable of infecting humans. Thus, with only two exceptions (Strongyloides stercoralis and Capillaria philippinensis, which are capable of internal human reinfections), increases in the number of adult hel minths (i.e., the “worm burden”) within the human host require repeated exogenous reinfections. In the case of protozoan parasites, a brief, even singular exposure (e.g., a single mosquito bite transmitting malaria) may lead rapidly to intense parasite loads and overwhelming infections; in contrast, for all but the two helminths noted above, increases in worm burden require multiple and usually ongoing exposures to infectious forms, such as ingestion of eggs of intestinal helminths or waterborne exposures to infectious cercariae of Schistosoma mansoni. This require ment is germane both to the consideration of helminthic infections in individuals and to ongoing global efforts to interrupt and/or minimize the acquisition of helminthic infections by humans.

Third, helminthic infections have a predilection toward stimulation of host immune responses that elicit eosinophilia within human tissues and blood. The many protozoan infections characteristically do not elicit eosinophilia in infected humans, with only three exceptions (two intestinal protozoan parasites, Cystoisospora belli and Dientamoeba fragilis, and tissue-borne Sarcocystis species). The magnitude of helminthelicited eosinophilia tends to correlate with the extent of tissue inva sion by larvae or adult helminths. For example, in several helminthic infections, including acute schistosomiasis (Katayama syndrome), paragonimiasis, and hookworm and Ascaris infections, eosinophilia is most pronounced during the early phases of infection, when migra tions of infecting larvae and progression of subsequent developmental stages through the tissues are greatest. In established infections, local eosinophilia is often present around helminths in tissues, but blood eosinophilia may be intermittent, mild, or absent. In helminthic infec tions in which parasites are well contained within tissues (e.g., echino coccal cysts) or confined within the lumen of the intestinal tract (e.g., adult Ascaris or tapeworms), eosinophilia is usually absent. CHAPTER 237 Introduction to Helminthic Infections ■ ■NEMATODES Nematodes are nonsegmented roundworms. Species of nematodes are remarkably diverse and abundant in nature. Among the many thou sands of nematode species, few are parasites of humans. Most nema todes are free-living, and these species have variably evolved to survive in diverse ecologic niches, including saltwater, freshwater, or soil. The well-studied organism Caenorhabditis elegans is a free-living nema tode. Nematodes can be either beneficial or deleterious parasites of plants. Parasitic nematodes have co-evolved with specific mammalian hosts and have no capacity to live their full life cycles in other hosts. Uncommonly, humans are exposed to infectious stages of nonhuman nematode parasites, and the resultant zoonotic nematode infections can elicit inflammatory and immune responses as larval forms migrate and die in the unsuitable human host. Examples include pulmonary coin

lesions due to mosquito-transmitted infections with the dog heartworm Dirofilaria immitis; eosinophilic meningoencephalitis due to ingested eggs of the raccoon ascarid Baylisascaris procyonis; and eosinophilic meningitis due to ingestion of larvae of the rat lungworm Angiostrongylus cantonensis. Nematode parasites of humans include worms that reside in the intestinal tract or localize in extraintestinal vascular or tissue sites. Roundworms are sexually dimorphic, with separate male and female forms that copulate to produce offspring (except for S. stercoralis, whose adult females are hermaphroditic in the human intestinal tract). Depending on the species, fertilized females release either larvae or eggs containing larvae. Nematodes have five developmental stages: an adult stage and four sequential larval stages. These parasites character istically are surrounded by a durable outer cuticular layer. Nematodes

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