Companion animals can harbor a wide range of parasites, some of which are transmissible to humans. The overall burden of human diseases attributable to companion animal-associated parasites is unknown and varies greatly between regions. The risks associated with some are often overstated while others are largely ignored, and the range of illness can extend from mild and self-limited to fatal.

**Ascaris lumbricoides**

Introduction

*A. lumbricoides* is a roundworm that has typically been considered host specific to humans; however, there is evidence of infection of dogs and the potential for dogs to be an uncommon source of human infection.

Etiology

As with other intestinal nematodes, *A. lumbricoides* is a nonsegmented, elongated, cylindrical parasite that undergoes sexual reproduction. Like other ascarids, as well as hookworms and *Trichuris, A. lumbricoides* undergoes a maturation stage in soil and is therefore sometimes referred to as a geohelminth. Female worms are larger than males and can reach 40 cm in length and 6 mm in diameter.

Life cycle

Adult worms live within the small intestinal lumen of humans and excrete massive numbers of eggs per day. As with other ascarids, eggs are not immediately infective and must mature to infective third-stage larvae in the environment over a period of days. After embryonated eggs are ingested by a human, larve hatch, penetrate the intestinal mucosa, and reach the liver via portal circulation. After migrating through the liver, the larvae eventually reach the lungs, penetrate the airways, ascend the tracheobronchial tree, and are coughed up and swallowed. They mature into adults in the small intestinal lumen and complete the life cycle. The time from ingestion of infective eggs to development of adults is approximately 8 weeks.

Geographic distribution/epidemiology

*A. lumbricoides* is one of the most prevalent nematodes in humans and is most common in tropical
and subtropical regions, infecting approximately 25% of the world’s population.\textsuperscript{3,5} Up to 80% of people can be infected in some areas.\textsuperscript{1,4,6–9} The regional prevalence varies depending on factors such as climate, sanitation, socioeconomic status, and human behavior. Areas with warm, humid climates facilitate maturation and survival of infective eggs. Poor sanitation leads to an increased risk of contamination of the environment with human feces. Outdoor defecation similarly results in increased likelihood of contamination, and outdoor activities in contaminated areas that are accompanied by suboptimal hand hygiene increase the risk of fecal–oral infection. \textit{A. lumbricoides} eggs can be found in the soil in public places such as parks,\textsuperscript{10,11} and can survive outdoors for years in favorable environmental conditions.\textsuperscript{1} Infections are more common in children.

Some older studies reported the presence of ascarid eggs that could have been \textit{A. lumbricoides} in canine feces.\textsuperscript{12,13} More recently, convincing evidence of the presence of \textit{A. lumbricoides} in dogs has been reported. A study of dogs in tea-growing communities in northern India identified \textit{A. lumbricoides} eggs in 18–37% of dogs.\textsuperscript{7} In that study, dogs were at increased risk of shedding \textit{A. lumbricoides} if one or more household members regularly defecated outdoors. Simply finding eggs in feces, particularly in an environment where dogs may ingest human feces, does not necessarily indicate that dogs are involved in the biological cycle of the organism. Indeed, there has been some thought that dogs only act as mechanical vectors and that eggs passed in feces simply moved passively through the intestinal tract. However, a recent study of dogs in an area in Egypt where outdoor defecation by humans is common reported detection of adult \textit{A. lumbricoides} in 8% of dogs.\textsuperscript{14} Furthermore, viable eggs were detected, suggesting that dogs can truly be infected and could potentially play a role in the life cycle of this human parasite. It has also been suggested that the dog’s coat could be a source of exposure since the eggs are “sticky” and highly tolerant of environmental effects, and could potentially adhere and mature to the infective stage on the animal.\textsuperscript{14}

A study of young Nigerian children indicated that children whose families owned dogs were 3.5 times as likely to be shedding \textit{A. lumbricoides} compared with non-dog-owning families.\textsuperscript{15} In contrast, contact with dogs was not a risk factor in a study of adult humans in northern India.\textsuperscript{7} Whether there truly is a risk from dogs is unclear, but the limited data indicate that consideration of the role of pets, particularly dogs, in the transmission of this predominantly human-associated parasite is required.

**Animals**

**Clinical presentation**

Little is known about \textit{A. lumbricoides} in dogs. While it was previously thought that dogs shedding the parasite represented a mechanical, not biological, vector, there is now evidence that adult worms can grow in the canine intestinal tract. It is not known whether this can result in disease.

**Diagnosis**

Diagnosis is based on the detection of eggs in feces using fecal flotation and subsequent speciation of the parasite by evaluation of micromorphological features\textsuperscript{14} or using molecular methods such as PCR-RFLP.\textsuperscript{7}

**Management**

No specific data are present, but presumably, any prophylactic or therapeutic agent that is used for the treatment of \textit{Toxocara} in dogs would be effective against \textit{A. lumbricoides}. These include milbemycin oxime, moxidectin, fenbendazole, and pyrantel.

**Humans**

**Clinical presentation**

Various presentations can occur, but most infections are asymptomatic.\textsuperscript{1,2} Large worm burdens can result in malnutrition, nonspecific gastrointestinal signs, or, in rare cases, intestinal obstruction.\textsuperscript{2} Obstruction of the bile duct can result in cholangitis, biliary colic, or pancreatitis.\textsuperscript{2} Chronic infections can produce insidious disease, with growth retardation and negative effects on cognitive function in children.\textsuperscript{5} During larval migration, acute pulmonary signs (Loeffler’s syndrome), fever, and marked eosinophilia can occur.\textsuperscript{2} There is also increasing
concern about the broad effects of ascarid infection on the immune system, something that may be particularly important with concurrent infections such as malaria or for the development of allergic diseases, though more research needs to be performed in this area.

**Diagnosis**

Eggs are usually easily detectable in stool because of the large numbers that are shed by adult worms. Rarely, adult worms will be passed in stool or vomitus. Adult worms may also be identified ultrasonographically as an incidental finding or during investigation of gastrointestinal complaints.

**Management**

A single dose of albendazole, mebendazole, or pyrantel pamoate has high cure rates (88–95%). Three days of mebendazole or a single dose of ivermectin has also been recommended in people over 2 years of age. Nitazoxanide is also effective. Retesting of stool 2 weeks after treatment has been recommended. Most drugs are only effective against adult parasites, so repeated treatment may be needed.

**Prevention**

Prevention of zoonotic transmission of *A. lumbricoides*, should it occur, involves basic measures to reduce the incidence of exposure of dogs, to reduce contamination of the environment by dog feces, and to prevent fecal-oral exposure in humans. Evidence-based data are not available for any of these areas, but reasonable recommendations can be made.

Reducing exposure involves decreasing the chance that dogs will ingest infective *A. lumbricoides* eggs, which are predominantly found in human feces. Reducing “promiscuous defecation” by humans, something that is common in some developing regions, is a means of achieving this and involves both education and improved infrastructure.

Reducing contamination of the environment by dogs is as discussed for similar organisms like *Toxocara canis* (e.g., reducing worm burdens, and therefore shedding levels, by routine antiparasitic chemoprophylaxis). Decreasing the numbers of free-roaming dogs and prompt removal of feces, particularly from public areas such as parks, would presumably help achieve that goal. General hygiene practices are the key to reducing inadvertent ingestion of infective larvae by humans, including good attention to hand hygiene and proper washing of food.

Prophylactic use of albendazole, mebendazole, or pyrantel pamoate in humans can be practical and affordable in endemic areas, particularly in school-age children. Based on the commonness of the parasite in humans in some regions and the very rare incidence of patent infections in dogs, prophylactic treatment of dogs directed specifically against *A. lumbricoides* is not indicated. However, routine deworming targeted against other roundworms will be effective against this parasite.

**Baylisascaris procyonis**

**Introduction**

*B. procyonis* is a large nematode that is highly prevalent in healthy raccoons in many regions. Human infections are very rare but can be devastating. Neural larva migrans is the most common form of this rare disease, but visceral (VLM) and ocular larva migrans (OLM) can also develop.

Dogs can shed *B. procyonis* in feces and can also theoretically be a source of human exposure through transporting infective eggs into the household on their hair coat. While objective evidence of a risk from pets is minimal, the severity of disease in humans indicates that basic measures should be taken to reduce the risk of exposure to this parasite.

**Etiology**

*B. procyonis* belongs to the order Aascaridida, along with *Toxocara canis* and *T. cati*. The North American raccoon (*Procyon lotor*) is the definitive host, and *B. procyonis* is often termed the “raccoon roundworm.” An unusual aspect of *B. procyonis* is its ability to infect a wide range of animal species, causing neural larva migrans in over 100 avian and mammalian species.
Life cycle

Adult worms are found in the small intestine of raccoons. They are large, tan roundworms that can be up to 22 cm long. Female worms are prodigious egg layers, and infected raccoons can pass millions of eggs in feces per day, leading to heavy contamination of the environment. Eggs are not immediately infective, and second-stage larvae must develop in eggs in the environment before infection is possible. This usually requires 2–4 weeks, but may occur as quickly as 11 days in some situations. After ingestion, infective eggs hatch in the small intestine. In intermediate hosts, larvae can penetrate the intestinal mucosa and migrate via portal circulation to the liver, then to the lungs, where they are subsequently distributed throughout the body via the systemic circulation. Larvae that reach the central nervous system (CNS) continue to migrate and grow, causing neurological damage. Migration through other tissues may also occur, and extensive somatic migration is common.

Young raccoons tend to be infected early in life by ingesting infective eggs off their mother’s hair coat or in the den environment. Adult raccoons are typically infected by ingestion of third-stage larvae in the tissues of infected intermediate hosts (i.e., rodents). Intermediate hosts (including humans) are infected by ingestion of infective eggs from the environment. Juvenile raccoons tend to have a higher parasite burden than adults.

Geographic distribution/epidemiology

*B. procyonis* can be found in most places that raccoons can be found. Raccoons are indigenous to North America and *B. procyonis* can be found widely across the continent, although there appear to be regional variations in prevalence (e.g., this parasite is less common in the southeastern United States). Shedding rates of 13–92% have been reported in North American raccoons. During recent years, the parasite has been found, sometimes commonly, in North American regions where it was not previously thought to exist, suggesting that its range may be expanding. It is reasonable to assume that *B. procyonis* is present anywhere raccoons can be found. This includes other continents, since raccoons have been introduced into other regions of the world, and *B. procyonis* has been found in raccoons in some areas of Europe and Asia.

Infected raccoons can shed massive numbers of eggs in feces and lead to marked environmental contamination. This is most pronounced in and around raccoon latrines, areas where raccoons tend to defecate. Raccoon latrines are thought to play a central role in *B. procyonis* transmission because they are so highly contaminated. Other environmental sites, including public parks and playgrounds, can also be contaminated. Infective eggs are highly resistant to environmental effects and can persist in the environment for years, long after obvious evidence of raccoon feces has disappeared. The surface of the egg is also rather “sticky,” and eggs tend to adhere to animal fur, hands, and other surfaces, which can contribute to exposure of pets and people.

Neural larva migrans and OLM are the main disease concerns associated with this parasite in humans. Neural larva migrans caused by *B. procyonis* is very rare but has been reported sporadically across North America. Most cases have involved children with developmental delays. Contact with infected raccoons, their feces, or a contaminated environment, and geophagia or pica are the main risk factors. Young children and developmentally delayed individuals are at increased risk because they are more likely to ingest raccoon feces and contaminated dirt. Children may also be more likely to play outside in or around raccoon latrines. Asymptomatic infections can occur, as evidenced by the presence of *B. procyonis* antibodies in some healthy individuals. While evidence is sparse, it is suspected that asymptomatic or subclinical infections are the most common form of infection. Asymptomatic infections probably represent infections caused by ingestion of small numbers of *B. procyonis*, which results in less damage through migration and inflammation. Since the likelihood of clinical infection and severity of neural larva migrans are thought to relate to the number of ingested larvae and the size of the brain (with damage to critical areas more likely in small brains), subclinical infections would be more likely in adults.

The role of dogs in the epidemiology of *B. procyonis* is poorly understood. They likely play a minimal role in the propagation of this parasite. However,
their close contact with humans raises concerns. There are reports of *B. procyonis* infection in dogs, both healthy dogs and dogs with neural larva migrans, though prevalence data are currently lacking. Even so, compared with raccoons, infections in dogs appear to be uncommon. Dogs can be infected by ingestion of infected small animals. They could also become infected by ingestion of eggs, particularly from raccoon latrines; however, infection following ingestion of eggs is much less likely than infection following ingestion of larvae. Given the ability of eggs to stick to surfaces, pets could theoretically be a source of infection as a mechanical vector, by bringing infective eggs from the environment into the household.

Infections have also been reported in other species, including wild rabbits, captive nonhuman primates, a cockatoo, and a pet guinea pig; however, patent infections have not been reported and the public health consequences are presumably minimal to nonexistent.

**Humans**

**Clinical presentation**

Neural larva migrans produces severe and rapidly progressive eosinophilic meningoencephalitis. It is almost exclusively identified in young children or people with developmental delays that make them more likely to ingest dirt or feces. Weakness, lethargy, irritability, behavioral changes, difficulty speaking, headache, and ataxia may be observed, usually with rapid progression.

OLM may occur with neural larva migrans or as a sole entity. Larval migration through the visual cortex or within the eye can lead to visual impairment or blindness. Chorioretinitis and optic neuritis or atrophy may be evident during ophthalmoscopic examination. Occasionally, motile larvae may be observed within the eye. VLM tends to occur most often in the head, neck, and thorax.

**Animals**

**Clinical presentation**

The implications of *B. procyonis* infection in dogs have not been well described, and it is likely that subclinical intestinal infection is most common. Neural larva migrans can occur and cause rapidly progressive encephalitis.

**Diagnosis**

Eggs can be identified in feces using routine fecal flotation. Close examination is required to differentiate *B. procyonis* from *Toxocara* or *Toxascaris* spp. PCR may offer another means of directly detecting *B. procyonis* eggs in feces and differentiating them from other ascarids.

Diagnosis of neural larva migrans is as described for humans below, involving clinical signs, peripheral and CSF eosinophilia and seropositivity, and exclusion of other possible causes of disease.

**Management**

Fenbendazole, milbemycin oxime, moxidectin, and pyrantel are likely to be effective for the elimination of intestinal *B. procyonis*. Milbemycin oxime was effective at eliminating *B. procyonis* from a small group of naturally infected and experimentally infected dogs. No information is available regarding treatment of larva migrans. Presumably, anthelmintics and corticosteroids are indicated, as is the case in humans, but a grave prognosis would be expected.

**Diagnosis**

Neural larva migrans is presumptively diagnosed through a combination of clinical signs, cerebrospinal fluid (CSF), and peripheral eosinophilia, and the presence of diffuse white matter disease on CT or MRI, ideally with a history of exposure to raccoons or raccoon feces. Demonstration of antibodies against *B. procyonis* in serum and CSF supports the diagnosis. Definitive diagnosis involves the identification of larvae on brain biopsy specimens. However, it is unlikely that a parasite would be obtained in a biopsy, and biopsy is not recommended if serological tests are available.

Diagnosis of OLM is based on the detection of chorioretinal lesions or larvae on ophthalmoscopic examination. Differentiation of *B. procyonis* from other ocular parasites can be done by measurement of the larvae, with *B. procyonis* larvae
being larger (1500–2000 × 60–70μm) than *Toxocara* (350–445 × 20μm).21

Management

Treatment is difficult because of a lack of objective information regarding different options and the typically advanced nature of disease by the time it is suspected or diagnosed. Currently, treatment involves anthelmintics, corticosteroids, and supportive care. Data regarding the efficacy of different anthelmintics in eliminating intestinal worms in raccoons must be used cautiously when considering the treatment of larva migrans, because drugs that are able to eliminate intestinal parasites in raccoons are typically much less effective in tissues of other hosts21 and adult worm stages may have different susceptibility to certain drugs compared with larval stages. Albendazole is the most commonly recommended treatment, along with high doses of corticosteroids.2

Regardless of treatment, the prognosis is poor. By the time the disease is suspected, patients are usually severely affected and there is little chance of effective treatment. Affected individuals typically die or are left with profound neurological deficits.37 There is only one report of recovery without residual neurological deficits—a 4-year-old child who had a relatively mild disease.35 Developmental disabilities, seizures, paralysis, and blindness are common sequelae.37

Prevention

Efforts at preventing *B. procyonis* infection in people are best directed against avoiding intentional or inadvertent ingestion of raccoon feces and soil from around raccoon latrines. Raccoons should not be kept as pets or encouraged to live around households. Contact with latrines and adjacent areas should be prevented, particularly by young children or other people at increased risk of geophagia or pica. Raccoon latrines should be cleaned, and contaminated areas should be disinfected.

The risk of human infection from dogs is probably very low, but measures should be taken to reduce the risk of dogs becoming exposed and potentially infected, or from having their hair coats become contaminated. Dogs should not be allowed to have contact with raccoon latrines. If a dog has been in a raccoon latrine or otherwise may have become contaminated with *B. procyonis* larvae, bathing it with soap and water to remove infective eggs is a reasonable measure. Gloves and protective outerwear (i.e., lab coat) should be worn when bathing, and hands should be washed thoroughly in soap and water after contact with a potentially contaminated animal. Ideally, bathing should occur outside. If *B. procyonis* infection is identified during routine fecal examination, treatment is warranted, as described above.

If larva migrans is suspected in a dog or other household pet, the animal should be handled on the assumption that it may also be shedding eggs in feces. Since eggs are not immediately infective, contact with the animal is relatively low risk; however, contamination of the hair coat would be possible. Care should be taken around feces of potentially infected animals. Feces should be promptly removed so that infective eggs are not formed.

Preventive therapy with albendazole is indicated in children that have ingested soil or feces potentially contaminated with *B. procyonis*.2 Prophylactic treatment of dogs that have ingested raccoon feces could be similarly considered, but the need or usefulness of this is unclear. Routine deworming targeted solely against *B. procyonis* is not indicated because of the apparent rarity of the parasite in dogs. However, most drugs used for routine monthly deworming directed against other helminths should be effective against *B. procyonis*.

**Cheyletiella** spp.

Introduction

Often referred to as “walking dandruff,” cheyletiellosis is a dermatologic disease caused by mites. Different *Cheyletiella* species have different animal hosts, but they can also infest other species, including humans. Cheyletiellosis is a mild zoonotic infection that is most often linked to infested cats.

Etiology

*Cheyletiella* species are large (350 × 500μm) mites belonging to the Arachnida class. There are three
main species in companion animals: *Cheyletiella yasguri*, *Cheyletiella blakei*, and *Cheyletiella parasitivorax*. Dogs are the host of *C. yasguri*, while *C. blakei* is found on cats and *C. parasitivorax* is found on rabbits. 49–52 *C. parasitivorax* has also been reported in dogs and cats. 33,54 A related genus, *Lynxacarus radovskyi*, can be found on cats in some regions.

### Life cycle

*Cheyletiella* are hair-clasping mites that do not burrow. Rather, they live in the fur of animals and move around freely. 49,50 Periodically, they attach to the epidermis and feed off the keratin layer. Eggs are laid on the host, attached to hairs by fine fibrillar strands. 50 Prelarvae and larvae develop within the egg, and fully developed nymphs emerge. 49 These nymphs develop through two stages and then become adults. The entire life cycle can be completed on a single host and takes approximately 35 days. 50 Adult mites may live off the host for short periods of time, with conflicting data regarding how long this may be. Some authors state that survival is typically for a few days but can be up to 10 days, while others claim that survival for up to 1 month is possible. 49,50 While *Cheyletiella* spp. can accidentally infect humans, they cannot complete their life cycle on human skin. 50,55

### Geographic distribution/epidemiology

Prevalence and incidence data for animals and humans are limited. *C. parasitivorax* was found on 57% of pet rabbits in a South Korean study, 56 but little information has been reported about typical pet dog and cat populations. It has been variably suggested that the disease is uncommon or common but frequently undiagnosed. In dogs, infections appear to occur most often in puppies. 50 No age, breed, or gender associations have been identified in cats. Infestations are most commonly found in animals in kennels or other confined systems. 49 Introduction of new animals into the household may be associated with animal and human infections, 57 although proper risk factor studies are lacking. Infested animals do not necessarily have signs of disease but can still act as a source of infection of people or other animals. 58

*Cheyletiella* species appear to be well distributed internationally. *Lynxacarus* has been most commonly reported in Australia, New Zealand, Fiji, Texas, and Hawaii. 59–64 Transmission is predominantly by direct contact between infected and susceptible individuals. Indirect transmission by the environment and fomites is also possible. Mites have also been found on fleas, lice, and flies, and these could be additional routes of transmission. 50 Human infestation appears to be relatively common, albeit mild and often undiagnosed. 65,66 One author has reported human infestations associated with 30% of infected cats, 50 but objective data on the incidence of infection are lacking. Infestations are most often associated with *C. blakei* and cats. 67–69 It is unclear if this relates to a higher infectivity of *C. blakei*, greater risk of transmission from cats to humans because of the types of cat–human interaction, or other factors. Human infestations have been associated with *C. yasguri* from dogs, 70–74 but this appears to be rare. Zoonotic *Lynxacarus* infestation has been reported on one occasion.

### Animals

**Clinical presentation**

Infection results in a variably pruritic exfoliative dermatitis with scaling and crusting, most commonly over the dorsum and rump in dogs and around the trunk, face, and tailhead in cats. 49,50 Mites are active, and the associated movement of mites and epidermal debris leads to the appearance of “walking dandruff.” The hair coat usually appears dull and dry, and may have a rust-colored tinge. Large numbers of mites and eggs may give the hair coat a granular appearance and feel. There may be excessive hair shedding, 49 and miliary dermatitis may develop in cats. 57 The distribution is usually different with *L. radovskyi* on cats. Mites are most commonly found on the tailhead, tip of the tail, and the perineum, but can be found over the entire body with severe infestations.

### Diagnosis

The presence of dorsal seborrhea sicca (dry white scales) and corresponding “walking dandruff” is
highly suggestive of cheyletiellosis. Mites are often visible to the naked eye over the dorsum. Use of magnification will assist in the identification of mites and eggs. Microscopic evaluation of mites allows for confirmation of infection and speciation. Mites may be observed with skin scrapings, not because they reside in the skin but because they are collected during the sampling process. They can also be identified with acetate tape preparations. Occasionally, mites are found in feces of cats after being ingested during grooming. Fecal examination for mites is, however, not a recommended diagnostic test.

**Management**

Ivermectin, selamectin, imidacloprid/moxidectin, or fipronil is effective. Ivermectin is also effective in rabbits. Pyrethrin- or pyrethroid-based shampoos, sprays, or spot-on formulations are effective for dogs, but pyrethroids should not be used on cats. Topical therapies are preferred by some authors because the mites do not live within the skin; however, there is good evidence of efficacy for various systemic treatments. Multiple treatments may be required depending on the potential for reinfection from other animals or the environment. All pets in the household should be treated at the same time. Bedding and grooming equipment should be disinfected or discarded.

**Diagnosis**

Diagnosis may be difficult if only the human patient is considered, and sometimes the diagnosis is only made after the pet has been diagnosed with cheyletiellosis. Mites may not be observed on the affected person and are rarely identified on skin scrapings. Usually, diagnosis is based on appropriate clinical signs and diagnosis of cheyletiellosis in a pet. Pet contact should be queried in all such cases, and the involvement of the veterinarian may be critical for diagnosis. The patient’s pet should be referred to his or her veterinarian if cheyletiellosis is suspected. Lack of history of contact with a pet with dermatologic disease does not rule out zoonotic cheyletiellosis as some animals can be infected without clinical signs. Resolution of skin lesions after treatment of the infected pet is further supportive of the diagnosis.

**Management**

Infection is self-limited since mites cannot complete their life cycle on human skin. Following elimination of infection in the pet, human skin lesions will resolve in approximately 3 weeks. Ivermectin is also effective in rabbits. Pyrethrin- or pyrethroid-based shampoos, sprays, or spot-on formulations are effective for dogs, but pyrethroids should not be used on cats. Topical therapies are preferred by some authors because the mites do not live within the skin; however, there is good evidence of efficacy for various systemic treatments. Multiple treatments may be required depending on the potential for reinfection from other animals or the environment. All pets in the household should be treated at the same time. Bedding and grooming equipment should be disinfected or discarded.

**Prevention**

Human infections are uncommon and mild, and the risk of transmission to other people is low. The mites are more likely to reside on parts of the body normally covered by clothing than on exposed skin. Frequent laundering of clothes and bedding will further help reduce the risk of transmission. The most important elements of prevention of zoonotic transmission from animals are prevention of infestation in pets and prompt diagnosis and treatment of any infestations that do occur.

If cheyletiellosis is diagnosed in a pet, owners should be made aware of the potential for accidental human infection. Pets should be promptly and appropriately treated. All pets should be treated at the same time to prevent cycling of infection in the household. The pet’s bedding, as well as other items with which the pet has frequent contact (e.g., bedsheets, sofa cushion covers).
should be cleaned thoroughly. Laundering and hot-air drying should be highly effective for this and are likely the best means of decontaminating bedding and similar items. Carpets should be thoroughly vacuumed; steam cleaning may also help eliminate any eggs or mites deep within the carpet pile. Grooming items or other objects that come into regular contact with the pet should be disinfected, or discarded if disinfection is not possible. There is little information regarding optimal cleaning and disinfection techniques. Permethrin sprays can be used to eliminate environmental contamination.25

Animals receiving monthly antiparasitic prophylaxis are typically considered to be at low risk because of the high efficacy of most available products against Cheyletiella.

**Cryptosporidium spp.**

**Introduction**

Cryptosporidiosis is an important and well-recognized zoonotic disease, particularly in people who work with young cattle. It is capable of causing severe diarrhea even in otherwise healthy, immunocompetent hosts, but it can cause life-threatening intestinal and extraintestinal infection in immunocompromised individuals. The relevance of cryptosporidiosis has increased because of its role in disease in HIV/AIDS and other immunosuppressed patients. The role of *Cryptosporidium* in disease in young cattle and humans is well established, but its clinical relevance in companion animals remains unclear. Similarly, the role of pets in human cryptosporidiosis is poorly understood.

**Etiology**

*Cryptosporidium* spp. are eukaryotic coccidian parasites of the suborder Eimeria in the phylum Apicomplexa. The taxonomy of the genus *Cryptosporidium*, like many protozoa, is controversial.88,89 Previously, two species were described, *Cryptosporidium muris* and *Cryptosporidium parvum*, but as many as 23 species have now been described based on various combinations of host predilection, geographic distribution, genotypic characteristics, and morphology.88 There is much debate as to which of these species should truly be called species with their own name versus genotypes or subgenotypes of *C. parvum*, of which there are also many.88 Currently, the more commonly accepted species (and primary hosts) include *Cryptosporidium andersoni* (cattle), *Cryptosporidium baileyi* (chickens and some other birds), *Cryptosporidium canis* (dogs), *Cryptosporidium felis* (cats), *Cryptosporidium galli* (birds), *Cryptosporidium hominis* (humans), *Cryptosporidium meleagridis* (birds and humans), *Cryptosporidium molnari* (fish), *C. muris* (rodents and some other mammals), *C. parvum* (ruminants and humans), *Cryptosporidium wrairi* (guinea pigs), *Cryptosporidium saurophilum* (lizards and snakes), and *Cryptosporidium suis* (pigs).88-90

Most cryptosporidia that infect reptiles and birds do not appear to infect mammals, except for *C. meleagridis*, which is the third most common type found in humans after *C. hominis* and *C. parvum*. *C. muris* has a limited host range91 and is not considered a significant concern in humans or companion animals (beyond rodents), although it has been isolated from a cat.92 *C. felis* can cause diarrhea in humans, although this is rare and may be of greatest concern in immunocompromised individuals. Infection is usually subclinical in cats. *C. canis* is found in dogs, with infection in both dogs and people being generally subclinical. *C. parvum* (also previously known as *C. parvum* genotype 2) has the widest host range, infecting primarily cattle (especially calves) as well as dogs, cats, sheep, goats, horses, laboratory rodents, and humans. *C. hominis* (also previously known as *C. parvum* genotype 1)89,93 is found primarily in humans and was previously thought to not cause natural infection in other species88 but has since been found in a few isolated animal cases.94 Nonetheless, *C. hominis* is responsible for the majority of human cryptosporidial infections.88 These various species can only be definitively differentiated based on DNA/genetic testing. The question remains whether or not other strains/species of the parasite are a significant public health threat in general, a threat to only immunocompromised individuals, or not a threat at all,88 as host adaptation does not necessarily imply host specificity.83 The five most common species of
Cryptosporidium (C. hominis, C. parvum, C. meleagridis, C. felis, and C. canis) have been found in both immunocompromised and immunocompetent individuals.\textsuperscript{88,95} Case reports of human infection with more uncommon species and genotypes have also been recently published.\textsuperscript{96–98}

**Geographic distribution/epidemiology**

Cryptosporidium infection has a worldwide distribution. The prevalence of oocysts in human feces in North America is thought to be between 0.6\% and 4.3\%\textsuperscript{99} In the United States, 15–32\% of the population may be seropositive for Cryptosporidium,\textsuperscript{100} while seropositivity in developing countries may be as high as 65\%,\textsuperscript{99} indicating that exposure is common. Outbreaks of clinical disease in humans have been associated with contaminated food or water, but not household pets. From 1991 to 2000, Cryptosporidium was implicated in 40/106 outbreaks of recreational water-associated gastrointestinal disease and 11/130 outbreaks of drinking water-associated gastrointestinal disease.\textsuperscript{101–106} However, outbreaks account for less than 10\% of diagnoses of Cryptosporidium in the United States,\textsuperscript{90} and large outbreaks would not be expected to occur from contact with pets. The limited information regarding the role of pets in human cryptosporidiosis must be tempered with an understanding that sporadic cases of cryptosporidiosis, the most likely form of pet-associated disease, would likely be undiagnosed or underreported, if they occur.

Risk factors for human infection include contact with infected farm animals, ingestion of contaminated recreational or drinking water, close contact with infected persons, and travel to high prevalence areas.\textsuperscript{83,99} Cryptosporidiosis is more common in immunocompromised individuals as well as in children under 2 years old, livestock handlers (particularly dairy farmers), and men that have sex with men.\textsuperscript{99} In most studies, contact with pets is either not associated or negatively associated with the risk of cryptosporidiosis, even among immunocompromised owners.\textsuperscript{90,106} Along with the negative association with pets, some studies have found a negative association with consumption of raw vegetables, and it has been hypothesized that these associations may be the result of repeated low-dose exposure to the parasite, producing better immunity and decreased disease.\textsuperscript{90} In contrast, several studies have shown contact with calves or cows\textsuperscript{107–109} or farm visits\textsuperscript{110} to be significant risk factors for cryptosporidiosis for the general population. Cryptosporidial diarrhea is also common among children in daycare centers, making daycare workers at higher risk for infection.

Some studies have shown a predominance of C. parvum among isolates from sporadic cases of cryptosporidiosis, compared with outbreaks in which C. hominis is usually implicated.\textsuperscript{110,111} These studies and other reports\textsuperscript{90} cite this as evidence of zoonotic transmission from livestock (primarily cattle), although given that humans are capable of carrying both species, human-to-human transmission of C. parvum must also be considered. Better epidemiological evidence and demonstration of contamination of the water source with infectious effluent from cattle are required to determine the source of the C. parvum in these cases.

Exposure to Cryptosporidium appears to be common in animals. Reported seroprevalence rates in domestic and feral dogs and cats range from 1.3\% to 74\%, depending on the region and type of population studied.\textsuperscript{112,113} Cats that are allowed outdoors are more likely to be seropositive.\textsuperscript{113} Shedding of cryptosporidial oocysts (or the presence of cryptosporidial antigen in feces) is less common, typically ranging from 0\% to 8\%.\textsuperscript{114–119}

In all affected domestic animal species, young unweaned animals are more susceptible to infection and disease from Cryptosporidium than adults.\textsuperscript{99} In general, kittens less than 6 months of age and cats living in households with more than one cat or with a dog are more likely to be infected.\textsuperscript{120}

Cryptosporidium can also be commonly identified in ferrets,\textsuperscript{121} but most, if not all, belong to the ferret genotype of C. parvum. It is unknown if this genotype can cause disease in humans.\textsuperscript{122}

Transmission of the infection occurs through ingestion of oocysts that are shed in the feces of infected humans or animals. As few as 30 oocysts of C. parvum can cause subclinical infection in an otherwise healthy person, and as few as 100 oocysts can cause clinical cryptosporidiosis,\textsuperscript{100} whereas as few as 10 oocysts of C. hominis can cause clinical disease in humans.\textsuperscript{123} There are three major routes of transmission in people: person to person, which is particularly important in daycare settings with young children; animal to person, which is some-
times implicated in outbreaks in rural areas although the relative importance of this route remains unclear; and transmission via contaminated water (or food) sources, which is a well-recognized route in outbreaks. Although owning a dog or a cat has not been identified as a risk factor for cryptosporidiosis in humans, transmission of the parasite from these animals to humans is possible. The most common species of Cryptosporidium in dogs, C. canis, has only been reported to cause subclinical infection in a few immunocompetent individuals. In contrast, C. felis has been reported to cause watery diarrhea in both immunocompetent and immunosuppressed individuals.

Life cycle

Cryptosporidia can undergo their entire life cycle in a single host. Animals or humans are infected by ingesting oocysts from the feces of other infected individuals. In the small intestine, the oocysts release sporozoites that invade the brush border of the epithelium, forming intracellular but extracytoplasmic vacuoles containing trophozoites. The trophozoites replicate asexually to form type I meronts containing merozoites. The released merozoites go on to replicate in other intestinal epithelial cells to form more type I meronts as well as type II meronts. Type II meronts reproduce sexually, producing macrogamonts and microgamonts. Fusing of one of each type of gamont results in the formation of a zygote, which in turn forms an oocyst containing four sporozoites. The oocysts are either thin or thick walled. Thin-walled oocysts rupture within the intestine, and the entire life cycle is repeated (autogenous infection). Thick-walled oocysts are passed in the feces and are immediately infectious to the next host.

Animals

Clinical presentation

Patent infections may be present in cats and dogs with no accompanying clinical signs. It is therefore debated whether or not the organism causes diarrhea in otherwise healthy, immunocompetent cats and dogs, or whether it may be a secondary finding in cases of other gastrointestinal disease. When clinical signs are associated with infection, the primary sign is diarrhea. In both dogs and cats, diarrhea is most severe in immunocompromised animals.

Clinically affected cats typically exhibit high-volume, low-frequency (small bowel type) diarrhea but can chronically develop tenesmus and hematochezia. In puppies experimentally infected with C. parvum from calves, the prepatent period was 3–5 days, peak shedding occurred at 7–9 days, and intermittent or low-level shedding continued for at least 80 days.

The parasite may be a primary pathogen in birds in which it can infect both the gastrointestinal and respiratory tracts and bursa of Fabricius. Cryptosporidia tend to infect the stomach of reptiles and therefore cause gastritis and vomiting.

Diagnosis

Although oocysts can be seen on direct fecal smears, concentration techniques using sugar solutions (e.g., Sheather’s solution, specific gravity 1.2–1.25) for fecal flotation are preferred. The use of phase-contrast or bright-field microscopy is recommended to detect oocysts on unstained preparations. Oocysts are typically slightly smaller than erythrocytes (approximately 2.5–5 μm in diameter) and are refractile (Figure 1.1). They appear as circular or possibly concave disks; dark shadows of four banana-shaped sporozoites can sometimes be seen within them. On wet mounts stained with crystal violet, the oocysts are apparent because

Figure 1.1 Cryptosporidium parvum oocysts (4–5 μm) in a stool sample from a person with cryptosporidiosis (public domain, Dr. Peter Drotman, Centers for Disease Control and Prevention).
they do not pick up stain. Of the various species that infect mammals, only *C. muris* and *C. andersoni* oocysts can be differentiated morphologically from the others.

Diagnostic laboratories may use formalin-ethyl acetate sedimentation followed by direct fluorescent antibody staining. The fluorescent antibody test has been used as the reference standard for comparison of other diagnostic tests. Enzyme-linked immunosorbent assays (ELISAs) designed for detection of parasitic antigen in human fecal samples are also available, although it is unknown if these tests can consistently identify certain species such as *C. canis* and *C. felis*. In a comparison of three antigen-based assays on feline fecal samples, the ProSpecT Microplate Assay had the highest sensitivity (71.4%) and specificity (96.7%) for detection of cryptosporidial antigen, compared with a direct fluorescent antibody test. Compared with fluorescent antibody testing of fecal samples from experimentally infected cats, PCR appeared to be more sensitive in another study. Further evaluation of these tests for use in veterinary medicine is warranted.

A serum ELISA for cats is available, but, as in humans, the test only indicates exposure and is not useful for predicting oocyst shedding in individual animals. Intestinal biopsy is an impractical means of diagnosis. Organisms can be found throughout the intestine in animals but are most numerous in the ileum.

**Management**

Infection in otherwise healthy animals is self-limited. Supportive care including intravenous fluid therapy may be required to prevent or treat dehydration if diarrhea is severe and the animal’s fluid intake is inadequate. Specific treatment of coinfections, if possible, should be considered. If no coinfection exists and clinical signs are persistent or severe, specific therapy for *Cryptosporidium* could be considered, although objective information regarding treatment is limited. Currently, there are no drugs that have been shown to be consistently effective and safe for treatment of cryptosporidiosis in companion animals. Paromomycin or azithromycin are the most commonly recommended specific treatments in dogs and cats.

**Humans**

**Clinical presentation**

Frequent, watery, and nonbloody diarrhea is the predominant clinical presentation. Nausea, abdominal cramps, low-grade fever, and anorexia may also be present. Fever and vomiting are more likely to occur in children. Diarrhea may be profuse and can result in dehydration, but illness is usually self-limited in immunocompetent individuals. However, cryptosporidiosis can be a serious disease in immunocompromised individuals, with severe diarrhea (over 70 evacuations per day, losing up to 25 L in fluids), dehydration, and a potentially fatal outcome. In HIV/AIDS, disease occurs more frequently and is more severe in patients with lower CD4+ lymphocyte counts, particularly those with CD4+ counts below 200 cells/μL. The incidence of symptomatic infection and severe disease in HIV/AIDS patients has declined with the widespread use of highly active antiretroviral therapy. Transplant patients and individuals with IgA deficiency are also at increased risk of severe disease.

Rarely, nonintestinal clinical signs of cryptosporidiosis may occur following acute diarrheal disease, including joint pain, eye pain, recurrent headache, dizzy spells, and fatigue. These signs and symptoms have only been associated with *C. hominis*. Infection of the respiratory and biliary tracts may also occur in immunocompromised individuals.

**Diagnosis**

Infected persons have been reported to shed up to a billion oocysts per day, yet immunocompetent, symptomatic human patients do not always have positive stool samples, and conversely, oocyst shedding may persist for up to 15 days following resolution of clinical disease. Evaluation of at least three stool samples collected on different days is recommended. As described above for animals, oocysts can be detected by microscopic examination of stained or unstained fecal preparations. Several antigen-based fecal tests (e.g., fluorescent antibody, ELISA) are also available. PCR-based tests have been developed and appear to have a very low detection threshold (10–100 oocysts/mL compared with 10,000 oocysts/mL for the fluores-
be walked in public areas. Feces should be promptly removed and hands should be thoroughly washed. If feces are passed in the house, contaminated areas should be promptly cleaned. Thorough cleaning to physically remove oocysts is the key because oocysts are resistant to most disinfectants. Care should be taken to avoid contamination of the environment or hands when cleaning litter boxes, and hands should be thoroughly washed after (even if gloves are used).

Immunocompromised individuals, especially people with HIV/AIDS, should take particular care, especially around diarrheic animals. Careful use of general infection control measures to reduce contact with fecal pathogens is important, regardless of whether the animal has diarrhea or not. Contact with diarrheic animals should be restricted. If possible, immunocompromised individuals should have someone else pick up feces or clean the litter box. If fecal staining of the pet’s hair coat occurs, this should be promptly and thoroughly cleaned, ideally not by the immunocompromised person. If contact with feces, litter boxes, or potentially contaminated hair coats is unavoidable, gloves should be used and hands should be washed immediately after glove removal. If there has been potential contamination of clothing, clothes should be promptly removed and laundered, using hot water and a hot-air clothes dryer.

In veterinary clinics, diarrheic animals should be isolated and handled with appropriate contact precautions (e.g., gown, gloves, and designated footwear or shoe covers if there is potential fecal contamination of the floor). Currently, there is insufficient evidence to warrant full isolation of clinically normal pets in which low-level shedding of Cryptosporidium is diagnosed as an incidental finding. However, the animal should not be allowed to defecate in common animal areas, feces should be removed and disposed of promptly, and contact with immunocompromised individuals should be avoided.

Cryptosporidium oocysts are highly resistant to routine disinfectants. Oocysts are resistant to routine chlorination of drinking water and are very small (4.5 × 5.0 μm), making them difficult to filter from water. Prolonged contact with high concentrations of chemicals such as formalin (>10%) or ammonia (>50%) can be effective; however, this is typically impractical. Moist heat (e.g., steam,
pasteurization), freezing and thawing, or thorough drying are more practical means of disinfection but may not be completely effective. Oocysts survive better in cool water: after 4 weeks in water at 8°C, 75% of oocysts survive, whereas only 50% survive after 4 weeks in water at 25°C. Because oocysts are so resistant to disinfectants, preventing environmental contamination through excellent sanitation (i.e., mechanical cleaning) is critical.

**Demodex spp.**

*Demodex* mites are part of the normal microflora of mammals and are not usually associated with disease. However, overgrowth of mites in certain situations can cause alopecia or mild to moderate dermatitis. *Demodex canis* is most common in dogs, although *Demodex injai* or other species may be found rarely. In cats, *Demodex cati* predominates, while *Demodex gatoi* can be found in some regions. *Demodex folliculorum* and *Demodex brevis* are most commonly reported in humans.

In animals, particularly dogs, demodectic mange can be localized or generalized. Either form is more likely to occur in purebred dogs, but any breed or sex can be affected. The localized form is most common in puppies from a few months to 1 year of age, causing alopecia and folliculitis on the head (often around the eyes) and extremities. The vast majority of infected dogs (90%) recover without treatment, but some will progress to the generalized form. Generalized demodecosis typically occurs in young dogs (6–18 months of age) but can also occur in geriatric or immunosuppressed animals. This form of infection is often complicated by secondary bacterial pyoderma, which can be life threatening. Demodecosis is rare in cats.

Demodecosis is not considered transmissible under normal conditions, even from a clinically affected animal to other animals of the same species. Furthermore, *Demodex* mites are host adapted, and there is no convincing evidence of cross-infectivity. There is one report of identification of *D. folliculorum* in a child and his pet dog; however, that is the only report of concurrent detection of the same *Demodex* species in humans and their pet and, being a human *Demodex* species, would possibly indicate human-to-pet transmission. Accordingly, *Demodex* should not be considered a zoonotic risk.

**Dipylidium caninum**

**Introduction**

*D. caninum* is a cyclophyllidean cestode that is also referred to as the common flea tapeworm. Both dogs and cats may be affected. Human infections can occur, particularly in infants and young children, but the clinical consequences are minimal. The greatest problem in most situations is the response of pet owners, patients, or parents to seeing tapeworm segments in feces.

**Life cycle**

Like other cyclophyllidean tapeworms, *D. caninum* has an indirect life cycle that requires an intermediate host (Figure 1.2). Adult tapeworms attach to the wall of the small intestine by an armed scolex. Gravid proglottids are shed in feces, and eggs are subsequently consumed by intermediate hosts, predominantly *Ctenocephalides felis* (cat flea) and *Ctenocephalides canis* (dog flea). The chewing louse, *Trichodectes canis*, can also act as an intermediate host, but this is rare. Infectious larvae (cysticercoids) develop within the intermediate hosts, and individuals (pet or humans) are usually infected by inadvertent ingestion of infected fleas. After ingestion, the tapeworm completes its life cycle in the small intestine. Proglottids may be visible in feces 2–3 weeks after ingestion of an infected flea.

**Geographic distribution/epidemiology**

*D. caninum* is found worldwide. Prevalence data in dogs and cats are highly variable, with most of the variability depending on flea exposure and flea control practices. Shedding rates of 0.3–42% have been reported in dogs, and up to 68% in cats. Rates tend to be higher in developing countries and in stray animals, as well as in older reports. More recent studies in developed countries tend to report rates of 0.1–2% in dogs and cats. Point prevalence studies are presumed to somewhat underestimate the prevalence because proglottids and eggs are unevenly distributed in feces and can be shed intermittently. In addition, fecal tests have a low level of sensitivity.
There are numerous reports of *D. caninum* infections in humans, all single case reports and almost all involving infants or young children. The incidence of human infection is quite low, and the clinical consequences are minor. This may be considered more of a social disease, with angst surpassing true health risks.

**Animals**

**Clinical presentation**

Disease is rare, and the vast majority of infected animals are clinically normal. The most common clinical abnormality is perianal irritation that may be associated with passing proglottids in feces.

**Diagnosis**

Motile proglottids may be seen exiting the anus or, less commonly, in the pet’s environment (i.e., bedding), and this is typically adequate for diagnosis, but these must be differentiated from proglottids of *Taenia* spp. A single fecal negative sample does not rule out the presence of *D. caninum* because of intermittent shedding and nonhomogeneous distribution in stool. The eggs themselves (which are released when the proglottids rupture)
can be differentiated microscopically from those of Taenia spp. and Echinococcus spp.

**Management**

Praziquantel or epsiprantel is effective against *D. caninum* and widely used for the elimination of adult tapeworms in dogs and cats. The commercially available combinations of emodepside and praziquantel, milbemycin and praziquantel, and pyrantel and praziquantel are also effective. Treatment of tapeworms alone, however, is not adequate for long-term resolution of the problem if infected fleas are still present on the infected animal, or other animals that it has contact with. To prevent reinfection, all pets in the household should be treated for flea infestation, and measures should be taken to reduce the risk of subsequent flea exposure. This may include management changes (e.g., keeping cats indoors) or prophylactic drug administration, as are discussed in more depth elsewhere.

**Humans**

**Clinical presentation**

Infections are usually asymptomatic and only identified because patients or their parents see tapeworm segments in stool.

**Diagnosis**

Diagnosis is based on the identification of proglottids or eggs in stool.

**Management**

Praziquantel is the drug of choice. Niclosamide is another option. Pets should be treated concurrently for *D. caninum* and fleas.

**Prevention**

The main preventive measure is flea control in dogs and cats. Animals that are at risk of flea exposure should be started on an appropriate flea control program.

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**Dirofilaria immitis**

**Introduction**

*D. immitis*, the canine and feline heartworm, is predominantly an animal health threat. The greatest impact in humans may be an indirect one since infection can be mistaken for more serious conditions and can necessitate invasive procedures such as thoracotomy.

**Etiology**

*D. immitis* is a mosquito-borne nematode parasite that naturally infects canids and can accidentally infect other species such as cats, ferrets, and humans. Many different mosquito species are competent vectors, including various species of *Aedes*, *Anopheles*, *Culex*, and *Psorophora*.

**Life cycle**

The natural life cycle involves canids and mosquitoes. Microfilariae are present in the blood of infected canids and are ingested by mosquitoes while feeding from infected host. After undergoing two molts, infective L3 larvae reside in the mosquito’s mouth parts and are deposited onto the skin during subsequent feeding. Once on the skin, they migrate through the bite wound into the host, where they molt to the L4 stage in subcutaneous tissues. These worms enter the vascular system and are carried to the pulmonary arterial vasculature, where they mature. Microfilaria production is usually detectable 6–7 months after infection.

In animals with extremely heavy worm burdens, the worm mass extends from the pulmonary artery into the right atrium or ventricle. However, in some ways, “heartworm” is a misnomer since the parasite is predominantly a vascular-dwelling organism that is often not present in the heart. Typically, it is found outside of the pulmonary arterial tree only with significant burdens.

While they can be infected, cats, ferrets, and humans tend not to act as biological reservoirs and rarely have detectable microfilaraemia.
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advantages over antigen testing. This type of testing is generally good for confirmatory testing in mature infections (those occurring at least 6 months in the past).

Radiography and echocardiography may be used to provide evidence of clinical heartworm infection involving the pulmonary arterial vasculature.

Management

Stabilization of the patient and management of clinical abnormalities that are occurring as a result of infection are important and may include the use of anti-inflammatories, diuretics, intravenous fluids, vasodilators, or positive inotropic agents.

Melarsomine dihydrochloride is the adulticide of choice. It is, however, ineffective against heartworms younger than 4 months of age, which may result in initial treatment failure. Macrocyclic lactones have been used as adulticides but are not recommended. These drugs are effective against microfilaria and migrating L3 and L4 larvae; they will also effectively sterilize adult worms (thus eliminating the risk of transmission to other animals via mosquitoes) and shorten the life span of adult worms. A combination of a macrocyclic lactone and melarsomine has been recommended because of the ability to kill a wider age range of worms and to kill microfilaria, thereby preventing transmission. In cases where clinical signs are not present, administering a macrocyclic lactone for up to 3 months prior to melarsomine therapy is a reasonable option.

A combination of ivermectin and doxycycline has been shown to have microfilaricidal and adulticidal activity and may be another option.

Surgical excision of adult worms can be considered with large worm burdens and is required promptly in dogs with caval syndrome and when infections in cats cannot be managed clinically. Melarsomine is contraindicated in cats.

Humans

Clinical presentation

The most common result of _D. immitis_ infection in humans is the development of vasculitis in the

Geography/epidemiology

The prevalence of _D. immitis_ varies geographically, with a high prevalence (up to 70%) in some dog populations. In North America, higher rates in dogs tend to be found in the southeastern United States and Mississippi River valley. Human infections follow the same pattern. In Europe, there is a similar distribution with widespread presence in southern countries with few to no cases in northern regions. Italy has the highest number of reported European cases. The geographic variation likely involves the prevalence of mosquito vectors, climate, the size of wild canid populations, and the percentage of pet dogs receiving routine heartworm prophylaxis.

Human infections are uncommon but have been reported internationally. The incidence of disease is not known, and the available literature consists solely of case reports or small case series.

Animals

Clinical presentation

In dogs, infection may result in pulmonary vasculitis, pulmonary hypertension, right-sided heart failure, and, less commonly, infections of other systems including the CNS. Severe respiratory disease can develop from rapid death of juvenile or adult worms if embolization of dead worms to the lungs occurs. Cats can be similarly infected, but much less often than dogs and tend to have short-term or nondetectable microfilaremia.

Diagnosis

Serum antigen testing is the most sensitive method of diagnosis in dogs; however, infections occurring within the previous 6 months and those involving low worm burdens may be missed. The specificity is very high, but positive tests are usually repeated. Repeated testing of negatives is indicated if there is a clinical suspicion of heartworm disease.

Detection of microfilaria in circulation used to be the standard for diagnosis but is uncommonly used now for either screening or diagnostic purposes because microfilaria are not present in all infected animals at all times, and there are few
small to medium branches of the pulmonary tree after the parasite dies. Overt clinical disease is present in less than 50% of patients with pulmonary dirofilariasis at the time the lesion is identified.\textsuperscript{182,193} Primary and secondary tumors, cysts, and granulomas can have the same radiological appearance, and because of the concern regarding malignancies, thoracotomy and biopsy are often the approach that is taken for any such lesion.\textsuperscript{182} This is compounded by the lack of accurate serological testing for humans to differentiate \textit{D. immitis} from other causes that require invasive surgical procedures. Considering the morbidity and healthcare costs associated with such an aggressive approach, the indirect impact of \textit{D. immitis} infection is apparent.

When clinical signs are present with pulmonary dirofilariasis, cough, chest pain, or hemoptysis may be reported, often associated with pulmonary infarction.\textsuperscript{192} Infections of other body sites may occur, including the eye,\textsuperscript{200} CNS,\textsuperscript{198} adipose tissue,\textsuperscript{202} liver,\textsuperscript{199} and testicular vasculature.\textsuperscript{204}

\textbf{Diagnosis}

The inflammatory response can ultimately lead to development of a granuloma with the radiographic appearance of a “coin lesion.”\textsuperscript{182} The lesion is a nonspecific finding that simply indicates a discrete pulmonary lesion but cannot be differentiated from malignancy.

Diagnosis is histologically from biopsy samples collected to rule out neoplasia. Dead intact worms are often visible, along with associated vasculitis and infarcted tissue, usually within a granuloma. Eosinophilic inflammation is sometimes present.\textsuperscript{193} Serological testing is not currently accurate enough to rely on.\textsuperscript{193,194} Microfilaremia does not occur in humans.\textsuperscript{194}

\textbf{Management}

Treatment is typically unnecessary since the diagnosis is usually incidental and humans are dead-end hosts for the parasite.\textsuperscript{197,209}

\textbf{Prevention}

Humans do not acquire \textit{D. immitis} directly from dogs and cats. However, dogs are likely the primary reservoir hosts and can infect mosquitoes that may subsequently bite and infect humans. Infected cats pose little to no public health risk because they are typically amicrofilaremic. Prevention of human infections involves two main components: decreasing \textit{D. immitis} in dogs and mosquito avoidance.

A variety of routine monthly preventive therapies are available for dogs, including milbemycin oxime, moxidectin, ivermectin, and selamectin. A 6-month injectable moxidectin formulation is available for use in dogs. These drugs should be administered to dogs throughout the transmission season in heartworm-endemic areas. The climate and period of mosquito activity must be considered when deciding the duration of preventive therapy. In some regions, there may be a risk of exposure all year, while in cooler climates, there may only be a risk for a fraction of the year. Annual serological testing of dogs is widely recommended, even in dogs that have received regular prophylactic therapy because of the possibility of treatment failure, missed drug doses, mosquito exposure outside of the treatment period, or other factors that could lead to infection of dogs receiving chemoprophylaxis. Annual testing is less effective in low prevalence areas because of the low predictive value of positive results.

General behavioral practices to avoid exposure to mosquitoes include avoiding areas of mosquito activity (particularly at dusk and dawn), wearing clothing that covers the arms and legs when in areas where mosquitoes may be present, using mosquito repellents, and eliminating standing water and other mosquito breeding grounds.

\textbf{Echinococcus spp.}

\textbf{Introduction}

\textit{Echinococcus granulosus} and \textit{Echinococcus multilocularis} are two species of cyclophyllidean tapeworms that have dogs (\textit{E. granulosus}) or both dogs and cats (\textit{E. multilocularis}) as their definitive hosts. Humans are intermediate hosts that are inadvertently infected from the feces of infected definitive hosts, with dogs posing the greatest risk. Echinococcosis is a rare but potentially devastating condition caused by the development of larval cysts in the liver, lungs, brain, or other tissues.
Etiology

*E. granulosus* is maintained in both domestic and sylvatic cycles. The domestic cycle involves dogs that are infected by ingestion of *E. granulosus* cysts in the intestinal viscera of infected ungulates (e.g., sheep) or in the muscle of rabbits. The sylvatic cycle is similar, with wolves and foxes being the main definitive hosts and becoming infected from ingestion of infected ungulates (e.g., moose) or rabbits. Humans can become infected by inadvertently ingesting eggs from canine feces.

*E. multilocularis* is the most pathogenic *Echinococcus* and is normally transmitted in a cycle involving wild canids such as the red fox, arctic fox, and sylvatic rodent species, along with other wild mammals. Pet dogs and cats can be infected with *E. multilocularis* following ingestion of infected rodents. As with *E. granulosus*, humans are accidental hosts that are infected by ingesting eggs from feces.

Another species, *Echinococcus vogeli*, is found in the South American highlands and is transmitted by wild canids. Because this species is rare and not associated with pets, it will not be discussed further here.

Life cycle

Adult worms inhabit the small intestine. The tape-worm consists of a head (scolex), neck, and tail (Figure 1.3). The neck and tail are made up of a chain of independent but connected segments: proglottids. Each proglottid has male and female sexual organs and produces eggs. Egg-laden proglottids break free of the adult worm and are shed in feces. Eggs may be released in stool if the proglottid degenerates, or may be shed still contained within the proglottid. Millions of eggs can be shed daily by an infected definitive host. Eggs are embryonated and immediately infective to the next susceptible host. The prepatent period is 1–2 months.

After ingestion by an intermediate host (including humans), the egg hatches in the small intestine and releases an oncosphere. This penetrates the intestinal mucosa and reaches the systemic circulation, where it can be disseminated to virtually any part of the body. A larval (metacestode) cyst may develop, depending on the tissue/organ that the oncosphere reaches and the *Echinococcus* species. In the viscera, oncospheres encyst.

The life cycle is completed when a definitive host ingests an infected intermediate host, and the cyst develops into an adult tapeworm in the definitive host’s small intestine.

Geographic distribution/epidemiology

Animals

*E. granulosus* is most common in Africa, the Middle East, southern Europe, Latin America, and the southwestern United States. The prevalence of *E. granulosus* infection of dogs also varies greatly within regions. Rates of 5–18% have been reported in stray dogs in endemic regions, with rates of 1.8–51% in pet dogs. Reported risk factors include infrequent (>4-month interval) treatment with praziquantel, being allowed to roam, being fed offal from intermediate hosts likely to be infected, and lack of owner knowledge about *Echinococcus*. The sylvatic life cycle is most important for maintenance of this parasite in most regions. High rates of infection are present in species such as moose in some regions.

*E. multilocularis* is most common in temperate and holarctic regions of the Northern Hemisphere, including the northern forest regions of Europe, Switzerland, the midwestern United States, Asia (particularly China and Japan), and the
The United Kingdom, Ireland, Sweden, and Malta are considered free of the parasite. As with *E. granulosus*, the prevalence of *E. multilocularis* infection varies greatly between and within regions. Rates of up to 58% have been reported in stray dogs in endemic regions, and 0.2–23% in pet or working dogs. Reported risk factors for fecal shedding by dogs include being fed raw viscera, catching rodents, the density of intermediate hosts in the area, and being allowed to roam. These risk factors are all associated with increased likelihood of ingestion of infected wildlife or being fed potentially infected foods. Limited feline prevalence data are available. While *E. multilocularis* eggs have been found in feline feces in different regions, the prevalence appears to be quite low. One study of over 10,000 cats identified *E. multilocularis* eggs in only 0.25% of samples. Experimental studies suggest that cats are poor definitive hosts of this species and are probably less important than dogs in maintenance of infection and transmission to humans.

For both *Echinococcus* species, the prevalence in animals is likely underestimated because of infrequent shedding of proglottids and eggs in the feces of infected animals, and the corresponding potential for false-negative fecal examinations.

**Hydatid cyst disease in humans**

*E. granulosus* infection of humans results in hydatid cyst disease (cystic echinococcosis). The main sites of *E. granulosus* hydatid cyst formation are the liver (50–70% of patients), followed by the lungs (20–30%). Other body sites are uncommonly affected, including the brain, heart, kidneys, and bones. In most (80%) patients, a single cyst is present. Hydatid cysts grow relatively slowly but can reach 5–10 cm in diameter over the first year. Cysts are typically filled with clear fluid containing brood capsules and protoscolices. Calcification of cysts is not uncommon. Depending on the location, cysts can reach large sizes over long periods of time (years to decades) before clinical signs are noted. Cysts may undergo asexual budding, resulting in the formation of “daughter” cysts within the main cyst. Proliferation of cysts may also occur following spontaneous or trauma-induced rupture of cysts, with subsequent release of protoscolices into the circulation or local tissues. The space-occupying nature of the hydatid is the reason for most clinical signs, and pressure on adjacent organs can result in impaired function or atrophy.

The incidence of hydatid cyst disease is low, having been estimated or reported at <1–220 per 100,000 persons in endemic regions. Living in a rural area, feeding offal to dogs, and owning a dog are reported risk factors. Housewives, farmers, and laborers have been reported as overrepresented among the infected population in endemic areas.

**Alveolar cyst disease in humans**

*E. multilocularis* infection produces alveolar hydatid disease (alveolar echinococcosis), a particularly serious disease that is characterized by tumorlike infiltration of local tissues. Metacestodes of this species almost exclusively develop in the liver (particularly the right lobe), though infections in other organs and tissues are possible. Cysts can range in morphology from collection of a small number of tiny (few millimeters) cysts to infiltration of various tissues with large (15–20 cm or greater) cysts. Lesions may develop granulomatous infiltrates, microcalcifications, and necrotic cavities. Spread to distant parts of the body can also occur through liberation of cystic contents into circulation.

The incidence of alveolar cyst disease is also low, being estimated at 0.03–6.6 per 100,000 persons in endemic regions. Despite the rarity of infection, this is a significant public health concern because of the severity of disease. There is evidence that dogs play a major role in human infection, at least in some regions. Reported risk factors for human infection include dog ownership, total number of dogs owned, cat ownership, and the distribution of small mammals’ habitats.

**Animals**

**Clinical presentation**

Clinical disease is rare and abnormalities are not usually identified, even with large worm burdens. Perianal irritation can occur from passage of proglottids, resulting in chewing at the anus or “scooting.”
Diagnosis

Occasionally, motile proglottids may be seen exiting the animal’s anus. Proglottids may occasionally be identified by pet owners on bedding or other environmental surfaces, or in the animal’s feces. Examination of the segment can be performed to differentiate Echinococcus spp. from other tapeworms. Proglottids are 1–2 mm in length and may contain 300 (E. multilocularis) to 600 (E. granulosus) eggs. Fecal flotation can be used to detect eggs that have been liberated from damaged proglottids; however, the intermittent nature of shedding means that a single negative sample does not rule out Echinococcus infection. Echinococcus spp. eggs cannot be differentiated from Taenia spp. eggs microscopically. To increase the sensitivity of fecal testing, purgation with substances such as arecoline can be used. This is not practical or justifiable in normal clinical settings.

Coproantigen testing is a potentially promising option, considering the limitations of microscopic testing. It has been shown to be able to reliably detect burdens of >50 Echinococcus worms in dogs and to be more sensitive than arecoline purgation. PCR may be a good option for identification and speciation in the near future.

Management

Praziquantel is effective against both E. granulosus and E. multilocularis and is the drug of choice. Epsiprantel is also effective against E. multilocularis in dogs and cats, but unlike praziquantel, is not licensed for this purpose. Concurrent measures should be taken to reduce the risk of reinfection. If no management changes are made, reinfection is likely.

Humans

Clinical presentation

Hydatid cyst disease
Most infections are asymptomatic, even with large lesions, as long as the cyst is not compromising organ function. Often, cysts are only identified as incidental findings on imaging studies. However, disease can occur, ranging from mild to fatal.

Clinical signs usually result from the space occupying nature of the cyst(s) in a confined space. Signs and symptoms relating to hepatic involvement include abdominal pain and a sensation of the presence of an abdominal mass. Cough, dyspnea, chest pain, and hemoptysis may be present with pulmonary involvement. Headache, vomiting, hemiparesis, visual deficits, seizures, and diplopia can occur with intracranial cysts.

If hepatic cysts erode into the biliary tract, cyst contents, including daughter cysts, may be released and result in biliary obstruction. Entry of bacteria into cysts can result in abscessation. If cysts leak or rupture, there can be a severe allergic (including anaphylactoid) reaction to cyst contents. Even if there is no severe allergic response to cyst rupture, this event can cause further problems from the dissemination of daughter cysts to other parts of the body. This can result in multiorgan involvement (and failure), with associated high morbidity and mortality.

Alveolar cyst disease
The onset of disease is usually gradual, with progressive signs relating to the organ that is involved. The incubation period is at least 5–15 years. Jaundice and epigastric pain are common signs when there is hepatic involvement. Serology is a relatively sensitive (80–100%) and specific (88–96%) method for differentiating liver cysts from other cystic structures, but it is less sensitive for the lungs and other organs.

Diagnosis

Hydatid cyst disease
The main method of diagnosis is the identification of obvious cysts using imaging studies, such as ultrasonography, CT, or MRI. Serology is a relatively sensitive (80–100%) and specific (88–96%) method for differentiating liver cysts from other cystic structures, but it is less sensitive for the lungs and other organs.

Alveolar cyst disease
Imaging with ultrasonography, CT, or MRI is often suggestive of neoplasia. In those instances, a suspicion of alveolar cyst disease usually arises after biopsy. Serological testing is useful, as described for hydatid cyst disease. Ultrasound-based screening has been used for early diagnosis of infection in some regions.
For both forms, testing of feces is useless because adult tapeworms do not develop in the intestinal tract.

Management

Hydatid cyst disease
Treatment is indicated for cysts that are causing clinical illness. Cysts that are identified incidentally and are not causing clinical problems should be monitored to detect potential complications. Ideally, clinically relevant cysts are surgically removed en toto, taking care not to rupture the cyst during removal. Rupture of the cyst during surgery can be fatal. Surgery is indicated for large liver cysts with multiple daughter cysts; single liver cysts that are superficially situated and may rupture spontaneously; cysts communicating with the biliary tree; cysts putting pressure on adjacent organs; and cysts in the lungs, brain, kidney, bones, or other organs. Surgical excision is preferred because it is the only approach with a likelihood of complete cure. Because of the potential for dissemination of infection with cyst rupture during removal, a common approach is to expose the cyst surgically, to remove some cystic fluid, and to infuse a cysticidal agent such as hypertonic saline cetrimide or ethanol. After approximately 15–30 minutes, surgical removal of the cyst is performed. While commonly used, there is little objective evidence supporting this approach and its use has been questioned. Infusion of cysticidal agents should never be performed when there may be communication with other structures such as the biliary tree. Alternative approaches involve anthelmintic treatment for 4 weeks, followed by a 2-week “rest period” before surgery. Albendazole is the drug of choice.

Surgery may not be an option, depending on patient factors or the presence of multiple cysts, cysts that are difficult to access surgically, cysts that are partially or totally calcified, and very small cysts. Anthelmintic therapy alone is unlikely to be curative but may reduce clinical signs. A cure rate of 30% has been reported for anthelmintic therapy alone, with reduction of cyst size in a further 30–50%. Drug therapy is more effective in young patients and patients with small, thin-walled cysts without secondary infection or communication. Another approach to inoperable cysts is the puncture, aspiration, injection, re-aspiration (PAIR) method. Mortality is uncommon (2–4%) if proper medical care is provided.

Alveolar cyst disease
Treatment of alveolar cyst disease is complicated and best performed by people with previous clinical experience. Early diagnosis is a key factor for successful treatment, but that is often a limiting factor because of the typically advanced state of the disease by the time it is diagnosed.

Surgical resection of the entire cyst is the treatment of choice, and radical excision of the entire lesion that is localized to a liver lobe is often the only potential curative treatment. Wide surgical margins are desired. Unfortunately, complete excision is not always possible. Anthelmintic therapy is indicated after surgery, and long-term treatment is required if there was incomplete resection of the lesion(s). Preoperative albendazole is sometimes used to reduce the risk of dissemination during surgery.

If surgical resection is not possible, treatment with albendazole or mebendazole has been used with some clinical success, although this should be regarded more as parasitostatic than parasitocidal therapy. Frequent monitoring is required, including PET scan and serological testing. Praziquantel has been evaluated, but animal model data indicate that it is much less effective against metacestodes compared with the other drugs. Liver transplantation has been performed in some cases. Regrowth of cysts or formation of distant cysts is a concern because of transplant-associated immunosuppressive therapy.

Mortality rates are much higher than in hydatid cyst disease. Seventy percent mortality within 5 years and 94% within 10 years has been reported, although screening to detect earlier infection can significantly reduce mortality.

Prevention

The need for, and intensity of, preventive measures depend on the risk in the geographical region. There are two main aspects for prevention of pet-associated zoonotic infection: decreasing the prevalence of Echinococcus spp. in pets and decreasing human exposure to Echinococcus eggs.
Decreasing *Echinococcus* prevalence in pets involves decreasing exposure and anthelmintic treatment. Since pets can acquire infection by ingestion of wild animals, decreasing roaming and scavenging is important. Keeping animals indoors is most effective, although it is not completely preventive because of the potential for exposure to infected rodents in the household. Accordingly, concurrent rodent control should be used to help reduce exposure to *E. multilocularis*. If animals are allowed outdoors, they should be kept on a leash or in a fenced yard. Offal from sheep or other potential intermediate hosts should never be fed to pets to prevent exposure to *E. granulosus*. Routine prophylaxis could be considered in areas where *Echinococcus* is endemic, particularly when there is reasonable likelihood of wildlife exposure. Deworming every 6 weeks has been shown to be effective in controlling *E. granulosus* in high-risk dogs, and this has been used as a mandatory control measure in some endemic regions. However, a study of rural dogs in Argentina, where such a program was in place, reported an 18% prevalence of cestode shedding, indicating issues with effectiveness of the program. Whether this is due to inadequate treatment of dogs, continued access to infected animals or offal, or some other reason, is unknown. Clearly, focusing on deworming alone may not necessarily have the broad impact that could be expected. Monthly treatment with praziquantel has also been recommended in endemic areas when pets have a reasonable expectation of being exposed, but the efficacy of this approach is unknown.

Decreasing human exposure to *Echinococcus* eggs in feces involves attention to hygiene, including prompt removal of pet feces and routine hand hygiene. Particular care should be taken by people that are in contact with soil in endemic areas with a high likelihood of contamination from foxes or dogs. When infected animals are treated, there is a window of time (~72 hours) where large numbers of eggs may be shed, necessitating extra attention to fecal handling and hygiene during the initial treatment period.

Disinfection of the outdoor environment is impractical so environmental efforts should be directed at decreasing contamination by removing feces, controlling feral animal populations, and decreasing the prevalence of infection in pet dogs. Multimodal approaches, including controlled slaughtering and meat inspection, as well as routine deworming of pet dogs, have been attributed with controlling human *Echinococcus* infection in some regions, although the true impact of different components is unknown. Monthly baiting with anthelmintics has also been used with success to reduce infection of periurban foxes. *Echinococcus* eradication programs have been successful in Iceland and New Zealand, and similar efforts are under way in other areas.

Early diagnosis of alveolar cyst disease is important, considering the potential severity of disease and treatment difficulties. Active screening programs have been shown to be successful in the reduction of morbidity and mortality in endemic regions.

Praziquantel treatment of imported dogs is mandatory in some *Echinococcus*-free countries. This is to reduce the risk of exposure of people and infection of wildlife, something that could result in endemic infection, and the potential for imported dogs to establish the parasite in the wildlife population is the main concern.

*Eucoleus aerophilus*

Previously known (and sometimes still referred to) as *Capillaria aerophila*, *E. aerophilus* is a trichurid nematode of the lungs that has been called an emerging zoonotic pathogen, although this designation is rather questionable. It can be found in dogs, cats, and wildlife (particularly foxes) in most, if not all, regions of the world. Foxes are thought to be the main reservoirs. Generally, low rates (<6%) are found in dogs and cats, with higher rates in some wildlife populations. Adult lungworms live within the epithelium of the bronchioles, bronchi, and trachea. Female worms lay eggs that are coughed up and swallowed, and subsequently passed in feces. Eggs are not immediately infective and require 30–45 days in the environment to pose a risk of infection. After ingestion by earthworms, eggs can develop into infective larval stages within the earthworm, although there is some debate as to whether earthworms are required for completion of the lifecycle. Infection of new hosts occurs through ingestion of embryonated eggs or earthworms. Ingested eggs
then hatch in the small intestine and larvae migrate to the lungs via the bloodstream.

Infections in dogs and cats are usually mild or subclinical. Coughing, sneezing, and nasal discharge may be observed. Occasionally, severe infections can be encountered, including respiratory distress. Diagnosis is based on the identification of eggs in feces or bronchoalveolar lavage fluid. Care must be taken to avoid misdiagnosis as Trichuris, since the eggs have a similar appearance, although Trichuris eggs are larger. While there are no controlled studies, treatment with ivermectin or fenbendazole appear to be effective.

While publications regarding this organism in dogs and cats have discussed zoonotic concerns, evidence is rather sparse. There are few reports of human infection. One described pulmonary capillaritis in a child in Iran that was probably caused by this parasite. Another describes pulmonary disease that mimicked bronchial carcinoma. In neither case was there adequate investigation of possible sources, and pet contact was not reported. Accordingly, there should be minimal concern about zoonotic transmission, particularly in households considering the 30- to 45-day period that is required for eggs to become infective. Proper litter box management should essentially negate the risk of exposure in the household as long as there is no fecal incontinence or long-term fecal staining of the hair coat. The risk of human exposure is presumably greatest from outdoor activities such as gardening that could result in contact with infective eggs from feces or earthworms, and hand hygiene is likely the most important preventive measure.

Etiology

Fleas are small, wingless insects that are 2–4 mm in length, with laterally compressed bodies. More than 2200 species and subspecies of fleas have been identified, but only a small number infect dogs and cats on a regular basis. Despite the name, dogs are primarily infested with Ctenocephalides felis (cat flea). C. canis can be found in wild and domestic canids but is not commonly found in pet dogs. Other fleas such as the Pulex irritans (human flea) and Echidnophaga gallinacea (poultry sticktight flea) can also infest dogs. C. felis is the predominant flea in cats, although other species like P. irritans and E. gallinacea may also be encountered. P. irritans primarily infests humans but can also infest a wide range of species, including cats, dogs, wild canids, and pigs. E. gallinacea is primarily found on poultry but may occasionally infest cats, dogs, and other species. Pulex simulans is mainly found on rodents but can also infest dogs, cats, and various mammals. Despite the vast number of flea species and subspecies, and the variety of fleas that can potentially infest dogs and cats, C. felis is the most important species in companion animals and their human contacts.

Life cycle

Adult fleas deposit eggs on the hair coat of the host or in the environment; however, eggs on the host quickly fall off and contaminate the environment. Eggs are small (~0.5 mm), oval, and pearly white, and are not easy to identify.

Larvae hatch after 1–12 days, depending on the temperature and humidity. Larvae feed on blood from flea feces, organic debris, and flea eggs that are present in their environment. Preferred environments are undisturbed, protected sites that are cool and shady. Larval development does not occur in areas exposed to direct sunlight, and larvae actively avoid light by burrowing deep into carpet fibers or under organic debris. Larvae molt twice then develop into pupae in this protected environment. Moisture is essential for development, and larvae typically fail to develop if the relative humidity is less than 50%.

With optimal environmental conditions (27°C and 80% humidity), adults begin to emerge from pupae in approximately 5 days, although pre-
emerged adults may remain quiescent for weeks or months in the absence of suitable stimuli (carbon dioxide, heat, physical pressure) that indicate the presence of a host. After emergence, adults locate hosts using visual and thermal cues, and need to find a host and feed within a few days. Under typical household conditions, this life cycle is completed in 3–8 weeks.

Within 20–24 hours of initial feeding, the females will start to produce eggs, and a female flea may lay several hundred eggs over the course of her approximately 50–100 day life span. Adult fleas can survive off the host for a short period of time. Data regarding survival off the host are somewhat conflicting with some sources indicating all will typically die within 1–2 weeks if a new host is not found and others stating that they can live for 2 months or longer off the host.

Geographic distribution/epidemiology

Flea infestation is very common internationally, and *C. felis* can be found worldwide. There can be a significant variation in the prevalence of fleas and risk of exposure between and within different regions. Fleas are much less common in regions where humidity tends to remain below 50%. In cold and temperate climates, fleas are most common in the summer and fall, and no stage of the life cycle can survive more than 10 days at 3°C or 5 days at 1°C. There is less seasonality in warmer climates, although infestations are still more common or severe in the summer and fall. Studies of pet dogs and cats have reported infestation rates of 6.8–17% and 2.5–23%, respectively. Rates of infestation tend to be highest in household pets that have outdoor access, in multipet households, and in households with cats.

The environment is the main source of infection of animals. Direct transmission of adult fleas from an infected host can also occur, but this likely accounts for a minority of cases. Animal–animal transmission can occur between pets in the same household, between pets from different households that have transient contact (i.e., parks, boarding kennels, veterinary clinics), between pets and stray animals, and between pets and wildlife. Both the environment and direct contact with infected animals are potential sources of exposure in humans. The relative importance of each is unknown.

There are two main human health consequences that can arise from exposure to fleas on pets. One is transient or recurrent pruritis from flea bites. This is not a universal response to flea bites and only occurs in sensitized individuals in response to antigenic substances in flea saliva, through type I and type IV hypersensitivity reactions. The other potentially more serious but much less common problem is pathogen transmission. A variety of zoonotic pathogens can be transmitted to people via fleas from pets. These include *Bartonella* spp., *Rickettsia felis*, *Rickettsia typhi*, *Yersinia pestis*, and *D. caninum*. More information about specific pathogens or diseases can be found in the appropriate sections of this book.

Animals

Clinical presentation

The most common problem with flea infestation is irritation and pruritis that develops as a result of fleas feeding on sensitized animals. This is flea bite allergy. It is rare in dogs and cats under 6 months of age, but beyond that, there are no age, gender, or breed predispositions. The inflammatory response is characterized by pruritic, erythematous, nonfollicular, papular, crusting dermatitis. Clinical signs, when present, may range from simple, uncomplicated pruritis to severe pruritis with significant self-induced trauma from scratching or chewing, along with secondary infections (pyoderma). The severity of response tends to worsen as the animal ages, presumably from increased sensitization with repeated exposure. Moderate to severe peripheral lymphadenopathy may be present in cats. Flea bite allergy is an important predisposing cause of pyoderma in dogs and should be considered in any dog with pyoderma of unknown origin, particularly recurrent infections. Flea bite dermatitis is a separate entity that involves local irritation in response to flea bites and does not necessarily involve an allergic component.

Another potential complication that is largely restricted to young animals with significant flea burdens is anemia, including chronic iron deficiency anemia from blood loss to fleas. This can cause death in severely infested young animals.
**Diagnosis**

Diagnosis is based on the identification of fleas or flea feces (“flea dirt”) on the hair coat of the animal. The hair coat should be closely examined. A flea comb may be helpful to identify fleas and flea dirt. Brushing the animal over a white towel or piece of paper may also be used, particularly in animals with dark hair coats and skin, since flea dirt and fleas may be more easily identifiable on the white surface. Flea dirt can be differentiated from other types of debris by moistening it with water, since true flea dirt will become red from the blood content. Since fleas may spend time off the host, failure to identify adult fleas by no means rules out flea infestation, particularly in highly sensitive animals that may develop severe pruritis with minimal exposure. Finding flea dirt in the absence of adult fleas should be considered a presumptive diagnosis. Intradermal skin testing can be used to confirm flea bite hypersensitivity.

**Management**

Control of fleas can be challenging. Elimination of fleas requires consideration of different factors: elimination of adult fleas from the animal, elimination of adult fleas from the environment, and prevention of reinfestation. The latter can consist of measures to reduce reexposure and/or routine prophylactic treatment to kill any fleas that are encountered.

**Elimination of adult fleas**

Various commercial products are available for elimination of adult fleas on dogs and cats (Table 1.1). All pets in the household should be treated at the same time if fleas are identified on any animal.

It is important to remember that even if all adult fleas are killed instantly, there will be a period of weeks where new adults may continue to emerge from the environment. Immediate elimination of the problem is therefore impossible.

### Table 1.1 Available options for flea treatment and prevention in dogs and cats

<table>
<thead>
<tr>
<th>Drug</th>
<th>Species</th>
<th>Use</th>
<th>Route</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dinotefuran</td>
<td>Dog/cat</td>
<td>Monthly</td>
<td>Topical</td>
<td>Adulticide; spot on combined with pyriproxyfen for effects on eggs</td>
</tr>
<tr>
<td>Fipronil</td>
<td>Dog/cat</td>
<td>Monthly</td>
<td>Topical</td>
<td>Spot-on or spray application; may be combined with methoprene to prevent development of eggs</td>
</tr>
<tr>
<td>Imidacloprid</td>
<td>Dog/cat</td>
<td>Monthly</td>
<td>Topical</td>
<td>Adulticide; may have some effect on larvae; may be administered as often as weekly, if needed</td>
</tr>
<tr>
<td>Lufenuron</td>
<td>Dog/cat</td>
<td>See “Comments” column Injectable (cat) Oral (dog, cat)</td>
<td>Injectable: before flea season then every 6 months</td>
<td>Does not kill adults; prevents larval development in eggs from exposed females</td>
</tr>
<tr>
<td>Metaflumizone</td>
<td>Dog/cat</td>
<td>Monthly</td>
<td>Topical</td>
<td>Available alone for cats and combined with amitraz for dogs (tick control; amitraz has no effect on fleas)</td>
</tr>
<tr>
<td>Nitenpyram</td>
<td>Dog/cat</td>
<td>Daily or as needed</td>
<td>Oral</td>
<td>Short-acting adulticide; lasts 24 hours. Not used as a preventive.</td>
</tr>
<tr>
<td>Permethrin</td>
<td>Dog</td>
<td>Monthly</td>
<td>Topical</td>
<td>Effective against adults and eggs</td>
</tr>
<tr>
<td>Pyrethrins</td>
<td>Dogs/cats</td>
<td>As needed</td>
<td>Topical</td>
<td></td>
</tr>
<tr>
<td>Selamectin</td>
<td>Dog/cat</td>
<td>Monthly</td>
<td>Topical</td>
<td>Kills adults and eggs</td>
</tr>
<tr>
<td>Spinosad</td>
<td>Dog</td>
<td>Monthly</td>
<td>Oral</td>
<td>Long-acting oral option</td>
</tr>
</tbody>
</table>

Products are effective against adult fleas unless otherwise noted.
Environmental treatment
Because the environment is an important source of infection, even after successful elimination of adult fleas on pets, environmental treatment may need to be considered in some situations. If there are minimal consequences of flea exposure (e.g., no flea allergy or significant effects on humans), focusing on eliminating adults that reach the pet and/or using medications to prevent successful reproduction may be adequate, and flea infestation of the household should be controlled over time if there is no ongoing external source. If a faster response is required, treatment of the household environment may be indicated.

Treatment of the outdoor environment is unlikely to be an important control measure and issues regarding safety and municipal restrictions on outdoor pesticide application must be considered. There is little indication for outdoor treatment in the control of flea infestation of pets. If this is to be considered, pest control specialists should be consulted.

Prevention of reinfestation: reducing reexposure
Vacuuming of carpets, cushions, and other pet contact areas and washing of pets’ bedding can be done to remove many (but not necessarily all) flea eggs and larvae. Removal of pupae is more difficult because they tend to be located deep within the carpets or fabric. Frequent vacuuming may be important, since the physical vibration from vacuuming may stimulate emergence of adult fleas from cocoons and therefore make them accessible during subsequent cleanings. Steam cleaning may help clean the deeper parts of the carpet pile.

Indoor environmental antiflea products (e.g., powders, sprays) may help eliminate certain flea life stages, but they must be used carefully to avoid toxic exposure to pets and children and are ineffective in the absence of proper treatment of the animals. The pupal stage is extremely resistant to pesticides and environmental extremes; therefore, physical removal of the cocoons (through vacuuming or laundering) is most effective, but repeated treatment/cleaning of the environment is required no matter what technique is used.

Restricting contact of pets with potentially infested animals is also important. Preventing roaming or other uncontrolled outdoor access should reduce the risk of acquiring fleas from infested domestic, feral, or wild animals. Minimizing the need to board animals at kennels or other similar multiple-animal environments would also presumably help but may not be practical. Use of a kennel that routinely inspects incoming animals for flea infestation (and does not admit infested animals) would be preferred.

The outdoor environment may also be a source of exposure. The risk only involves shaded areas (e.g., under decks or porches), so eliminating those when practical and reducing the ability of pets to encounter those areas should be considered.

Prevention of reinfestation: prophylactic treatment
A variety of different medications are available for killing adult fleas, either as routine treatment or in response to infestation (Table 1.1). Numerous topical options exist and many have residual activity through the presence of drug residues in the superficial layers of the skin. These can be highly effective, but the potential impact of excessive bathing or other water exposure (i.e., swimming) must be considered. Periodic bathing or swimming should not be a problem, but excessive water exposure, especially if shampoo is used, could reduce efficacy. Water exposure has no impact on the efficacy of orally administered medications, which are also widely available and effective. There is no standard recommendation for a flea control program, and factors such as the presence or absence of flea allergy in the pet(s), whether owners are concurrently affected, the ability of the owner to administer medications, and the potential for excessive bathing or swimming must be considered, as well as whether the program is being implemented for treatment of an existing problem or purely as a preventive measure. If there are significant consequences of flea infestation, such as flea allergy in a pet or bites in an owner, rapid-acting treatments to kill adult fleas along with a plan to address emerging adults from the environment must be developed. If prevention is the key, then approaches directed against either adults or development of immature stages can be considered. While permethrins have been used widely in the past, it is difficult to justify their continued use because of toxicity concerns (particularly in cats) and the availability of other effective and safer options.
If routine monthly treatment is considered appropriate, then treatment should be started as soon as indicated by the label on the chosen product. Treatment should be continued throughout the at-risk period, which varies depending on the climate. Year-round treatment is required in some regions.

Alternative approaches such as administration of garlic, brewer’s yeast, and thiamine have been tried, but there is currently no objective evidence of efficacy.\(^{286}\)

Flea-allergic pets should be on a flea-prevention program, which includes prophylactic treatment throughout the at-risk period.

Humans

Clinical presentation

The severity of reaction to flea bites varies between individuals, and both flea bite allergy and flea bite dermatitis can occur. Some people may have no noticeable effects of flea bites, while others have severe hypersensitivity reactions.\(^{50}\) In adults, there are usually fewer lesions, which often occur in groups of three,\(^{50}\) sometimes referred to as “breakfast, lunch, and dinner.” Extensive lesions are most common in children.\(^{50}\) Most commonly, urticarial papules are present over the distal extremities, particularly the lower legs.\(^{50,294,295}\) A hemorrhagic punctum may be present in the center of the lesion, and there may be secondary lesions from self-trauma or secondary bacterial infections.

Diagnosis

Fleas or flea dirt are rarely identified on a person, so diagnosis is made indirectly. Clinical signs and a history of flea infestation of pets or other potential exposure to flea-infested animals or environments provides a high index of suspicion.

Management

Elimination of flea exposure, through control of fleas on pets and in the household, and reduction of contact with potentially contaminated environments are the key aspects of treatment. Topical corticosteroids or oral antihistamines may be required for symptomatic control of pruritis.\(^{50,294}\)

Continuous or repeated exposure to fleas tends to result in desensitization over time.\(^{50}\)

Prevention

Preventing transmission of fleas from animals to humans involves controlling fleas on pets. The intensity of flea prevention activities should depend on geographic and pet management factors, including the prevalence of fleas, the risk of exposure of the pet, the sensitivity of pets and people to flea bites, and the prevalence of flea-borne zoonotic diseases in the area. Because of marked variation in these factors between and within populations, a standard program applicable to all pets is not reasonable. Individual aspects of flea control in pets are discussed above.

Giardia spp.

Introduction

*Giardia* is an important cause of diarrhea in humans and animals, and a common cause of waterborne outbreaks in humans in some regions. The most common source of infection of humans is surface water contaminated by human feces (i.e., sewage), and there is very little evidence of direct transmission of *Giardia* infection from companion animals to humans or vice versa. Nonetheless, it is important to be aware of the potential risks of transmission, particularly for high-risk individuals.

Etiology

*Giardia* spp. are protozoan parasites that can be found in the intestinal tract of virtually all vertebrate species. There are at least 41 species of *Giardia*; however, *Giardia intestinalis* (also known as *Giardia duodenalis* or *Giardia lamblia*) is the most common species involved in infection of wild and domestic animals, and the only species recognized as a cause of infection in humans.

An important aspect with respect to zoonotic disease risk is the *G. intestinalis* assemblage (type).
individuals, the trophozoites can cause villous atrophy, crypt hyperplasia, and extensive invasion of the lamina propria by inflammatory cells within the small intestine.

Geographic distribution/epidemiology

Giardiasis is endemic worldwide, but the prevalence and incidence vary considerably between different populations and geographic locations. In industrialized countries, the prevalence of Giardia shedding in healthy people is estimated to be between 1% and 7%, and may be higher in some regions. In general, all age groups are equally affected during epidemics, but both infection and clinical disease are more common in children in endemic areas. Outbreaks occur regularly in childcare facilities. The disease also tends to be seasonal, with the highest incidence over the summer and early fall, especially among hikers and campers. Chronic disease is more common in people with humoral immunodeficiencies.

Giardia can also be found in healthy and diarrheic animals of various species, particularly young animals. Shedding rates of 1.3–17% (typically ≤7%) have been reported in healthy dogs. Rates can be higher (21–24%) in dog kennels and shelters. Despite the fact that Giardia is considered an important canine and feline pathogen, no association has been found between diarrhea and the presence of Giardia cysts in feces because of the relatively common occurrence of the parasite in healthy animals. The assemblage is an important consideration in assessing the potential for zoonotic transmission. Dog-specific assemblages C and D predominate in most canine studies, however, zoonotic assemblage A1 can also be found and is occasionally the dominant strain.

The prevalence in cats (5.9–14%) is similar but perhaps somewhat lower than in dogs, and infections are also usually subclinical. As in dogs, Giardia in cats is more common in high-density populations such as catteries, as well as in kittens less than 6 months of age, multi-cat households, and in households that also contain dogs. The feline-specific assemblage F is most common, but zoonotic strains can be found.

### Table 1.2 Host range of the genetic assemblages of *Giardia intestinalis*.

<table>
<thead>
<tr>
<th><em>G. intestinalis</em> assemblage</th>
<th>Host range</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>Humans, livestock, cats, dogs, beavers, guinea pigs, ferret</td>
</tr>
<tr>
<td>A2</td>
<td>Humans</td>
</tr>
<tr>
<td>B</td>
<td>Humans, beavers, dogs, chinchillas, rats</td>
</tr>
<tr>
<td>C</td>
<td>Dogs</td>
</tr>
<tr>
<td>D</td>
<td>Dogs</td>
</tr>
<tr>
<td>E</td>
<td>Cattle, goats, pigs, sheep, alpacas</td>
</tr>
<tr>
<td>F</td>
<td>Cats</td>
</tr>
<tr>
<td>G</td>
<td>Rats</td>
</tr>
</tbody>
</table>

There are various types with different host ranges, and many types are restricted to a single host (Table 1.2). Assemblages A1 and B are potentially zoonotic. Assemblage A2 appears to only infect humans, not animals, so there should be no risk of zoonotic transmission. The other assemblages infect different animal hosts but are of limited to no risk for zoonotic transmission.

Life cycle

*Giardia* exists in one of two forms: trophozoites or cysts (Figure 1.4). Trophozoites reside primarily in the proximal small intestine and are responsible for causing clinical disease. They have a characteristic appearance that is likened to a smiling face, formed by the appearance of their two nuclei, central axonemes, median bodies, and four pairs of flagellae. Typically, as the trophozoites pass down the small intestine, they form a resistant cell wall, ultimately forming ovoid cysts approximately 10μm in length (somewhat smaller than the original trophozoite), which contain four nuclei. Cysts are passed in the feces and are immediately infective to the next susceptible host that ingests them. After ingestion, the organism excysts in the proximal small intestine, releasing two trophozoites that can attach to the mucosal surface but not invade the epithelium. The trophozoites then divide by binary fission, and the cycle continues. In diarrheic
Giardia is transmitted by ingestion of cysts of an appropriate species and assemblage. As few as 10 cysts can cause infection in a person, while infected individuals may shed up to 900 million cysts per day. Infection most commonly occurs in humans from contamination of drinking water or recreational water such as lakes, ponds, and inadequately treated swimming pools. Hand-to-mouth transmission may occur, especially in childcare facilities. Contamination of food (i.e., vegetables irrigated with contaminated water or handled by infected persons) is also possible.

There is currently little convincing evidence that household pets play an important role in human giardiasis. Contact with farm animals or pets was found to be a risk factor for giardiasis. Isolation...
of the same assemblage of *Giardia* in children and stray dogs that lived in the vicinity has been reported, but clear evidence of pet-to-human transmission is lacking. The potential carriage of zoonotic assemblages by dogs and cats cannot be dismissed, however, and one should assume that there is some degree of risk.

Exposure to *Giardia* from canine feces in parks and other public areas has raised concern. The risk of dog–dog transmission may be high, but zoonotic risks are likely minimal. Even though *Giardia* can sometimes be found in canine feces in the environment, zoonotic assemblages are uncommon (0.6% of canine fecal samples in one study of urban green areas) and human exposure is probably rare. Less information is available regarding the route(s) of infection of animals, but it is reasonable to assume that environmental contamination with feces from infected animals is the main source. Outbreaks of disease can occur, particularly in kennels, but it is impossible to differentiate environmental sources of contamination from direct animal–animal transmission in outbreaks.

**Animals**

**Clinical presentation**

The prepatent period is approximately 8 days (range 5–12) in dogs and 10 days (range 5–16) in cats, but clinical signs may develop 1 or 2 days before the organism can be detected in the feces. Infection is usually subclinical, and disease is most common in animals that are young, stressed, immunocompromised, or kept in high-density housing. Acute, intermittent, or chronic small bowel diarrhea may occur in both dogs and cats. Blood or melena should not be present. Fever, vomiting, or inappetance are uncommon, and if these are present, other causes should be considered, and additional diagnostic testing should be performed.

**Diagnosis**

Diagnosis can be difficult, and *Giardia* spp. have been called “one of the most commonly misdiagnosed, underdiagnosed and overdiagnosed parasites” in veterinary practice. A combination of direct smear, fecal flotation with centrifugation, and a sensitive and specific fecal ELISA optimized for use in the target animal species is recommended.

Direct smear is mainly used to detect trophozoites. Trophozoites are rarely seen unless very fresh (<30 minutes) diarrheic feces are examined. A drop of fresh, warm feces mixed with a drop of warm (37°C) saline can be examined at 40× magnification for trophozoites exhibiting the characteristic “tumbling leaf” motion of *Giardia*. Care must be taken not to mistake yeasts, plant remnants, and debris as *Giardia*. Lugol’s iodine stain may be added to facilitate the identification of trophozoites. In cats, trophozoites must be differentiated from those of *Tritrichomonas foetus*.

Fecal flotation using the zinc sulfate concentration technique (ZSCT) can be used to identify cysts in formed or diarrheic feces. The slides should be examined within 10 minutes or the characteristic internal structures of the cysts may no longer be apparent. *Giardia* cysts will stain with Lugol’s iodine, which helps differentiate them from coccidian oocysts and sporocysts.

Immunoassays directed against *Giardia* antigen can be used. Species-specific validation is important, as one cannot assume that a test that performs well on feces from one species will perform similarly when used with feces from other animals.

Shedding of cysts is inconsistent, in terms of number and frequency; therefore, testing of multiple fecal samples may be necessary for diagnosis. Testing of at least three fecal samples over 3–5 days may be optimal; three fecal flotation examinations on samples collected over a 2-week period identified approximately 94% of positive dogs in one investigation.

Duodenal sampling via endoscopy is unnecessarily invasive for diagnosis of giardiasis in dogs, unless endoscopy is being performed for another reason. Duodenal sampling via the peroral string test is insensitive in dogs and carries the risk of intestinal foreign body obstruction. This test has not been evaluated in cats.

PCR has also been used to detect *Giardia* in fecal samples from cats. As with other molecular assays, test development, validation, and quality control affect the usefulness of the tests, and assays that have been specifically validated on feces from dogs and cats should be used.

Identification of the assemblage is important for the determination of the potential for zoonotic
transmission. Unfortunately, different assemblages of *G. intestinalis* are morphologically similar and therefore cannot be differentiated microscopically. Molecular-based tests are required to determine the assemblage, and these are now offered by a limited number of veterinary diagnostic laboratories. *G. intestinalis* can be differentiated morphologically from *Giardia agilis* (found in amphibians) and *G. muris* (found in birds, rodents, and reptiles), which are not known to infect humans.  

**Management**

In most cases, infections are subclinical and treatment is not indicated in nondiarrheic animals, particularly those that are otherwise healthy and from a low-risk environment. Treatment might be justifiable in situations where there is particular risk of transmission, although what defines those situations is unclear.

Treatment is usually recommended in diarrheic animals; however, disease is typically self-limited and therefore may require only supportive therapy, which usually consists of oral or parenteral fluids to replace fluid volume lost due to diarrhea. Specific treatment is indicated in moderate to severe cases, or when the risk (or implications) of transmission to humans is high.

Metronidazole has been the mainstay of therapy for *Giardia* infections, in both humans and animals, but it is not universally effective, and there are potential problems with toxicity. Accordingly, fenbendazole is more commonly recommended. Combination of fenbendazole and metronidazole can be considered, particularly in refractory cases; however, clear evidence of efficacy is lacking. Albendazole should be avoided because of toxicity concerns.

Concurrent bathing of the animal to remove fecal debris and cysts is important and should be performed at the beginning and the end of the treatment period to reduce the risk of reinfection.

Retesting of animals after treatment is not required. The aim of treatment is resolution of clinical disease, not necessarily eradication of *Giardia*. If *Giardia* were found in feces after the clinically successful treatment, further treatment would not be recommended, thereby negating any benefit of retesting.

**Humans**

**Clinical presentation**

Infection is usually asymptomatic. It has been estimated that of each 100 people that ingest *Giardia* cysts, 5–15 will pass cysts asymptptomatically, 25–50 will develop acute diarrhea, and 30–70 will have no trace of infection. When symptoms do occur, there is an incubation period of 1–4 weeks, followed by acute onset of watery (sometimes explosive) nonbloody, foul-smelling diarrhea; bloating; and abdominal pain, which usually lasts for 3–4 days. In most individuals, the infection is self-limited; however, duration of diarrhea may be prolonged and chronic infections can develop.

Weight loss is common, and decreased growth in children and anemia can develop from anorexia and malabsorption. Severe illness requiring hospitalization is most common in children less than 5 years of age, pregnant women, and the immunocompromised.

Chronic disease may be accompanied by malaise, diffuse abdominal discomfort that is exacerbated by eating, greasy and foul-smelling stools, frequent and small-volume diarrhea, and weight loss.

**Diagnosis**

Fecal examination can be used for diagnosis in humans, but shedding of cysts may be inconsistent. Cysts may be identified by direct microscopic examination, microscopic examination using specific staining methods (i.e., trichrome direct fluorescent antibody assays), detection of antigen in stool by enzyme immunoassay (ELISA, fluorescent antibody test [FAT]), or by PCR. Direct examination of stool has a moderately high (75–95%) sensitivity and is more sensitive in diarrheic individuals because of the larger numbers of excreted cysts. Testing of multiple (three or more) samples can improve sensitivity. Immunoassays have a high sensitivity and specificity and are most commonly used. Testing of duodenal contents obtained by direct aspiration or via the peroral string test can be effective, but because of the increased invasiveness, these are typically reserved for situations where giardiasis is suspected but fecal samples have yielded negative results.
Management

When clinical disease occurs, it is usually self-limited, and supportive therapy alone may be adequate. When antimicrobial therapy is required, options include nitroimidazoles (metronidazole, tinidazole, ornidazole), nitazoxanide, paromomycin, and albendazole. Metronidazole has a cure rate of 80–95%. Tinidazole has a cure rate of 80–100% and may be preferable since single-dose therapy can be used. Other options can be similarly effective and may be preferred in certain situations. Paromomycin is recommended for the treatment of pregnant women in their second and third trimesters. Relapsing disease can be a problem, particularly in immunocompromised individuals.

Treatment of healthy Giardia carriers is not generally recommended but could be considered in high-risk households, such as those with people with immunocompromised individuals, especially humoral deficiencies.

Prevention

Giardia can only be transmitted by ingestion of cysts from an infected animal or person, and then only if the species and strain of Giardia are compatible with the new host. Because zoonotic and non-zoonotic strains are difficult to differentiate, it is prudent to consider any Giardia infection of an animal as potentially transmissible to humans, until proven otherwise. Therefore, control of fecal contamination, both human and animal, is of primary importance. Hand hygiene is an important measure and should be performed after contact with an infected animal or its environment, or contact with feces. Animal feces should be collected and disposed of immediately to prevent environmental contamination with resistant cysts, especially in public areas like parks where other dogs and children may play. Pets should also be prevented from drinking from puddles, ponds, lakes, or other open water sources that may be contaminated with feces from other animals.

An animal with a confirmed or suspected infection should be kept separate from other animals and high-risk individuals including children or immunocompromised persons and sick or immunocompromised animals. Pet areas, particularly runs or kennels, should regularly be thoroughly cleaned to remove all visible fecal material and then disinfected, as discussed below. Bedding and blankets that become soiled with fecal material should be removed and washed.

A Giardia vaccine is available for dogs and cats but it has not been shown to prevent infection and is not recommended by the American Animal Hospital Association or the American Association of Feline Practitioners vaccination guidelines.

There is little indication to test pets after diagnosis of giardiasis in a person since pets are unlikely to be the source of infection. Further, identification of Giardia in the pet would not indicate whether the pet was the source of infection, whether the pet was infected by the person, or whether both were infected by the same source. If pets are to be investigated as the potential source of human infection, this is best reserved for situations with recurrent or chronic disease. Concurrent testing of the pet and person, with determination of the assemblage(s) involved, is critical to obtain any useful information.

There is no indication to treat clinically normal animals that are shedding Giardia considering the prevalence of Giardia shedding by healthy animals, the lack of evidence indicating that shedding predisposes to subsequent disease in the animal, the low risk of transmission of Giardia from a healthy pet to an owner (particularly if basic hygiene and infection control measures are used), and the lack of evidence of efficacy of treatment for eradication of shedding in healthy animals. It might be reasonable to consider treatment of healthy animals in very specific circumstances, namely in households where a particularly high-risk person is present and when the animal is known to be shedding a zoonotic assemblage.

Giardia cysts can survive for more than 8 weeks in cool water (8°C), or 4 weeks in warmer water (21°C), but they are killed by freezing, drying, direct sunlight, and certain disinfectants such as accelerated hydrogen peroxide, bleach (1:10 dilution of household bleach), or quaternary ammonium disinfectants. Thorough cleaning to remove organic debris is critical for effective disinfection. Cysts may also be able to survive on an animal’s hair coat for variable periods of time.
Animals with diarrhea are especially likely to have trace fecal contamination of their coats, even if it is not visible to the naked eye. Therefore, hands should be washed thoroughly after handling any infected pet, even if there is no obvious evidence of fecal contamination.

**Hookworms**

**Introduction**

Hookworms are parasitic nematodes that live in the small intestine of their preferred hosts. Intestinal infections are often subclinical or mild in adult dogs and cats, but serious disease can occur in puppies and kittens with large worm burdens. Dog and cat hookworms are the main cause of cutaneous larva migrans in humans, a common condition in some regions that, while uncomfortable, is rarely serious. They can also cause other conditions such as eosinophilic pneumonitis, localized myositis, folliculitis, erythema multiforme, and eosinophilic enteritis in humans.  

**Etiology**

In dogs, *Ancylostoma caninum*, *Ancylostoma braziliense*, and *Uncinaria stenocephala* are the main hookworms, while *Ancylostoma tubaeforme*, *A. braziliense*, and *U. stenocephala* predominate in cats. Other species may also be present in some regions, such as *Ancylostoma ceylanicum* in Australasia. Infection with more than one hookworm species can occur.

*Ancylostoma duodenale* and *Necator americanus* are the human equivalents to the dog and cat hookworms. They inhabit the intestinal tract of humans and are not a zoonotic concern.

**Life cycle**

Adult hookworms live within the small intestine of their host and shed eggs in feces. Eggs are not immediately infective and must larvate, hatch, and develop into infective third-stage larvae before becoming a source of infection. This typically takes 2–9 days and depends on temperature and humidity. Infection occurs when a susceptible host encounters infective third-stage larvae, becomes infected by larvae penetrating the skin, or ingests a prey with infective larvae in its tissues.

Larvae that penetrate the skin migrate through the bloodstream to the lungs. They may then migrate up the respiratory tree and subsequently be coughed up and swallowed, or may migrate through other body tissues. Some may become dormant in tissues. Larvae that reach the small intestinal mucosa mature into adult worms. Some larvae may enter a state of arrested development and be subsequently reactivated after adult worms are removed. With some hookworm species (e.g., *A. caninum*), reactivation can also occur during pregnancy with subsequent transmammary infection. In others (e.g., *A. tubaeforme*), young animals are often infected after birth from environmental contamination. The ability of *A. caninum* to be transmitted through the transmammary route is a major factor in the high prevalence in puppies. Even if the mother is regularly dewormed, systemic infection is common, and exposure of young puppies should be assumed.

Larvae that are ingested may penetrate the oral cavity or gastrointestinal mucosa and migrate through tissues as described above, but most remain in the gastrointestinal tract and either mature to adults or enter an arrested state. Similarly, arrested larvae that are ingested from the tissue of prey typically remain in the gastrointestinal tract and mature into adult worms.

In the small intestine, adult worms may live for 4–24 months, attaching to the mucosa and ingesting blood. The worms may move to new attachment sites and leave behind small bleeding ulcers.

**Geographic distribution/epidemiology**

These parasites are most common in tropical and subtropical countries. There are regional differences in the prevalence of different hookworm species, and *A. braziliense* and *U. stenocephala* have a much narrower range than the other important dog and cat hookworms. In general, *U. stenocephala* (sometimes called the northern hookworm) is found in cooler climates, such as in the northern United States, Canada, and Europe. *A. braziliense* is
most common in tropical and subtropical regions such as the Caribbean and in warm coastal regions of the United States.

Hookworms are very common in dogs and cats in some regions, and rare in others. Climate, contact with feral animal populations, access to potentially contaminated environments, and prophylactic anthelmintic use can vary regionally and have profound impacts on the prevalence. Accordingly, reported prevalence rates vary dramatically between studies, ranging from 0.9% to 100% in dogs and 0.2% to 91% in cats. In general terms, higher rates are found in tropical and subtropical regions and prevalence rates in cooler developed countries tend to be low. Reported risk factors for hookworm shedding in dogs include living in multi-dog households, being a stray or living in a shelter, age less than 1 year, sampling during hot and humid periods, and a history of no anthelmintic treatment. Similarly, originating in a shelter and not having recent anthelmintic treatment are risk factors for cats. Studies of animals on admission to veterinary hospitals, which are likely more representative of the average, cared-for pet population, typically report shedding rates of 0–4% in dogs and 0–0.5% in cats.

Care must be taken when interpreting prevalence studies because of the vast differences in prevalence among regions and among different populations (i.e., pet vs. stray) within regions. Extrapolation of data to other regions and populations should be avoided.

Cutaneous larva migrans develops in humans when there is contact of bare skin with infective larvae from the environment. Infections are most common in young children and people that come into contact with soil or sand that might be contaminated with dog and cat feces. Environmental contamination with hookworm larvae can be found in parks and other public areas, particularly in tropical regions with large feral animal populations. There is significant variation in the types of disease caused by different species. is the most commonly implicated species. In contrast, and do not appear to cause cutaneous larva migrans, but can mature to adults in humans and cause intestinal disease. can also occasionally cause other conditions such as folliculitis, myositis, and eosinophilic enteritis. The role of in cutaneous larva migrans is unclear.

In the United States, most autochthonous cases originate in the Southeast and Gulf Coast states. In other regions where endogenous cases are rare, most infections are travel associated, particularly in individuals that have spent time on beaches in tropical countries. Outbreaks have also been associated with contaminated sandboxes. Any other surfaces contaminated with dog or cat feces could also be a source of infection, such as the outbreak of cutaneous larva migrans associated with the material for dried floral arrangements. Oral infection can also occur in humans, at least experimentally; however, the role of this in natural zoonotic disease is not known.

Eosinophilic enteritis can occur uncommonly from the presence of adult hookworms in the intestinal tract. While the development of adult dog and cat hookworms in the human intestinal tract is rare, there are a few cases of this occurring in association with mild to severe eosinophilic enteritis. There are also reports of identification of adult in humans.

Animals

Clinical presentation

Severe disease is most common in puppies that have been infected through nursing shortly after birth because adult are voracious feeders. Severe infections may result in anemia, ill thrift, poor weight gain, dehydration, and melena. Death can occur.

In adult dogs, overt signs of infection are uncommon, particularly in dogs that are otherwise healthy and well fed. Anemia, anorexia, weight loss, and weakness may develop in some cases, along with tarry diarrhea. This is more common in feral, stressed, and otherwise ill or malnourished dogs.

Clinical issues are similar in cats. Infections with tend to be most serious because, like , it is a voracious feeder. Anemia, weight loss, failure to thrive, diarrhea, and sudden death can occur, mainly in kittens. Infections with and tend to be mild
because they consume much less blood than *A. caninum* and *A. tubaeforme.*\textsuperscript{344}

In some situations, cutaneous larva migrans can develop from hookworm larvae penetration of the skin, most commonly on the feet. Erythema, pruritis, and papular rash are common, and *A. braziliense* is usually involved.

**Diagnosis**

Hookworms are diagnosed by detection of their thin-shelled, morulated eggs in feces using fecal flotation (Figure 1.5). The prepatent period is 2–4 weeks, and worms begin feeding before eggs are passed in feces. With severe burdens in young puppies and kittens, severe disease or death can occur during the prepatent period.\textsuperscript{344}

Morphological differentiation of hookworm species is difficult as there is overlap in the egg sizes between different species.\textsuperscript{342} Only eggs of some *U. stenocephala* can be reliably distinguished because of their larger size.\textsuperscript{340} More recently, molecular methods such as PCR-RFLP have been used for the detection and differentiation of hookworm species.\textsuperscript{342,367}

**Management**

In dogs, fenbendazole, moxidectin, moxidectin/imidacloprid, milbemycin oxime, nitroscanate, and pryanthel pamoate are effective against adult *U. stenocephala.* Limited information about anthelmintic resistance is available, but high-level pyrantel resistance has been reported in *A. caninum,*\textsuperscript{371} and monitoring fecal egg counts after deworming is an important means of detecting the emergence of resistance.

In cats, ivermectin, selamectin, moxidectin/imidacloprid, fenbendazole, milbemycin oxime, pryanthel pamoate, and emodepside are effective against adult *A. tubaeforme,* while emodepside and moxidectin are approved for the treatment of fourth-stage and adult *A. tubaeforme.* Fenbendazole is effective against *U. stenocephala.*

Deworming does not kill arrested larvae in tissues. Furthermore, dormant larvae present in the intestinal tract are resistant and can repopulate the intestine with adult worms after existing adults have been successfully eliminated with anthelmintics; therefore, repeated treatment may be necessary to eliminate infection. Detection of hookworm eggs in feces after deworming is most likely a result of this “larval leak” phenomenon, not anthelmintic resistance.

**Humans**

**Clinical presentation**

Zoonotic hookworms can cause cutaneous larva migrans. Initially, pruritic, reddish papules develop
Prevention

Deworming is the critical component for disease prevention in puppies and kittens and will help decrease environmental contamination. Particular attention should be paid to deworming of puppies and kittens because of the greater likelihood of infection and the potential severity of disease. Puppies and kittens should be treated at 2, 4, 6, and 8 weeks of age. New puppies or kittens that are first brought home should receive a minimum of three treatments, 2 weeks apart, then monthly treatment until 6 months of age.

Recommendations for animals over 6 months of age are conflicting and include monthly, once or twice a year, or at least four times a year at intervals not exceeding 3 months. Basing treatment recommendations for adult dogs and cats on fecal examination in low-risk households, with no regular prophylactic treatment has also been recommended. The prevalence of hookworms in the area, management of the pet(s), risk of exposure of the pets, number of pets in the household, and whether there are high-risk humans in the household need to be considered when determining the appropriate strategy. There are concerns about the development of resistance, as has occurred in sheep and horses, and concerns about resistance and prudent anthelmintic use need to be considered when designing deworming regimens.

Pregnant bitches should be treated during pregnancy to prevent transmammary infection, particularly if they have previously had a litter with a hookworm problem. Daily administration of fenbendazole from the fortieth day of gestation to the fourteenth day of lactation or two to four doses of ivermectin during the same time frame have been recommended. A single dose of moxidectin on day 55 of pregnancy or a single dose of moxidectin–imidacloprid on day 56 of gestation was shown to be effective in small clinical trials. Nursing animals should be treated concurrently with their offspring.

Regular fecal examination is recommended to monitor worm burdens and efficacy of deworming. It has been recommended that fecal examination should be performed on puppies and kittens two to four times during the first year and one to two times annually thereafter. Centrifugal flotation methods are recommended because of the
higher sensitivity compared with other fecal examination methods.

There are currently no proven means for eliminating hookworm larvae in the environment, so decreasing fecal contamination of the environment and the likelihood that feces contain hookworm eggs are the key. Prompt removal and proper disposal of feces will assist in reducing the environmental burden of hookworms attributable to pets.

Regular (every day or two) cleaning of litter boxes will prevent infective third-stage larvae from developing. Preventing predation and scavenging will also reduce the risk of infection from ingestion of infected prey.

While important, measures directed at pet dogs and cats may only have a limited role in the successful prevention of cutaneous larva migrans because much of the environmental contamination, particularly in many tropical and subtropical regions, is from feral animals. If large feral dog and cat populations are present in an area and the prevalence of infection of those animals is high, environmental contamination will continue to be a risk.

Avoiding contact of bare skin with potentially contaminated soil or sand is the key preventive measure, although that can be difficult. Keeping dogs and cats off beaches could be an effective measure but is difficult to achieve, particularly in tropical regions with large feral dog populations. People should avoid contact with potentially contaminated soil, such as through wearing shoes and/or gloves. Similarly, wearing footwear on beaches could reduce the risk of exposure. Sandboxes should be covered when not in use to prevent cats from defecating in them.

**Leishmania spp.**

Introduction

Leishmaniasis is a wide-ranging spectrum of diseases caused by protozoal parasites of the *Leishmania* genus. There are various *Leishmania* species that can cause human infections, each with different geographic ranges and reservoir hosts. The primary reservoirs are sylvatic mammals such as rodents and wild canids, but pet dogs can be involved. Dogs are the primary reservoir for zoonotic infections in some regions and may also act as a link between sylvatic and domestic cycles of leishmaniasis. Humans are typically accidental hosts but might be reservoir hosts for some species.

The clinical presentation of leishmaniasis can be highly variable, and this variability probably relates to factors such as the individual parasite’s invasiveness, tropism, and inherent pathogenicity, plus host factors such as the cell-mediated immune response. Visceral, cutaneous, and mucocutaneous leishmaniasis are the most common forms, and the same *Leishmania* species may cause multiple syndromes. Dogs are most relevant in the transmission of visceral leishmaniasis.

**Etiology**

*Leishmania* species are intracellular protozoal parasites. The *Leishmania* genus is divided into two subgenera: *Leishmania* and *Viannia*. Various *Leishmania* species are known to cause disease in humans and animals, but the main companion animal risk comes from *Leishmania infantum* in dogs. *Leishmania chagasi*, the agent implicated in visceral leishmaniasis in South America, is now considered to be the same organism as *L. infantum* based on genetic analyses. *Leishmania braziliensis* and *Leishmania peruviana* can cause cutaneous leishmaniasis in humans and dogs. Less is known about the role of dogs in the transmission of these species, but there is increasing information suggesting dogs may play a role in the transmission of *L. braziliensis*. Dogs are thought to be the reservoir for *L. peruviana*; however, this pathogen is only currently of relevance in the Peruvian Andes. Numerous other *Leishmania* species exist, and pets can sometimes become infected; however, their role as reservoirs of these *Leishmania* species is probably negligible.

**Life cycle**

*Leishmania* reside in mammalian macrophages as amastigotes. Transmission is via female sand flies...
Leishmaniasis is an important human health issue in some regions. An estimated 12 million people are affected worldwide,375 with the vast majority of cases occurring in eastern India and Bangladesh, Sudan, and Brazil.386,387 The range of the infection depends on both the presence of Leishmania in a reservoir population and the presence of the sand fly vector. Dog-associated leishmaniasis is primarily associated with L. infantum, which is endemic in the Mediterranean, Middle East, and certain areas of the New World, particularly in Latin America.375,388 It was previously a problem in southern China but is now rare.389 Most human L. infantum infections occur as sporadic cases in rural areas, but outbreaks can occur and can involve urban and suburban areas.375 Clustering of cases can occur in households. There are concerns that of the Lutzomyia genus in the Americas and Phlebotomus genus elsewhere (Figure 1.6a).375 After a sand fly bites an infected host and acquires Leishmania, the parasites develop into extracellular promastigotes in the sand fly gut within approximately 1 week.375 The transmission cycle is completed when the infected sand fly feeds on another susceptible host, as promastigotes are phagocytosed by macrophages, convert to amastigotes, and multiply. Reservoir hosts may be infected for years, if not lifelong.378

Rarely, infection of humans or dogs can occur through other routes such as congenital infection, transfusion of contaminated blood products, needlestick injury, or sharing contaminated needles.379–384 The potential for dog fleas to transmit L. infantum through dogs ingesting infected fleas has been investigated, but it is equivocal whether there is a real risk.385

Geographic distribution/epidemiology

Figure 1.6  (a) Phlebotomus species sand fly (public domain, Centers for Disease Control and Prevention). (b) Cutaneous leishmaniasis (public domain, Centers for Disease Control and Prevention, Dr. D.S. Martin).
the range could expand if the insect vector range expands as a result of climate change.\textsuperscript{300}

The prevalence of anti-\textit{Leishmania} antibodies in dogs is variable in endemic regions. Rates of 1–81% have been reported in areas of Brazil, Colombia, Italy, Spain, Portugal, and Turkey.\textsuperscript{391–398} There is an age-related component; however, different studies have identified different at-risk age groups.\textsuperscript{391,392,396} The prevalence of infection has been steadily increasing in some regions, particularly in Europe,\textsuperscript{399,400} and leishmaniasis may be an emerging problem in some areas.

The epidemiology of leishmaniasis is different in some regions such as the United States and Canada, where the disease can be found in some populations of animals, but autochthonous vector-borne cases are not recognized.\textsuperscript{374} Infected animals belong to two groups: dogs that have been infected while visiting endemic regions\textsuperscript{401} and endemic leishmaniasis in select dog breeds that is maintained without vector-borne transmission.\textsuperscript{374,402–407} The latter group is the most important and has largely involved foxhounds,\textsuperscript{402,405,408} within which leishmaniasis is endemic in at least 18 U.S. states and 2 Canadian provinces.\textsuperscript{402} Both dog-to-dog and vertical transmission are suspected.\textsuperscript{374,402} Dog-to-dog transmission could include transmission from bites, breeding, or reuse of needles.\textsuperscript{402} Vertical transmission is likely as well since transplacental infection has been demonstrated experimentally.\textsuperscript{409} There may be some degree of genetic predisposition among, and within, the foxhound breed.\textsuperscript{374} Other breeds, particularly breeds that originated in southern Europe like corsicas, Italian spinones, and Neapolitan mastiffs may be similarly overrepresented.\textsuperscript{374}

Less information is available regarding cats, although the disease has been recognized in cats for almost 100 years.\textsuperscript{410} Cutaneous and visceral leishmaniasis can occur, but cutaneous disease appears to predominate.\textsuperscript{376,411} Limited prevalence data are available, but seroprevalence or parasitemia rates of 0.6–59% have been reported.\textsuperscript{412–416}

Leishmaniasis is a very important human disease in some regions, where it is the most commonly detected zoonotic disease.\textsuperscript{417} Visceral leishmaniasis is mainly caused by \textit{L. infantum} and \textit{Leishmania donovani}, although other species can be involved.\textsuperscript{375} Visceral leishmaniasis has traditionally been considered a disease of children; however, adults with HIV/AIDS, as well as those receiving cytostatic or immunosuppressive therapy are also at increased risk.\textsuperscript{418–420} While those groups are at higher risk of infection, disease can occur in anyone.

Dogs are important reservoirs of \textit{L. infantum} but play little to no role in the transmission of other species that cause visceral disease. Dogs are not considered important reservoirs for cutaneous leishmaniasis since they are not natural hosts for the main species that are involved (\textit{Leishmania major}, \textit{Leishmania tropica}, or \textit{Leishmania aethiopica}), except for \textit{L. peruviana}, which is associated with localized ulcerative cutaneous disease in the Peruvian Andes.\textsuperscript{377} Transmission of infection from dogs to humans via sand flies is the primary route of transmission of \textit{L. infantum}, but conflicting data are available regarding the risks posed by pet dogs, and there are probably regional differences in risk based on the prevalence of zoonotic \textit{Leishmania} spp. in dogs, the prevalence of vectors, dog density, and dog management (e.g., closeness of contact with humans, time spent outdoors). Village dog density and dog ownership have been identified as risk factors for visceral disease.\textsuperscript{421,422} A significant association between the risk of human cutaneous leishmaniasis and the prevalence of corresponding disease in dogs was reported in Peru.\textsuperscript{423} Daily contact with animals (but not necessarily dogs) was a risk factor for human disease in an Italian study.\textsuperscript{424} Control of leishmaniasis in dogs can decrease human infection rates, providing further evidence of a role of dogs in human infection.\textsuperscript{425} Other modes of dog–human transmission have not been proven, such as transmission through contact with infected canine blood or bites. Evidence of a role for cats in human infection is limited.

**Animals**

**Clinical presentation**

Only a small percentage of infected animals develop clinical disease.\textsuperscript{377,392,397} When disease does occur, the visceral form is most common.

**Visceral leishmaniasis**

Depression, weight loss (particularly decreased muscle mass over the shoulders, hips, and spine), abdominal distension, splenomegaly, generalized
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These are more rewarding in cats since dogs tend to have low numbers of parasites in skin. PCR detection of the parasite in blood and bone marrow is possible since hematogenous dissemination is common. Serological testing is suggestive but can be problematic to interpret in areas with a high baseline seroprevalence.

Management

Treatment can be difficult, and dogs seem to respond poorly compared with humans. While treatment can improve clinical signs or produce short- or long-term remission, it is seldom curative. Disease may be advanced by the time leishmaniasis is considered or diagnosed, and the prognosis in emaciated, chronically affected animals is very poor. If treatment is elected, the main goal is clinical improvement, not microbiological cure, and relapse is a common problem. Furthermore, the inability to completely eliminate the parasite means that these animals may pose a risk for further transmission.

There are a limited number of drugs that may be efficacious, and information regarding optimal treatment regimens is limited. Allopurinol has been recommended as the first-choice treatment because it is relatively efficacious and nontoxic. It may be used alone or in combination with pentavalent antimonials such as sodium stibogluconate or meglutamine antimoniate. These may be of limited availability, and sodium stibogluconate, in particular, can be highly toxic. Liposomal or lipid emulsion amphotericin B may also be used, although these are not thought to be superior to allopurinol and are more toxic. Miltefosine and paromomycin have not been adequately studied in dogs. Relapses are common, regardless of the drug(s) used, and may occur months to a year or more after an apparently successful therapy, so regular monitoring is required.

Recently, immunotherapy with a saponin-enriched commercial vaccine was shown to reduce or eliminate clinical signs and latent infection. This may be a critical tool for the management of clinical disease and reducing the zoonotic implications in treated animals. Other aspects of therapy depend on the clinical condition of the animal and may include nutritional support or management of renal disease.
Humans

Clinical presentation

Visceral leishmaniasis
Occasionally, a small papule is noticed at the site of inoculation, but this is not typical. The incubation period is prolonged, typically 3–8 months, although it can be as short as 10 days or longer than a year. It is possible for infection to occur years earlier, only to be expressed when the individual becomes immunocompromised.

The clinical presentation can be highly variable, ranging from inapparent, self-limited infection to classical visceral leishmaniasis with fever, anorexia, weight loss, hepatosplenomegaly, and hyperpigmentation. Onset may be insidious or rapid. Fever may be remittent, intermittent, or, less commonly, continuous, and may mimic malaria. Abdominal enlargement may be present because of massive splenic and hepatic enlargement.

Immunocompromised individuals, such as those with HIV/AIDS or neoplasia, or on immunosuppressive therapy, are at increased risk of developing disseminated visceral disease. In severe cases, death can occur from secondary infections, malnutrition, severe anemia, or hemorrhage.

Cutaneous leishmaniasis
Simple cutaneous leishmaniasis, the typical presentation of infections by dog-associated species, involves the presence of one or more crusting, dry lesions, with occasional large, deep ulcers (Figure 1.6b). They can be found on any part of the body, but are most common at sites of exposed skin. Cutaneous leishmaniasis rarely develops into visceral disease.

Diagnosis

Visceral leishmaniasis
Presumptive diagnosis is often made in endemic areas based on the presence of prolonged fever, weight loss, marked splenomegaly, hepatomegaly, along with normocytic/normochromic anemia, leukopenia, thrombocytopenia, and hypergammaglobulinemia. Demonstration of amastigotes in tissue or isolation of promastigotes in culture is diagnostic. Splenic aspirates are the highest yield material for testing, but testing can also be performed on bone marrow or lymph node aspirates. Liver aspirates are lower in yield. Amastigotes can sometimes be identified or isolated from buffy coat samples or whole blood. Serological testing can be performed, but while sensitive, there may be a lack of specificity from cross-reaction with other organisms. False-negative serological results may be obtained from immunocompromised patients. Leishmanin (Montenegro) skin testing is not useful diagnostically as it is usually negative in people with visceral leishmaniasis, although they typically become positive after spontaneous resolution of infection or successful treatment.

Cutaneous leishmaniasis
Diagnosis of cutaneous leishmaniasis is often presumptive in endemic regions based on the characteristic clinical signs. Definitive diagnosis involves detection of amastigotes in tissue using Wright–Giemsa staining of tissue biopsies or, less commonly, using monoclonal antibodies or molecular methods. Isolation of promastigotes using tissue culture is also diagnostic. Amastigotes may also be seen occasionally on skin scrapings from affected areas. Serological testing is not very useful since antibodies are detected in a minority of infected individuals, and cross-reacting antibodies may be present.

Management

Visceral leishmaniasis
While disease is often self-limited, treatment is indicated in patients diagnosed with visceral leishmaniasis. Liposomal amphotericin B is the drug of choice, but cost and availability may be limiting factors in some countries. Conventional amphotericin B is another option. Sodium stibogluconate can be highly effective but carries risks of toxicity, particularly cardiotoxicity. It is avoided in South Asia because of the high prevalence of antimonial resistance, and miltefosine is now widely used in India. Supportive therapy may also be required, including nutritional support and treatment of secondary infections.

Cutaneous leishmaniasis
Treatment of cutaneous disease should be considered in all cases, particularly when there is the
potential for disfiguring or debilitating injury (i.e., facial lesions, lesions near joints).²

Prevention

There are four main approaches to reducing the risk of Leishmania transmission: reducing the insect vector, reducing insect bites, reservoir control, and immunoprophylaxis.

Sand flies are weak fliers and tend to stay close to their breeding sites, so elimination of breeding sites in close proximity to humans and susceptible animals is a potential control measure. However, breeding sites are usually difficult to identify, so this is not a highly effective approach.

Bite avoidance includes basic practices (Table 1.3),²,⁴²⁷ but complete avoidance is difficult to impossible.

The use of insecticides on dogs to repel and kill sand flies has been an effective approach and is important in endemic areas. Deltamethrin- and permethrin-impregnated dog collars can reduce sand fly biting⁴²⁸–⁴³¹ and consequently seroconversion in people and dogs.²,⁴²²,⁴³¹–⁴³³ Collars can provide protection for up to 34 weeks, making them a practical control method.²,⁴²⁸,⁴³⁰ Long-acting topical insecticides may also be effective, as application of a deltamethrin-based emulsifiable concentrate had excellent short-term and residual activity, and appears to be suitable for administration every 5–6 months.⁴³⁴

Dog culling has also been used to reduce the reservoir population in endemic regions; however, this has been met with little success for various reasons such as the high prevalence of infection (particularly in dogs without clinical signs of disease); the infectiousness of the agent; high replacement rates from migrating strays; high birth rates; test limitations; and time delays between diagnosis and culling.⁴³⁵,⁴³⁶ A recent report did identify an association between the reduction of human visceral disease and canine euthanasia rates.⁴³⁷ However, based on the conflicting data and other potential (and more effective) control approaches, it is hard to justify an extreme approach like mass culling.

While transmission through contact with dog blood has not been demonstrated, the fact that this parasite can be transmitted human–human through shared needles indicates that it should be considered a possibility. Accordingly, particular care should be taken by veterinary personnel to avoid needlestick injuries. Direct contact with blood, especially contact with mucous membranes or broken skin, should also be avoided.

A canine vaccine is available in Brazil for the prevention of visceral leishmaniasis.³⁹³,⁴³⁸ Canine vaccination has also been shown to reduce the incidence of human infection⁴²⁵ and may be a critical control measure.

Recommendations have been developed for infected dogs (predominantly foxhounds) in the United States, including reducing exchange of hounds, segregating infected animals, and banning infected dogs from dog shows or hunts.¹⁰² However, these seem to have been followed only for a short period of time, largely based on the perception that the disease is associated with low illness and death rates and that there are minimal risks to humans.¹⁰² In the absence of more aggressive measures, basic practices such as breeding only known seronegative dogs should be considered.¹⁰²

Euthanasia of infected dogs has been recommended,¹⁰² and in some jurisdictions, positive dogs must be euthanized, treated, or kept under sand fly-proof netting.³⁹⁹ The aggressive approach to positive dogs in nonendemic regions is designed to reduce the risk of establishment of the disease in the area. This is perhaps most justifiable if sand fly vectors are present in the area, given the low risk of transmission through other means. While euthanasia is a reasonable consideration, the impact of this on overall animal and public health is unclear, and recent evidence of the potential efficacy of vaccination for elimination of Leishmania³⁹³

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Table 1.3  Sand fly bite avoidance practices.

<table>
<thead>
<tr>
<th>Practice</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Screen windows and doors</td>
<td>Wear long-sleeved clothing and long pants</td>
</tr>
<tr>
<td>Avoid areas of sand fly activity, especially at dusk and dawn</td>
<td>Using insect repellent containing DEET or picaridin</td>
</tr>
<tr>
<td>Using insecticides on dogs to repel and kill sand flies</td>
<td>Spray clothing with permethrin-containing insecticides</td>
</tr>
<tr>
<td>Spray insecticides on infested living spaces</td>
<td>Use a bed net soaked in permethrin when sleeping in nonscreened areas</td>
</tr>
</tbody>
</table>
may decrease the pressure and need for automatic euthanasia of infected animals.

**Notoedres cati**

*N. cati* is the cause of notoedric mange, a disease that occurs worldwide and often occurs in periodic regional outbreaks. It is most commonly found in domestic cats and has been called the feline counterpart to *Sarcoptes scabiei* in dogs. It can also be found in other felid species such as tigers, cheetahs, leopards, ocelots, and panthers, as well as hamsters, squirrels, civets, raccoons, coatis, and hedgehogs. Rarely, it can infect dogs. *N. cati* var. *cuniculi* can be found in rabbits. Transmission is by direct contact with an infected individual.

Adult mites burrow deep within the dermis, where females lay eggs. After hatching, larvae crawl to the surface of the skin, then dig their own burrows to molt. After molting, the first nymphal stage creates a new, superficial burrow where it molts again, at which point the second-stage nymph digs yet another burrow to develop into an adult.

Lesions tend to develop first around the margins of the ears. They are intensely pruritic, and infected animals may have bloody crusts and hair loss from self-mutilation. Weight loss and debilitation may develop in severe cases, particularly when treatment is delayed.

Diagnosis is based on the identification of mites on skin scrapings. Adult mites are almost round and 200–240 μm in diameter (smaller than *S. scabiei*). Mites may also be identified in feces because of ingestion during grooming.

Often, people living with infected cats will develop papular lesions and rashes, usually over the arms and legs. In one study, 63% of human contacts of cats with *N. cati* infection had symptoms of notoedric scabies, with *N. cati* recovered from 50% of skin specimens. Symptoms can develop within hours of contact with an infected cat. Lesions differ from classical scabies since they lack detectable mite burrows and occur over variable sites, including the face. While intensely pruritic and a nuisance, infections are transient and self-limited, typically resolving within 2–3 weeks if contact with infected cats is prevented. Lesions subside when cats are segregated from people. The risk posed by other *Notoedres* species is not known.

Prompt diagnosis and treatment of infected cats with a macrocyclic lactone (ivermectin, moxidectin, doramectin, selamectin) or fipronil is important for both animal welfare and reduction of zoonotic transmission. Restricting contact with infected animals during the initial treatment period may reduce the risk of transmission, but the period of infectivity after treatment has not been described. Keeping cats indoors will reduce the risk of exposure. If cats may have been, or are at risk of being, exposed, prophylactic treatment with selamectin or fipronil may be indicated.

**Ornithonyssus bacoti**

*O. bacoti*, the tropical rat mite, is a hematophagous mite that can be found on a variety of wild and captive small mammals and birds worldwide. The “tropical” designation is misleading as the mite can be found throughout the world. Pet rodents can be infected, from inapparent to pruritic with excoriation. *O. bacoti* will bite humans, resulting in dermatitis. The mite is also the intermediate host for the filarial nematode *Litomosoides carinii*, which can potentially act as a vector of murine typhus, Q fever, Chagas’ disease, and Coxsackie virus; however, it is thought that this is of minimal relevance for natural transmission of infection.

Diagnosis is based on the identification of mites on the animal or in its environment. Identification of the mite may be difficult. Unfed mites are gray-white and often very active, while fed mites are darker, red-brown, and sluggish.

Human infections can occur from direct or indirect contact with wild and pet rodents. Cases have been reported in laboratory animal and veterinary personnel, as well as people living or working in rodent-infested areas. There are also reports of transmission from pet rodents. In one case report, transmission of *O. bacoti* from a pet hamster was suspected based on the development of infection after contact with the animal. In another, bites developed on members of a family...
Affected animals are pruritic and may shake their head or scratch at their ears. Violent scratching and head shaking may lead to further inflammation, excoriations, erythema, and aural hematoma. Uncommonly, lesions may be present on other parts of the body with severe infestations. The typical “coffee grounds” appearance of the aural exudate provides a high index of suspicion. Mites may be identified directly in the ear canal with an otoscope or via cytological examination of ear swabs (Figure 1.7).

Treatment of Otodectes infestation involves cleaning the ear canal and administering parasitidal drugs. Long-acting compounds or repeated administration is required to kill new mites from hatching eggs and mites acquired from the environment. Milbemycin and ivermectin may be applied directly into the ear canal in cats and dogs. Otic application of fipronil was also reportedly effective in a small study of dogs and cats. Topical selamectin or imidacloprid/moxidectin have also been shown to be efficacious in dogs and cats. If multiple pets are in the household, all

Figure 1.7 Adult Otodectes cynotis (public domain, photo credit: Joel Mills, GNU free documentation license).

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should be treated concurrently. Grooming equipment and bedding should be discarded or disinfected. Under experimental conditions, mites can survive off the host for 15–17 days at 10°C and 5–6 days at 34°C, while under natural conditions survival should not exceed 12 days. Therefore, new animals should be restricted from entering potentially contaminated areas for 12 days if environmental disinfection is not possible.

O. cynotis is not host specific and can infect humans, although this appears to be rare. This can include ear infestation or more widespread disease including one report of intensely pruritic excoriated papules that began on the torso and spread over the extremities. In another report, a child whose two cats had severe O. cynotis infestation developed numerous pruritic papules over the abdomen, and the lesions resolved shortly after the cats were successfully treated. These reports are all somewhat circumstantial, being based on lack of another identifiable cause of the human infection and concurrent diagnosis of O. cynotis infestation in the person’s pet. There is one report of identification of O. cynotis from a person with tinnitus. The most convincing evidence of the potential for zoonotic transmission comes from one enterprising veterinarian who, after seeing two suspected cases of O. cynotis infestation in owners of infested pets, intentionally infected himself with an O. cynotis mite from a cat. Intense pruritis developed and persisted for almost a month, but resolved without treatment, leaving behind an ear full of exudate. Rather astoundingly, this person reinfected himself two more times to confirm the findings and to determine whether immunity developed, with milder disease reproduced each time. Clearly, O. cynotis from animals can infect humans and cause self-limited disease.

The risk of zoonotic transmission is quite low given the rarity of reports of human infection and commonness of infection in pets. Good household hygiene practices, particularly hand washing after contact with the ears of infected animals, should reduce any risks. Potentially contaminated fomites (i.e., bedding) should be laundered and dried using high heat in a clothes dryer, and hands should be washed after handling laundry. If human infestation is identified or suspected, treatment of the infested animal is likely to result in clinical resolution of human disease.

**Sarcoptes scabiei**

**Introduction**

S. scabiei is a burrowing mite that can cause intensely pruritic skin disease, particularly in dogs, foxes, coyotes, and humans. Infestations of humans and dogs are caused by different varieties of S. scabiei; however, cross-infection can occur.

**Etiology**

While there is only one species, S. scabiei, mites found on dogs are often referred to as S. scabiei var. canis, while those naturally found on humans are called S. scabiei var. hominis. These designations are more physiological than morphological or genetic, but there is evidence of some degree of genetic variation between S. scabiei var. canis and S. scabiei var. hominis. This genetic variation is best illustrated by a study that showed that mites recovered from people from Australia and North America were more closely related to each other than mites from dogs and humans in the same region (or even in the same household). While this supports strong host adaptation, determination of cross-species infection potential of an individual mite is not straightforward because there are typically few or no morphological differences, and genotyping is not readily available. Further, there is ample evidence that S. scabiei var. canis can infect humans, although disease is usually relatively mild and self-limited.

**Life cycle**

After exposure, mites burrow into the epidermis where they trigger an intensely pruritic dermatitis, caused by type I and type IV hypersensitivity reaction to the parasite. Female mites lay eggs in the walls of the burrows. Six-legged larvae hatch and molt to become first- and second-stage nymphs, then adults. Adults feed on damaged skin and tissues. After mating, the males die while females migrate to a suitable body site for burrowing. This entire life cycle can be completed in approximately 30 days.
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**Geographic distribution/epidemiology**

*S. scabiei* can be found worldwide. The prevalence is higher in wild and feral animal populations, with rates of 7–19% being reported for studies of stray dogs. Pet dogs that interact with stray animals are presumably at higher risk of infection. Transmission of host-adapted mites to other species can occur but infestations tend to be mild and self-limited. Cats are rarely infected.

**Human scabies**

Human scabies is endemic in many countries and affects people of all socioeconomic levels, although poverty, poor hygiene, overcrowding, malnutrition, and sexual promiscuity increase the risk of infection. It is a reemerging disease in some areas, particularly in immunocompromised individuals. Transmission is from direct (including sexual) contact with an infected individual or from indirect transmission from the environment or fomites. Mites can live off the host for up to 21 days. Outbreaks of human scabies have been reported in various facilities, particularly schools, hospitals, and nursing homes. These seldom involve animals. Repeated infections tend to be milder than primary infections.

In areas where scabies is endemic in humans, most human cases are from close contact with infected people. Zoonotic transmission is of greater relevance where human scabies is rare, since there is a greater likelihood of having contact with an infected animal (especially a puppy) than an infected person. Multiple household members may be infected. A skin rash is usually noted within 24–96 hours of contact with an infected dog. Canine scabies mites can live on humans for up to 6 days and produce ova.

Determination of the role of animals in human disease is not necessarily straightforward. In areas where scabies is rare in humans and an affected individual has had contact with a dog diagnosed with scabies, it is likely that the pet was the source. However, if scabies is endemic in both humans and dogs in an area, determination of the source of infection is difficult since human and canine scabies may be maintained in separate transmission cycles.

**Animals**

**Clinical presentation**

Lesions are usually first noted in thinly haired areas such as the ear margins, elbows, stifles, feet, and ventrum. The ears are almost always involved. Intense pruritis is normal, and infected animals will scratch and chew incessantly, with rapid development of secondary traumatic lesions and alopecia. Papular eruptions may be noted. With time, hair loss along with thickening and hyperpigmentation of the skin will develop. Lesions often spread rapidly and, in severe cases, can cover the entire body.

**Diagnosis**

Despite the often dramatic nature of the disease, diagnosis can be a challenge. Few mites may be present at the time of examination and only small numbers are required to produce intense disease. Mite burrows may be identified in the skin using magnification. Skin scrapings are more commonly used for diagnosis. Scrapings should be obtained from the edges of the lesion, not excoriated, hyperkeratotic, or otherwise chronically and severely affected areas. Deep scrapings that allow for the examination of the full thickness of the epidermis are required. If blood-tinged scrapings are not obtained, it is likely that the sample is not deep enough. Scrapings are suspended in mineral oil or microscope immersion oil. Multiple (up to 10) scrapings should be evaluated. Adult mites are approximately 0.5 mm long, with a morphology as depicted in Figure 1.8. Eggs, which are approximately 230 μm long, may also be seen.

Failure to identify mites, even with multiple properly collected deep scrapings, does not rule out disease because of the small number of mites that may be present. Consistent clinical signs with no other apparent cause are suggestive of scabies, and response to treatment supports the presumptive diagnosis.

A serum ELISA has been evaluated in dogs; however, it is questionable if it has a useful role in diagnosis. It might be useful in cases where mites cannot be observed on scrapings. The “pinnal-pedal” reflex, hind leg scratching in response to
vigorously rubbing of the ear, is used by some as a presumptive diagnosis; however, its positive predictive value is poor (0.57). It is truly just an indicator of ear pruritis, a common sign in scabies, and its main possible role might be to rule out scabies since the negative predictive value is high (0.98). Management

The coat should be clipped and an antiseborrheic shampoo should be used to remove crusts. Lime sulfur dip, while effective, is not often used because of the foul odor and the potential to stain light-colored hair coats. Amitraz bathing, weekly or every 2 weeks, is another option, however, it should not be used in Chihuahuas, pregnant or nursing bitches, and in puppies less than 3 months of age. Application of 0.25% fipronil as a spray has been used effectively, though this approach may be best with early disease or in patients where other products are contraindicated. Topical or systemic selamectin, ivermectin, milbemycin oxime, moxidectin, and moxidectin/imidacloprid can also be used. Regional availability and label indications affect the options that are available.

Humans

Clinical presentation

Scabies is characterized by an intensely pruritic papular eruption. In adults and older children, the interdigital folds, flexor aspects of the wrists, extensor surfaces of the elbows, anterior axillary folds, waistline, thighs, navel, genitalia, abdomen (especially periumbilical region), intergluteal cleft, and buttocks are most commonly infected. In younger children, vesicular lesions are more common and tend to appear on the scalp, face, neck, palms, and soles. Itching is most intense at night, and excoriations are common from scratching. As is the case with dogs, humans will usually only be infected with 10–15 mites.

Scabies may have a different clinical picture in immunocompromised patients, particularly individuals with HIV/AIDS, and the elderly. In those individuals, widespread or localized hyperkeratotic or crusted plaques may be present. As opposed to classical scabies, lesions are often non-pruritic because of the altered immune response. This is often termed “Norwegian scabies,” and it is highly contagious because of the massive numbers of mites that are usually present. Nosocomial transmission to patients and healthcare workers with subsequent infection of family members can occur, at times causing relatively large outbreaks.

It is impossible to differentiate zoonotic from human-associated scabies clinically, although S. scabiei var. canis tends to cause milder and self-limited disease and burrows should not be present. Zoonotic scabies lesions are more common on exposed skin areas that have direct contact with the pet, and lesions may be more extensive in people with close, prolonged contact with the pet or when diagnosis of the pet is delayed.

Diagnosis

Definitive diagnosis is based on the identification of mites, mite eggs, or mite feces from skin scrapings. Scrapings should be collected from papules or intact burrows. Scabetic burrows are gray or white tortuous lines, though these can be difficult to identify and may be destroyed by scratching. Burrows are not present in people with S. scabiei var. canis infestation. Scrapings should be collected and evaluated as described above for

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**Figure 1.8** *Sarcoptes scabiei*, 350–450 μm (public domain, Centers for Disease Control and Prevention, no specific provider information).
animals. Skin scrapings are often negative, so clinical signs and exclusion of other likely causes may be required for presumptive diagnosis. Mite morphology cannot be used to distinguish between human and canine origin *S. scabiei*. When exposure to infected animals is known or considered likely, measures to reduce the risk of further zoonotic transmission are indicated.

Owners of dogs with sarcoptic mange should restrict contact with the animals until they have been treated. The duration of infectivity after treatment has been started is not known, but animals probably become noninfectious within a few days of treatment. In the interim, attention should be paid to reducing contact with infected dogs, avoiding direct skin-to-dog contact and not permitting the dog to sleep on beds or furniture. As mites can live off the host for a period of time, bedding and other potentially contaminated items should be laundered and dried in a clothes dryer. Steam cleaning of carpets and furniture should help reduce or eliminate mites, though it is unclear whether this is really necessary. Grooming equipment should be disinfected or discarded. All dogs in contact with infected dogs should be treated concurrently. Treatment of potentially exposed cats is not required.

Prophylactic treatment of exposed immunocompetent individuals is generally not indicated; however, it is reasonable to consider prophylactic therapy in certain high-risk individuals, particularly those with low CD4 counts since the likelihood of Norwegian scabies increases as CD4 count declines.

Routine preventive therapy for *S. scabiei* is not indicated, though routine administration of selamectin or moxidectin/imidacloprid for other purposes will help prevent infection. Efforts should be directed to decreasing the likelihood of exposure, including preventing pet dogs from coming into contact with feral animals or wildlife, prompt treatment of infected animals, quarantine of facilities with ongoing outbreaks, and isolation of infected animals.

**Strongyloides stercoralis**

**Introduction**

*S. stercoralis* is a nematode that is sometimes referred to as the human threadworm. While
Infection can then result from penetration of the skin by these infective larvae in soil. After the penetration of the skin, larvae migrate to the lungs and ascend the tracheobronchial tree. After being swallowed, they mature to adults within the gastrointestinal tract and continue the life cycle. Rarely, infection can occur following ingestion of filariform larvae from inadvertent ingestion of feces. Rarely, in immunocompromised individuals, larvae may migrate throughout the body, including the CNS.

Geographic distribution/epidemiology

There is a sporadic geographic distribution, with \textit{S. stercoralis} being more common in tropical and subtropical regions. Endemic foci can be present in some temperate countries. Highest rates of infection in humans are found in parts of Southeast Asia, Latin America, and the Caribbean. Rates of fecal shedding tend to be low (<3%) in endemic areas \cite{8,9,305,307} but can be very high in some groups, such as alcoholics and people with HIV/AIDS. \cite{508,509}

All ages can be affected, but disease is more common in children. There are numerous reports of \textit{S. stercoralis} in the feces of dogs, most from tropical and subtropical regions, with reported prevalences of larvae in feces ranging from 0% to 1.8%. \cite{6,313,510,513} Infections are more common in young animals, particularly puppies in pet stores and breeding kennels, \cite{313,510,514} because of close mixing of young puppies and greater environmental contamination. It can be a cause of chronic disease in kennels. \cite{515} It is possible that \textit{S. stercoralis} is underdiagnosed because of infrequent and low-level shedding of larvae and the infrequent use of techniques that would detect larvae. \cite{515} Cats are rarely infected, and some studies have failed to find \textit{S. stercoralis}. \cite{516,517} However, there is a report of infection of 18% of stray cats in Qatar. \cite{518}

Human infections usually result from the penetration of infective larvae through the skin, after contact with soil contaminated with human feces. Direct contact with feces containing infectious larvae and fecal–oral infection can also occur. Person-to-person transmission can occur in certain situations, such as day care, mental institutions, and among men that have sex with men. \cite{1,519}
Infections in dogs presumably develop in a similar manner; however, transmammary infection may also be important. The likelihood of transmammary infection depends on the time of the dam’s infection. Infection of puppies is almost certain if the dam is infected with L3 larvae during lactation. Unlike Strongyloides infections in many other species, there is no hypobiotic state in tissue, and transmammary infection of puppies will only occur during acute infection of the dam.

The role of dogs in human disease is presumed to be minimal. Direct evidence of zoonotic transmission from companion animals is limited. There is a report of S. stercoralis infection in a dog colony worker and dogs that he worked with. There is also some evidence that people who work with dogs, such as dog breeding kennel personnel, may be at higher risk of exposure. The seroprevalence in one study of kennel workers in Brazil was 27%.510 which was higher than the expected community rate, although care must be taken in interpreting results since there was no direct comparison with a control group, and seroprevalence data indicate exposure, not necessarily disease.

**Animals**

**Clinical presentation**

Infection is usually inapparent and clinical disease is largely confined to breeding kennels, shelters, and pet stores. Diarrhea, pneumonia, dermatitis, and weight loss can develop but are usually mild in immunocompetent adult dogs. Clinical signs occur most commonly in young dogs. Disseminated disease can occur in immunocompromised dogs and in puppies. Disease in cats is rare.

**Diagnosis**

Diagnosis is based on the detection of larvae in feces. Fecal flotation or Baermann methods are used, but flotation methods are not recommended because of low sensitivity. Zinc sulfate fecal flotation or formalin-ethyl acetate sedimentation techniques can be used to identify larvae. Specimens should be examined promptly because hyperosmotic solutions may make larvae shrink and difficult to detect. Serological testing has been used because of the low recovery rates of other methods, though interpretation of results may be difficult because of the high seroprevalence rates in some groups and the potential that positive results simply indicate historical exposure.

**Management**

Ivermectin, fenbendazole, or thiabendazole is effective. These drugs will not kill migrating larvae. Otherwise healthy dogs are unlikely to have many migrating larvae in their body at any time, but relapse is possible and retreatment may be necessary. Feces should be examined 2–3 weeks after treatment, then monthly for 6 months, to ensure that there is no persistent infection resulting from migrating larvae that escaped initial treatment. All dogs in the household or kennel should be treated concurrently.

**Humans**

**Clinical presentation**

Most infections are asymptomatic. Clinical disease, when present, can be the result of cutaneous invasion or systemic migration. Disease in immunocompetent individuals most commonly starts as a localized, pruritic, and erythematous rash at the site of larval penetration. Serpiginous tracks (larva currens) that advance as fast at 10 cm/hour can be observed. After several days, transient pneumonitis can develop as larvae migrate to the lungs. Overt respiratory disease is rare in people without underlying pulmonary disease. Several weeks later, diarrhea and other signs of abdominal disease may develop. Signs often mimic peptic ulcer pain. Rarely, heavy infestations can result in bowel obstruction from the associated intestinal inflammation. With chronic disease, recurrent larval migration can result in pruritis around the anus, perineum, buttocks, and upper thighs. There may also be intermittent eosinophilia and/or meningitis.

Hyperinfection syndrome occurs as a result of “accelerated autoinfection” from filariform larvae. This is a rare but potentially devastating syndrome that can occur in immunocompromised individuals, particularly people with HIV/AIDS,
tuberculosis, neoplasia, and solid organ or stem cell transplantation, as well as people on immunosuppressive therapy and alcoholics. The most significant risk factor for developing Strongyloides hyperinfection syndrome is treatment with high-dose corticosteroids. Hyperinfected individuals have large numbers of *S. stercoralis* in the lungs and intestinal tract, and throughout the body, particularly in the CNS, kidneys, and liver. Wide-ranging and often severe clinical signs may be present. Extensive migration of parasites through the intestinal mucosa can result in translocation of intestinal bacteria, particularly gram-negative organisms, with the potential for sepsis, meningitis, or other sequelae of bacteremia.

**Diagnosis**

Definitive diagnosis involves detection of *S. stercoralis* larvae in feces by direct smear or culture on agar plates. Diagnosis can be difficult because of the typically low worm burden and infrequent excretion of larvae, and at least three serial stool samples should be evaluated. Larvae are similar to hookworm larvae but have a shorter buccal cavity. Eggs are rarely, if ever, identified in feces. Collection of duodenal contents by the string test or through endoscopic aspiration may also be used for the detection of larvae. Real-time PCR of feces offers twice the sensitivity of Baermann testing but is not yet available as a routine diagnostic test.

Serological testing is sensitive but nonspecific because of possible cross-reaction with other helminths. Eosinophilia is common and *S. stercoralis* should be considered in all instances of unexplained eosinophilia. Identification of larva currens is considered pathognomonic. Disseminated disease may be diagnosed by the detection of *S. stercoralis* larvae in sputum, bronchoalveolar lavage fluid, or CSF.

**Management**

Ivermectin is the drug of choice. Albendazole and thiabendazole may also be used but are associated with lower efficacy or poor drug tolerance, respectively. Prolonged or repeated treatment may be required, particularly with disseminated disease. The prognosis is good in immunocompetent individuals but poor in people with disseminated disease. Even with appropriate treatment, mortality may exceed 25% in disseminated disease, with rates of 80–100% mortality in untreated individuals.

**Prevention**

Human feces are the main source of infection, so measures aimed at avoiding environmental contamination with human feces and reducing the risk of contact with contaminated sites are the keys for prevention. Serological testing has been recommended in people in endemic areas that are immunosuppressed or starting immunosuppressive therapy, followed by either fecal examination of seropositive individuals and treatment of people shedding *S. stercoralis* or simply treatment of all seropositive people.

Overall, the risk of dog–human transmission of *S. stercoralis* is low, and it is probably only a reasonable consideration in certain tropical or subtropical regions or in people who work closely with young puppies and have a high likelihood of contact with feces (e.g., kennel workers, pet store personnel). Measures to reduce the risk of exposure to *S. stercoralis* from dogs involve basic concepts of avoiding fecal exposure. Particular care should be taken with puppies from breeding kennels or pet stores. Factors such as prompt removal of feces, avoiding direct contact with feces during removal, avoiding contamination of surfaces when handling feces, prompt hand hygiene after handling feces or having contact with a dog with fecal staining of the coat, and proper cleaning of fecal accidents are key points. Because infective larvae can be passed in feces, some degree of risk is present with fresh feces, not just feces that have been in the environment for prolonged periods of time.

**Taenia spp.**

**Introduction**

Infections with *Taenia* species tapeworms are a significant risk to humans in some regions. They are typically associated with cattle and pigs, and, more specifically, ingestion of undercooked beef and pork. Human infections with *Taenia* species that
infect dogs and cats are rare, and pets play a very minor role in human infection.

Etiology

The most relevant human pathogens are *Taenia saginata*, the beef tapeworm, and *Taenia solium*, the pork tapeworm. Pets are not involved in the transmission of these species. Dogs can occasionally act as intermediate hosts for *T. solium* but are not definitive hosts, and therefore do not develop patent intestinal infections and shed eggs.

A variety of *Taenia* species can be found in dogs, including *Taenia crassiceps*, *Taenia hydatigena*, *Taenia multiceps*, *Taenia pisiformis*, and *Taenia serialis*. *Taenia taeniaeformis* is found in cats. Of these, *T. multiceps* is of the greatest relevance in humans.

Life cycle

As with other cyclophyllidean tapeworms, *Taenia* spp. have a life cycle involving definitive and intermediate hosts. Definitive hosts are carnivorous/omnivorous species such as dogs, coyotes, foxes, and humans. Intermediate hosts are species such as cattle, sheep, pigs, hares, rabbits, and various rodents. Humans can be accidental intermediate hosts of many *Taenia* spp.

Adult *Taenia* can be very large, ranging from tens to hundreds of centimeters in length, depending on the species. They live in the small intestine of the definitive host, and gravid proglottids (segments) or eggs are shed in feces. Eggs are released when proglottids are damaged during intestinal passage or in feces as the proglottid degenerates. Eggs are immediately infective and hatch after ingestion by a suitable intermediate host, including humans. Hexacanth embryos then penetrate the intestinal wall and migrate to different sites, such as the liver, skeletal muscle, or heart. There, they mature into second-stage larvae, which are infective to definitive hosts when they ingest infected tissues. Intermediate structures (e.g., coenurus for *T. multiceps*) can develop in tissues, containing the intermediate stage of the parasite. Whether or not disease develops depends on the size and location of the structure.

Geographic distribution/epidemiology

*Taenia* spp. are commonly found in dogs and cats in some regions, most often in warm climates and in feral populations. In dogs, *Taenia* spp. shedding rates of 1.1–45% in feral and shelter dogs, and 0–4% in household pets may be present. Shedding rates of 9.1–76% have been reported in studies of *T. taeniaeformis* in stray cats, with lower rates (0–3.5%) reported in household pets.

Human infections with *Taenia* species found in pets are rare. The main concern regarding pet-associated disease is cystic infection caused by *T. multiceps*, *T. crassiceps*, and *T. serialis* from dogs, which can involve formation of unilocular cysts in the CNS, eye, subcutaneous tissues, or within the muscle.

Disease is rare in humans and is most common in African and South American countries. Only a small number of cases have been reported in North America. Dogs presumably play a minor role in human disease. “Significant” prior exposure to dogs was reported in all six infected people in one report; however, it is uncertain whether that truly represents a causal association in any or all of the cases.

Human infections with *T. taeniaeformis* are exceedingly rare. A larval cyst was identified as an incidental finding in the liver of an elderly man. Adult *T. taeniaeformis* worms were apparently identified in the vomitus of a child in Sri Lanka, although the authors were unclear whether the child may have vomited on a spot on the floor where the child’s pet cat had deposited the worms, whether the child may have ingested live worms because of the poor level of hygiene, or whether it was a true infection. If it was a true intestinal infection, however, the source would not have been the cat, since the child would most likely have been infected by ingestion of cysts from an infected intermediate host.

The role of pets in human disease is poorly defined and presumably minimal. The authors are unaware of any studies that have made an objective link between pet ownership or contact and human *Taenia* spp. infection, although the potential certainly exists. The primary concern with intestinal *Taenia* spp. infection in pets is the fact that it cannot be differentiated from infection with
**Echinococcus** spp. (which is a much more significant zoonotic concern) based on clinical signs or fecal examination.

Systemic *Taenia* infections have been reported in dogs, cats, and rabbits. These pose no direct risk to humans, although they indicate that humans could be exposed to the same source as the pet (i.e., undercooked meat).

### Animals

**Clinical presentation**

Disease is rare. Typically, infected animals have no apparent clinical signs. Sometimes, perianal irritation can occur as a result of the passage of proglottids. This may cause “scooting” or chewing at the anus.

Cystic lesions, while exceedingly rare, can cause a wide range of clinical signs in dogs, cats, and rabbits, depending on their location. Progressive and severe neurological disease may be present with CNS lesions. Subcutaneous lesions present as a soft mass, which would be similar to other types of cysts or possibly abscesses.

**Diagnosis**

Diagnosis is based on the identification of tapeworm segments in feces by direct examination or detection of eggs using fecal flotation (Figure 1.10). The individual-sample sensitivity is low because proglottids are not uniformly distributed in feces nor are they consistently shed in infected animals, and testing of three fecal samples collected over one week is preferred. Purgation with substances such as arecoline can be used to increase recovery, but this is not a practical or justifiable test in routine clinical settings.

### Management

Praziquantel and epsiprantel are highly effective for the elimination of intestinal *Taenia*. Concurrent measures must be taken to reduce exposure to intermediate hosts.

Treatment of systemic infection depends on the location and severity. CNS infections are typically fatal. Surgical removal of cysts is the best option, if they are accessible. The use of anthelmintics alone has not been adequately investigated but probably is of limited efficacy.

### Humans

**Clinical presentation**

Infections with adult *Taenia* spp. are usually asymptomatic. In some cases, there may be mild nonspecific gastrointestinal symptoms such as nausea or abdominal pain. Proglottids may be passed intermittently and noted in the stool.

Cystic disease may occur when a human inadvertently ingests a *Taenia* spp. egg. Clinical manifestations depend on the location and size of cysts. Most commonly, the eye or CNS is involved. CNS disease produces nonspecific signs such as generalized weakness, seizures, inability to walk, and gradual deterioration in neurological status. Hydrocephalus and basal arachnoiditis are common. Ocular infections may be associated with vision loss and involvement of vitreous, anterior chamber or subconjunctival tissues.

**Diagnosis**

Diagnosis of intestinal disease is made by the identification of eggs in the stool.

Diagnosis of cystic disease is usually made by CT or MRI, which identify the characteristic cysts. Serological testing is available, but it has poor sensitivity when there are single or only a few cysts.
Management

Surgical removal of the cyst is recommended, if feasible.\textsuperscript{213,534} Praziquantel is often used as an adjunctive measure to surgery.\textsuperscript{534} Information regarding the potential efficacy of praziquantel or other anthelmintics alone is limited. In some cases, treatment with praziquantel has been used as the sole initial approach, and the intermediate stage was apparently killed; however, surgical removal of the mass was still required.\textsuperscript{534} Praziquantel has been used for ocular disease, with successful killing of the coenurus but loss of vision.\textsuperscript{563} Albendazole may also be used for cystic disease.

Prevention

Efforts for preventing intestinal \textit{Taenia} infection in humans need to involve control of infection in food animal intermediate hosts and avoiding ingestion of undercooked meat. Pets play no role in intestinal \textit{Taenia} infection in humans, and the role of pets in human coenurosis is apparently limited, based both on the rarity of disease and lack of evidence to the contrary. However, considering the potential for transmission and the potential severity of disease, it is still reasonable to consider \textit{Taenia} control in pets to help prevent human infection. Reducing exposure of pets to infected intermediate hosts involves decreasing roaming and scavenging, as well as avoiding feeding raw meat or offal from livestock or wildlife. If owners are determined to feed raw meat, it should be frozen prior to feeding to kill any \textit{Taenia} cysticerci it may contain. \textit{T. solium} cysticerci are effectively killed in 4 days at $-5^\circ C$, 3 days at $-15^\circ C$, and 1 day at $-24^\circ C$.\textsuperscript{564} Other \textit{Taenia} species are presumably similarly susceptible, and keeping meat frozen for at least 10 days prior to feeding is a reasonable precaution. If treatment is based on fecal testing, then multiple fecal samples must be examined at each interval due to the low test sensitivity. If tapeworm eggs are identified, treatment should be administered as soon as possible because the eggs cannot be differentiated from those of \textit{Echinococcus} spp.

\textit{Taenia} spp. eggs can also be found in the soil in various environments.\textsuperscript{565} The role of environmental exposure in disease is unclear, but general hygiene measures to avoid inadvertent fecal–oral exposure and controlling roaming of animals may help reduce any risks.

Ticks

Introduction

Ticks are blood-sucking insects that belong to the Arachnida class. There are two main types of ticks: Ixodidae (hard ticks) and Argasidae (soft ticks). Hard ticks include the three most common genera involved in the transmission of zoonotic diseases that can involve both pets and humans: \textit{Ixodes}, \textit{Rhipicephalus}, \textit{Dermacentor}, and \textit{Amblyomma} (Figures 1.11–1.13, Table 1.4).\textsuperscript{272,566–571} There is marked geographic variation in the presence and prevalence of ticks, and an understanding of the regional prevalence, the types of ticks, and the prevalence of tick-borne diseases is important. The simple presence of a tick does not mean that tick-borne infection is likely or even possible, since not all ticks are sources of infection and typically only a minority of ticks are infected.

An important aspect of tick-borne disease is the time required for infection. Infection is transmitted during feeding, something that does not occur

![Figure 1.11 Ixodes scapularis (public domain, photo credit: James Gathany).](image-url)
Table 1.4  Examples of zoonotic pathogens that can be found in ticks from companion animals.

<table>
<thead>
<tr>
<th>Tick</th>
<th>Pathogen(s)</th>
</tr>
</thead>
</table>
| *Rhipicephalus sanguineus* (brown dog tick) | *Coxiella burnetii*  
|                               | *Rickettsia rickettsii*  
|                               | *Rickettsia conorii*  
|                               | *Bartonella vinsonii* subsp. berkoffii                                      |
| *Ixodes scapularis* (deer tick) | *Anaplasma phagocytophilum*  
|                               | *Ehrlichia chaffeensis*  
|                               | *Ehrlichia ewingii*  
|                               | *Bartonella henselae* (possibly)  
|                               | *Borrelia burgdorferi*  
|                               | *R. rickettsii*  
|                               | *R. conorii*                                                                |
| *Ixodes pacificus*             | *B. burgdorferi*                                                            |
| *Ixodes ricinus*               | *A. phagocytophilum*  
|                               | *C. burnetii*  
|                               | *Borrelia spp.*  
|                               | *Tick-borne encephalitis virus*                                              |
| *Amblyomma americanum* (lone star tick) | *E. chaffeensis*  
|                               | *E. ewingii*  
|                               | *B. burgdorferi*  
|                               | *Francisella tularensis*                                                    |
| *Dermacentor variabilis* (dog tick) | *R. rickettsii*  
|                               | *F. tularensis*                                                             |
| *Dermacentor andersoni* (wood tick) | *R. rickettsii*  
|                               | *F. tularensis*                                                             |

until 24–36 hours after attachment for most tick-borne diseases. This is a critical control point since prompt identification and proper removal of ticks can reduce or negate any risk of pathogen transmission.

Human health relevance of ticks on pets

Finding ticks on pets indicates that ticks are present in the area and that there is the potential for human exposure from the same infected environments. The other concern is the potential that ticks brought into the household could leave the animal and subsequently attach to humans. The incidence of intrahousehold transmission is unknown and is probably low. Pets are probably a better indicator of what ticks are in the environment than a likely source of human infection. An additional but still theoretical risk is the potential for human exposure is contact with infectious fluids from ticks that are crushed during tick removal. Pets could also potentially transport ticks able to cause tick paralysis into the house.

Tick avoidance

One way to reduce the risk of contact is to avoid areas that are likely infested with ticks. If exposure to tick-infested areas is unavoidable, various measures can be taken. These include wearing long-sleeved shirts that seal tightly around the wrists,
wearing long pants that are tucked into high socks, and using DEET-containing repellents. Wearing permethrin-treated clothing is also a highly effective measure. Use of DEET on pets is not recommended by the Animal Poison Control Center because of the high sensitivity of dogs and cats.

Identification of ticks

Human and animal bodies should be carefully inspected for ticks after being in potentially tick-infested areas. Careful examination is required, particularly for nymphs that can be the size of a poppy seed. While ticks require 24–36 hours to transmit most relevant diseases, tick inspections should be performed promptly after being in potentially tick-infested environments. In humans, particular attention should be paid to the scalp, pubic, and axillary areas.

Tick removal

Ticks should be carefully removed, to ensure removal of the entire tick and to avoid crushing it and potentially being exposed to infectious fluids. Slow and deliberate movements are required. Constant traction with curved forceps or a tick removal device is ideal. Tweezers are less desirable since they are more likely to result in crushing of the tick. Ticks should be grasped as close to the skin as possible, and twisting should be avoided. Bare fingers should not be used to remove ticks because of the potential for exposure to tick feces or hemolymph, which may be infected with pathogens such as *Rickettsia rickettsii*. Application of substances such as alcohol or the use of direct heat is ineffective at removing ticks and should not be attempted.

Tick control products for pets

Routine use of tick control products (Table 1.5) should be considered in animals at risk of exposure, particularly in areas where ticks are likely to be infected with important pathogens. The use of tick control products should not be relied on as a sole preventive measure, since no product provides 100% protection. Some authors have advocated year-round treatment because of the greater cold tolerance of ticks compared with fleas. This is reasonable in many areas but unlikely to be necessary in regions with long cold periods. The key is to use tick control products during the at-risk period, and that varies between regions.

As all life cycle stages of *Rhipicephalus sanguineus* can use dogs as suitable hosts, infested dogs can be a long-term source of infestation for other dogs. Therefore, treatment of all dogs in a household should be performed if one or more dogs are exposed.

Environmental control

Reducing habitats amenable to intermediate hosts should be performed when possible. This may involve removal of piles of brush or yard waste, or trimming of weeds and plants in areas where the pet has frequent access. Access of wildlife to crawl spaces or similar yard areas should be prevented.

More intensive environmental control is required if *R. sanguineus* is present, since dogs are suitable long-term hosts. The use of environmental acaricides (i.e., synthetic pyrethroids) should be considered in response to finding an infested dog in a household. Methodical treatment of the environment is necessary since these ticks may be found in cracks and crevices, on ceilings, and in other difficult-to-reach areas.

Toxocara and Toxascaris spp.

Introduction

*T. canis* and *T. cati* are dog and cat roundworms (ascarids), respectively. These parasites are commonly found in dogs and cats, and often receive much attention as possible causes of human infection. *Toxascaris leonina* is another roundworm that can infect dogs and cats. Humans are accidental hosts of *T. canis* and *T. cati*, but infections can result in visceral larva migrans (VLM), ocular larva migrans (OLM), and other syndromes, particularly in young children. The relative importance of *T. canis* and *T. cati* is somewhat controversial and difficult to determine because of cross-reactivity of
Companion Animal Zoonoses

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Table 1.5  Examples of commercial tick preventive formulations for use in dogs and cats.

<table>
<thead>
<tr>
<th>Active ingredient(s)</th>
<th>Route</th>
<th>Label claims*</th>
<th>Animal species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amitraz</td>
<td>Collar</td>
<td>Ticks: no specific species claims</td>
<td>Dog</td>
</tr>
<tr>
<td>Dinotefuran, pyriproxyfen, permethrin</td>
<td>Topical: spot-on</td>
<td><em>Amblyomma maculatum</em>, <em>D. variabilis</em>, <em>I. scapularis</em>, <em>R. sanguineus</em></td>
<td>Dog</td>
</tr>
<tr>
<td>Fipronil, methoprene</td>
<td>Topical: spot-on</td>
<td><em>A. americanum</em>, <em>D. variabilis</em>, <em>I. scapularis</em>, <em>R. sanguineus</em></td>
<td>Dog, cat</td>
</tr>
<tr>
<td>Fipronil</td>
<td>Topical spot-on or spray</td>
<td>A. americanum, D. variabilis, I. scapularis, R. sanguineus</td>
<td>Dog, cat</td>
</tr>
<tr>
<td>Imidacloprid-permethrin</td>
<td>Topical: spot-on</td>
<td>A. americanum, D. variabilis, I. scapularis, R. sanguineus</td>
<td>Dog</td>
</tr>
<tr>
<td>Metaflumizone, amitraz</td>
<td>Topical: spot-on</td>
<td>A. americanum, D. variabilis, I. scapularis, R. sanguineus</td>
<td>Dog</td>
</tr>
<tr>
<td>Permethrin</td>
<td>Topical: spot-on</td>
<td>A. americanum, D. variabilis, I. scapularis, R. sanguineus</td>
<td>Dog</td>
</tr>
<tr>
<td>Permethrin, pyriproxyfen</td>
<td>Topical: spray</td>
<td>Ticks: no specific species claims</td>
<td>Dog</td>
</tr>
<tr>
<td>Pyrethrins</td>
<td>Topical: dip</td>
<td>Ticks: no specific species claims</td>
<td>Dog, cat</td>
</tr>
<tr>
<td>Selamectin</td>
<td>Topical: spot-on</td>
<td><em>D. variabilis</em></td>
<td>Dog</td>
</tr>
</tbody>
</table>

Adapted from Blagburn and Dryden [272].
* Label claims in the United States.

serological testing. It has classically been assumed that *T. canis* is the main cause of human infection,\(^{575}\) however, the importance of *T. cati* may be underestimated, especially in ocular disease.\(^{576,577}\)

Etiology

Ascarids are large, elongated, nonsegmented, cylindrical intestinal nematodes that undergo sexual reproduction in the intestinal tract of their animal hosts, and have a maturation stage outside of the body in soil. *T. canis* is the most common canine roundworm, and *T. cati* is the most common in cats. *T. canis* is not known to infect cats nor is *T. cati* known to infect dogs. *Toxascaris leonina* can be found in both dogs and cats. Other *Toxocara* species have been identified in cats, such as *Toxocara malaysiensis*.\(^{578}\) *Toxocara mystax* is a synonym for *T. cati*.\(^{579}\) The zoonotic significance of these is not known.

Life cycle

The life cycle is shown in Figure 1.14. Adult roundworms inhabit the small intestine of their preferred host. Nonembryonated eggs are passed in feces
Toxocariasis

*(Toxocara canis, Toxocara cati)*

**Figure 1.14** Toxocara life cycle (public domain, Centers for Disease Control and Prevention, Alexander J. da Silva, Melanie Moser).

and mature to the infective third-stage larval form in the environment. Typically, 2–4 weeks are required for *T. canis* and *T. cati* to become infective, although this varies with environmental conditions. Infective larvae can develop in 9–15 days at 25–30°C but require 35 days at 16.5°C.580 *T. leonina* larvae may become infective in as little as 1 week.47 Susceptible hosts become infected by ingestion of infective eggs or from ingestion of animals (paratenic hosts) with larvae in tissues. Earthworms and perhaps other invertebrates can harbor larvae in their intestinal tracts and transmit infection if ingested.

When definitive hosts ingest infective eggs, *T. canis or T. cati* migrate through the intestinal wall to the liver and eventually the lungs. After reaching the lungs, larvae are coughed up and swallowed, and mature into adult worms in the small intestine, thereby completing the life cycle. Some larvae remain in tissue in an arrested state. After
ingestion of an infected paratenic host, larvae usually do not migrate but mature into adults in the small intestine.\textsuperscript{581} The larvae of \textit{T. leonina} do not undergo extraintestinal migration in definitive hosts, regardless of the source of infection.

The prepatent period for \textit{T. canis} is 2–5 weeks, while it is approximately 8 weeks for \textit{T. cati} and 8–11 weeks for \textit{T. leonina}.

In other species (paratenic hosts), after ingestion of infective eggs, the larvae penetrate the intestinal lining and migrate throughout the body. Unlike in definitive hosts, these larvae are unable to mature and complete the life cycle. Migration can continue, usually intermittently, for years, and clinical disease can develop from migration and the associated inflammatory response.

Transplacental infection can occur with \textit{T. canis} in puppies. This may be from acute infection of bitches but is primarily associated reactivation of latent larvae in tissues during late pregnancy, with subsequent in utero infection. There is no evidence of transplacental infection with \textit{T. cati} or \textit{T. leonina}.

Transmammary infection can occur in both puppies and kittens.\textsuperscript{47} In cats, while transmammary infection can occur, chronically infected cats tend to harbor few somatic larvae, and transmammary infection only occurs when the female is infected during late gestation.\textsuperscript{582} Bitches can be reinfected via ingestion of larvae in the feces of puppies.

Geographic distribution/epidemiology

**Dogs and cats**

\textit{Toxocara} species are common internationally, particularly in young kittens and puppies, as well as feral animals and those in shelters. The ability of \textit{T. canis} to be transmitted in utero and both \textit{T. cati} and \textit{T. canis} to be transmitted during nursing, along with the environmental tolerance of larvated eggs, creates an excellent opportunity for high parasite burdens in puppies and kittens. It is often assumed that almost all puppies are born infected with \textit{T. canis}; however, this is based on old data and it is unclear whether this is still true. Reported prevalence rates for dogs and cats vary with age, location (i.e., household, shelter, feral), geography, and the presence or absence of routine deworming. Studies of stray or shelter animals have reported prevalences of \textit{Toxocara} shedding ranging from 5.3% to 82% in dogs and from 0.8% to 54% in cats.\textsuperscript{129,155,158,162,345,536,542,543,583–592} Puppies are more often infected than adult dogs,\textsuperscript{158,165,313,351,590,593–596} as are hunting dogs.\textsuperscript{597} The prevalence of these parasites in adult cats and dogs in households is lower and is typically 0–4% in developed countries.\textsuperscript{115,119,129,154,307,308,312,313,355,541,587,596,598–600} As with \textit{T. canis}, \textit{T. cati} is more common (up to 33%) in kittens versus adults.\textsuperscript{117,119,591} Higher rates have also been found in house versus apartment cats,\textsuperscript{591} presumably reflecting greater likelihood that cats living in houses are allowed to have outdoor access compared with those living in apartments. \textit{T. leonina} is less common (0–32%) and tends to be focally distributed.\textsuperscript{154,160,161,307,536,542,592,593}

**Routes of human exposure**

Human toxocariasis can be found wherever dogs and cats are found, but the prevalence is highly variable between regions. Since dogs and cats (along with wild canids and felids) are the definitive hosts of these parasites, they clearly play a role in human infection. However, determination of the role of pets versus feral animals, and whether they act as a direct source of infection versus indirect infection from contamination of the outdoor environment can be difficult.

Human infections typically occur following ingestion of infective eggs from contaminated soil, ingestion of larvae in the tissues of infected paratenic hosts (e.g., raw livers of cattle, chickens, ducks, and pigs), or ingestion of inadequately washed or cooked fruits and vegetables.\textsuperscript{575,576} Direct contact with dogs or cats is of limited relevance because of the time required for eggs to become infective, though concerns have been raised about exposure to infective eggs on the hair coats of dogs. Studies have identified \textit{Toxocara} eggs on the hair coats of dogs, including a study of pound dogs from Ireland where 67% of dogs (mainly puppies) were contaminated.\textsuperscript{601} Another study reported the presence of \textit{Toxocara} eggs on 22% of (mainly young) dogs in Turkey.\textsuperscript{602} In that study, only 8% of eggs were embryonated and therefore potentially infective. Egg counts were relatively low in these studies: 8–12 embryonated eggs per gram of hair. Another study found \textit{Toxocara} eggs on the coats of 12% of dogs, but none were viable,\textsuperscript{312} while one other reported the presence of
Parasitic Diseases

T. canis eggs on 25% of dogs, with 4.2% embryonated and 24% embryonating. The individual animal does not need to be the source of hair coat contamination, as demonstrated by the presence of eggs from other animal species on the hair coat, indicating that contact with eggs in the outdoor environment may be the source. This has implications for control, since controlling Toxocara in pets may not necessarily prevent the risk of exposure from the hair coat of animals that are allowed outside. The true risk of human infection from the hair coat is unclear, particularly considering the small numbers of infective eggs that are typically present. One author used an estimate of 300 eggs per gram of hair and a 4% embryonated egg rate, and determined that someone would have to ingest over 4 g of hair to ingest 50 infective eggs, a level of ingestion that certainly is beyond casual, inadvertent exposure. Hair coat exposure is probably of even less concern in cats because of their fastidious grooming habits, but could be more relevant in debilitated or obese cats that do not groom properly, long-haired cats with a tendency for fecal staining of the perineum, or cats that have close contact with highly infected environmental sites. There is no evidence of transplacental infection in cats.

Contamination of the outdoor environment is common in many areas. Contamination rates of <1–55% of samples from parks, playgrounds, and family gardens have been reported. The ability of infective eggs to survive for prolonged periods of time under many climatic conditions allows for accumulation of potentially large egg burdens.

Seroprevalence in humans

Seroconversion is much more common than disease. Seroprevalence rates are variable depending on geographic region and risk factors for exposure. Rates of 1.6–85% have been reported, with the highest rates tending to occur in rural, poor, and/or tropical regions, although conflicting risk factor data are present. The seroprevalence increases with age, and males tend to be more commonly positive than females, perhaps due to differences in outdoor play and work.

Dog ownership has been widely reported as a risk factor for seroconversion, despite the fact that the source of infection is probably environmental. Dog ownership, regular contact with dogs, or the presence of dogs in the household have been reported as risk factors for seropositivity in children, as well as OLM. It is unclear whether the apparent risk of pet ownership is because of household environmental contamination that results from owning a dog or whether there may be other factors involved such as increased exposure to potentially contaminated external environmental sites (i.e., public parks) in dog-owning families. The latter possibility is perhaps supported by a study that reported an association of seroprevalence and pet ownership but not the presence of pets in the household.

The risk of exposure may be higher in dog breeders because of the high prevalence in young puppies and the likelihood of significant environmental contamination. This was demonstrated by a study that found seropositivity in 16% of British dog breeders compared with 2.6% of healthy controls. The likely role of the contaminated canine breeding environment is supported by other studies that did not show increased seroprevalence in other groups with frequent contact with dogs and cats, such as veterinary personnel, kennel workers, and cat breeders compared with the general population. Other reported risk factors for seroconversion include pica, living in rural areas, visiting a playground frequently, developmental delay in children, reduced IQ scores in children, low socioeconomic status, frequent playing in a sandbox, and frequent contact with soil. Most of these are associated with increased likelihood of direct or indirect ingestion of soil and poor hygiene. Not surprisingly, habitual hand washing before eating has been reported as a protective factor in children.

Disease in humans

While seroprevalence data are available, there is little information about the incidence of clinical disease. There is presumably significant variation in the incidence of disease and a parallel between high seroprevalence regions and disease incidence. Risk factors for seroconversion are also presumably risk factors for infection; however, there has been limited objective study. Care must be taken when considering the often high sero-prevalence
data (some of which are quite dated) from specific high-risk regions or populations, and extrapolating that to the risk of clinical disease in other areas. Anecdotally, the incidence of infection in many developed regions appears to be low. However, given the relative paucity of data and the potential severity of disease, toxocariasis should be considered a reasonable, if variable, zoonotic disease threat.

The two main human diseases associated with dog and cat ascarids are VLM and OLM, although other syndromes can also occur. Zoonotic disease is most commonly associated with *T. canis*, but *T. cati* can also be involved. VLM occurs most commonly in children less than 4–6 years of age, particularly in children with a history of pica or those living in unsanitary conditions. After ingestion, infective *Toxocara* can migrate throughout the tissues of the body, sometimes entering a dormant state and undergoing further migration later. The potential for dormancy and reactivation means that disease can occur well after infection, and the incubation period range is not known. Infection is most often asymptomatic, with seroconversion being the only detectable change, though fulminant infection and death can occur. Disease manifestations depend on various factors, including the number of larvae and the tissues they are migrating through.

Migration of *Toxocara* larvae into the eye is the cause of OLM. Typically, only one larva is involved, and infection is almost always unilateral. OLM presumably develops from chance migration of a larva into the eye, where it produces an eosinophilic inflammatory mass. As with VLM, children are most commonly affected, but they tend to be a few years older than those affected with VLM. OLM appears to be quite rare. One large American study estimated the incidence of disease in schoolchildren at 6.6–9.7 cases per 100,000 persons, while an earlier American study estimated an incidence of 1 case per 1000 persons and a study of children in Ireland did not detect any cases of OLM in greater than 2000 children. Concurrent VLM and OLM is very rare but can occur.

Other manifestations of *Toxocara* infection and migration depend on the tissues involved and the body’s immune response. *Toxocara* infection has been suspected as a cause of a range of allergic or inflammatory diseases. Numerous studies have investigated a possible role of *Toxocara* infection in bronchial asthma in children, with conflicting results. It has also been implicated as a cause of epilepsy, although not all studies have supported that association. Infection has also been associated with other disorders such as chronic urticaria, chronic pruritis, eczema and allergic rhinitis, and idiopathic eosinophilia.

### Animals

#### Clinical presentation

**Dogs**

Infection is usually subclinical, and clinical infections are mainly found in puppies. Puppies with disease attributable to *T. canis* usually have signs such as ill thrift, failure to gain weight, poor hair coat, and a pot-bellied appearance. In rare cases, severe disease or sudden death can occur. Some puppies with significant worm burdens may expel a large number of worms in vomitus.

As larvae migrate through the liver, scarring may develop, but this rarely produces any identifiable signs. In contrast, migration of large numbers of larvae through the lungs can result in respiratory disease from the associated hemorrhage and inflammation. This is usually in young puppies that acquire large numbers of *T. canis* in utero.

Clinical infections in adults are uncommon but can range from mild enteritis to intestinal obstruction from large worm burdens. Vomiting can occur from gastric irritation caused by larvae migrating through the gastric mucosa. Larva migrans has been reported but seems to be very rare. It has been suggested that OLM might be a problem in some dogs, such as working sheepdogs, although clear data are lacking.

Clinical disease from *T. leonina* infection is rare and has been poorly described.

**Cats**

Since in utero infection does not occur in cats, kittens are older at the time of infection and clinical disease does not occur until later, when compared with puppies. Clinical disease in kittens can be similar to that described above for puppies, but the
tendency for kittens to be older age at the time of infection may account for the lower incidence of clinically apparent and severe disease. Mild signs, particularly a pot-bellied appearance, may be all that are evident. Regardless, as far as zoonotic risk is concerned, shedding eggs is more important than clinical disease, and there is clear evidence that kittens can shed eggs by 3 weeks of age.

As with dogs, clinical infections in adult cats are uncommon. Nonspecific signs such as poor hair coat, diarrhea, and a pot-bellied appearance may be present.

**Diagnosis**

Clinical signs are nonspecific but suggestive in young puppies or kittens, particularly those with no or minimal history of deworming. Identification of worms in vomitus is diagnostic.

Diagnosis is most often based on the detection of eggs in feces using centrifugal flotation. Typically, large numbers of eggs are passed on a regular basis, but detection is not always straightforward. *Toxocara* eggs are difficult to differentiate from *B. procyonis* microscopically; however, *B. procyonis* is very uncommon in dogs and cats. The prepatent period is 2–4 weeks.

**Management**

Fenbendazole, milbemycin oxime, nitroscanate, moxidectin, febantel, and pyrantel pamoate are effective in dogs and cats. Piperazine can be used but is less effective than the other options. Emodepside is effective for the treatment of *T. cati* in cats. Most drugs used for monthly heartworm prophylaxis are effective against ascarids. Chemoprophylaxis is discussed below under Prevention. Antihelmintic resistance has not (yet) been identified in *Toxocara* spp.

**Humans**

**Clinical presentation**

**VLM**

Most infections are asymptomatic. Patients with clinical disease can have signs ranging from mild to fulminating to fatal. Mild disease may be characterized by nonspecific signs such as cough, fever, wheezing, and hepatomegaly, as a result of migration through the liver and lungs. Anorexia, headache, weight loss, fatigue, and abdominal pain may also be present. Radiographic evidence of lung involvement is quite common although severe respiratory disease is rare. Splenomegaly may be present in a small percentage of cases. Myocarditis is another rare manifestation. Concurrent OLM is uncommon but can occur.

Overt neurological disease is uncommon (as opposed to larva migrans caused by *B. procyonis*), but seizures may occur. Headache, fever, and other nonspecific neurological or systemic signs may also be noted in patients with neural larva migrans.

**OLM**

Endophthalmitis and retinitis are most common. Clinical complaints and signs may include loss of visual acuity, leukocoria, strabismus, pars planitis, uveitis, and retinal granuloma or detachment. Visual acuity may be maintained in many patients but greatly decreased in others. Blindness is uncommon but can occur. Bilateral disease is rare. Systemic signs such as hepatomegaly and fever are typically absent.

**Others**

Various other diseases have been associated, with varying strengths of evidence, with zoonotic ascarid infection. Nonspecific eosinophilia may be identified based on the body’s response to migrating larvae. Larval migration is a common, but not sole, cause of eosinophilia, and larva migrans should be considered in all cases of unexplained eosinophilia. An association has been made between anti-*Toxocara* antibodies and chronic idiopathic urticaria.

**Diagnosis**

**VLM**

Eosinophilia is a classical sign, and VLM should be considered in any patient (particularly any child) with unexplained eosinophilia. Leukocytosis and hypergammaglobulinemia may also be present. Possible exposure risks should be queried, especially pica.
Finding larvae in biopsies of affected tissues (i.e., liver) is diagnostic, but larvae are infrequently found because the inflammatory response often occurs in response to the external coat of the parasite that can be shed frequently during migration, so larvae may not be present at the site of active inflammation. Detection of serum antibodies against *Toxocara* is supportive but not definitive because asymptomatic individuals may also be seropositive, and the positive predictive value of serological data depend on the baseline seroprevalence in the population.

**OLM**

OLM should be considered in any child with vision loss and strabismus. Diagnosis is predominantly based on clinical signs during ophthalmologic examination. Posterior pole granuloma that mimics a retinoblastoma may be observed. B-scan ultrasonography is useful to differentiate those two conditions. Serum antibody levels are not particularly helpful because some people with OLM are seronegative and a variable percentage of healthy individuals may be seropositive. Identification of high antibody levels in vitreous fluid versus serum may be useful diagnostically.

Peripheral eosinophilia is rare.

**Others**

Diagnosis of other manifestations can be difficult because of the often vague nature of the disease. Seropositivity along with the presence of clinical signs potentially attributable to *Toxocara* infection is suggestive but is obviously complicated by the baseline seroprevalence rate in the healthy population.

**Management**

**VLM**

Most people have mild disease and recover without therapy. Treatment is provided in people with severe disease, such as neurological disease or severe respiratory disease. Albendazole is the drug of choice. Corticosteroids may be considered in patients with CNS or cardiac involvement.

**OLM**

There is no standard approach to OLM, and treatment is often unrewarding because of the typically long delay from infection to diagnosis.

Albendazole is the anthelmintic of choice, but anthelmintics are often avoided because of concerns about severe, sight-threatening inflammation from dying larvae. Corticosteroid injections may reduce ocular inflammation. Vitrectomy is often required.

**Prevention**

**Deworming dogs and cats**

Every puppy and kitten should be considered infected, and proper deworming of these animals is critical. All puppies should be dewormed with pyrantel pamoate, fenbendazole, or milbemycin oxime at 2, 4, 6, and 8 weeks of age, then monthly to 6 months of age. Deworming of kittens should start at 3 weeks of age. Nursing dams should be treated at the same time as their offspring. If bitches have previously had a litter with significant *T. canis* burdens, they should be dewormed with daily fenbendazole during pregnancy or two to four times during pregnancy with ivermectin. Recommendations for animals over 6 months of age are conflicting and include deworming monthly, once or twice a year, or at least four times a year at intervals not exceeding 3 months. Basing treatment recommendations on fecal examination in low-risk households with no regular prophylactic treatment has also been recommended. Factors that need to be considered when developing a roundworm control program include the prevalence of roundworms in the area, the breeding status of the animal, management of the pets, number of pets in the household, and whether there are high-risk people (e.g., children with pica) in the household.

**Fecal examinations in dogs and cats**

Fecal examinations should be performed periodically to determine the need for deworming and to assess the efficacy of the preventive program.
Varying recommendations have been made, including testing two to four times the first year and one to two times per year thereafter.\textsuperscript{47} Centrifugal flotation methods should be used because of their higher sensitivity compared with gravitational flotation techniques.

**Reducing exposure of pet dogs and cats**

Restricting outdoor exposure, especially uncontrolled outdoor exposure that could be associated with ingestion of feces or killing and eating paratenic hosts, could also help reduce (but not eliminate) the risk of exposure of household pets.

**Reducing human exposure**

Avoiding contact with feces in the environment is a logical control measure but may be difficult. Because of the time required for eggs to become infective and the tolerance of eggs in the environment, evidence of fecal contamination may not be apparent in environments where infective eggs are present. Prompt removal of feces that are passed outside is therefore an important control measure. Similarly, regular removal of feces from litter boxes will prevent the formation of infective eggs.

Decontamination of the environment is difficult to impossible because of the inherent difficulties in eliminating pathogens from organic-rich sites and the environmental tolerance of the parasite. Application of disinfectants is not a practical method in outdoor environments. Temperature plays an important role in environmental development and persistence of eggs. Larval development ceases at temperatures below 10°C, and larvae die at temperature of −15°C or less.\textsuperscript{580} Thorough cleaning is important in areas where puppies or kittens and their dams are housed and after accidental fecal contamination of the environment. Physical removal of eggs from surfaces by thorough cleaning is important because of the resistance of *Toxocara* eggs to most disinfectants.

Ultimately, infection in humans requires ingestion of infective larvae in eggs, so close attention to hand hygiene, particularly after contact with high-risk areas (e.g., puppy/kitten environment) or animals in those environments is important. Close supervision of children should be used to prevent ingestion of soil, sand, feces, or other potentially contaminated items. This is particularly true for children or other individuals with a tendency toward geophagia or pica. Close attention to hand hygiene after working or playing outside is also important. Sandboxes should be covered to prevent cats from defecating in them, whenever possible. Some cities have removed sandboxes from municipal parks because of the risk of larva migrans.\textsuperscript{667} This may be difficult to justify given the low incidence of disease in humans and the ability to reduce the risk with good hygiene practices and child supervision.

There are no specific recommendations for chemoprophylaxis following exposure, such as when a child is observed to ingest potentially contaminated soil.\textsuperscript{2}

Education of pet owners and nonpet owners alike is important to increase awareness about the need for proper roundworm control in pets, proper fecal handling, and avoiding inadvertent ingestion of contaminated soil. Understanding of the risks and required infection control measures is poor in the general population. In a British study, pet owners were no more knowledgeable about zoonotic toxocariasis than nonpet owners, and understanding of human or animal *Toxocara* infection was poor.\textsuperscript{672}

**Toxoplasma gondii**

**Introduction**

This intracellular protozoal parasite is a significant zoonotic pathogen and receives ample attention with respect to risks of infection of immunologically naive pregnant women. It is also of particular importance in immunocompromised individuals. Cats and wild felids are the only known definitive hosts of *T. gondii*, but other sources of transmission, including consumption of tissue cysts in undercooked meat and fecal–oral transmission from contaminated soil or water, are equally, if not more, responsible for human infection. The incidence of toxoplasmosis in humans in the United States has declined despite increases in cat ownership.\textsuperscript{673}

**Etiology**

*T. gondii* is an apicomplexan protozoal parasite capable of infecting almost any warm-blooded
species, including humans. There are three major genotypes of *T. gondii* that can be differentiated for epidemiological purposes, but clinically, they are not significantly different.674

Life cycle

As with all coccidian parasites, *T. gondii* has both sexual and asexual stages (Figure 1.15). Both cycles occur in the definitive host, the cat, while only the asexual stage occurs in nonfeline (intermediate) hosts.675 Unlike most other coccidians, *T. gondii* can be transmitted in multiple ways, including fecal–oral, carnivorism, and transplacental infection.675

Cats, the definitive hosts (along with wild felids), are thought to be infected mainly through ingestion of tissue cysts in infected intermediate hosts.675 After ingestion of tissue cysts, bradyzoites are released in the intestinal tract and invade the epi-

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**Figure 1.15** *Toxoplasma gondii* life cycle (public domain, Centers for Disease Control and Prevention, Alexander J. da Silva, Melanie Moser).
thelial cells. Schizonts are formed, followed by the development and release of merozoites, which invade other epithelial cells and form either male or female gamonts. The male gamonts (microgamonts) divide to form numerous flagellated, motile microgametes, which penetrate and fertilize the female gamont (the macrogamont). The macrogamont then forms a wall and becomes an unsporulated oocyst, which is passed in the feces of the cat in its noninfective state. Approximately 97% of naive cats fed tissue cysts will shed oocysts in their feces, usually within 3–10 days (the prepatent period). Patency may last up to 20 days, with the majority of oocysts being shed over only 1–2 days. In contrast, only ~20% of previously exposed cats fed oocysts will develop a patent infection, and the prepatent period for cats fed oocysts may be 18 days or longer. Immunosuppression may increase the likelihood of a previously infected cat shedding oocysts. Other circumstances under which reshedding may occur remain undefined. Regardless, further shedding is likely an uncommon event, meaning that there is only a very small window in an infected cat’s life when it is shedding oocysts.

Unsporulated oocysts passed in the feces of cats must sporulate in the environment to become infective. This occurs most efficiently in warm (20°C) and moist conditions, and typically takes between 1 and 5 days at room temperature. This results in the formation of two sporocysts, each containing four infective, banana-shaped sporozoites. Sporozoites, within the oocyst, are infective and can survive in the environment for prolonged periods of time, waiting to be ingested by a susceptible warm-blooded host. After ingestion by nonfeline species, the sporozoites excyst in the small intestine, invading intestinal cells and dividing asexually to produce two lunate-shaped tachyzoites. The tachyzoites migrate throughout the body, invading cells in various tissues and multiplying until the cells rupture. Clinical signs of toxoplasmosis, including fetal injury, are caused by cellular destruction due to this migration and multiplication of tachyzoites. The most commonly affected tissues are the brain, liver, lungs, skeletal muscle, and eyes. The process remains subclinical in the majority of cases.

If an infected cell fails to rupture, the tachyzoites eventually cease multiplying and encyst, becoming bradyzoites and remaining within the cell. A cyst may ultimately grow to 15–60 μm but remain separated from the cytoplasm of the host cell by a very thin elastic wall. Cysts can form in the CNS, muscles, and other internal organs, and, in most cases, likely persist until the death of the host, usually without causing any clinical signs. Reactivation of latent infections is an important process in immunocompromised individuals.

Geographic distribution/epidemiology

Toxoplasmosis is present worldwide. Seroprevalence rates in cats are high (9.3–40%) and can be influenced by their diet and whether they are allowed outside. Seroprevalence is also related to age, with older animals more likely to be seropositive. While cats are the definitive host and seroprevalence is high, the likelihood that any given cat is shedding *T. gondii* is very low, with the prevalence of oocyst shedding often ranging from 0% to 1%. In an Australian aboriginal community where 18% of cats were shedding oocysts, it is reasonable to assume that the likelihood of shedding is higher in cats that are allowed outdoors and hunt.

Less information is available for other companion animal species. Seroprevalence rates of 11–89% have been reported in dogs. Higher rates are usually present in studies from developing countries and those evaluating stray versus pet dogs. Shedding of oocysts is very rare; one study only found *T. gondii* oocysts in 2/24,089 fecal samples from German dogs.

Human exposure is common. Seropositivity indicates previous exposure and likely latent infection, and is relatively common with reported rates of 12–97%. Higher rates are present in older individuals. While exposure is clearly a relatively common event, disease is much less common. Because toxoplasmosis is not a reportable disease in most regions, it is difficult to estimate the prevalence of disease in humans. An average of 15,000 human cases of clinical toxoplasmosis are reported annually in the United States, but it has been estimated that the actual number of
cases that occur is likely closer to 225,000, of which 50% of cases are thought to be the result of foodborne transmission.695

Because cats are the definitive host for *T. gondii*, investigations have not surprisingly investigated the impact of cat ownership or contact on seroconversion or disease. Cleaning a cat litter box was found to be a strong risk factor for *T. gondii* infection in pregnant women in one study.696 However, the same study and others have reported no association between *T. gondii* seropositivity and just owning or living with a cat.692,696 Other studies have found associations between *T. gondii* exposure and owning three or more kittens,697 and cat ownership in children in rural (but not urban) areas.698 Studies that only look at cat ownership, however, provide only partial information, considering the studies that have implicated fecal exposure, not cohabitation, as the risk factor. Several studies have identified consumption of undercooked meat as the principle risk factor for *T. gondii* infection.676,697 There is also evidence that people who handle raw meat (such as abattoir workers) may be more commonly exposed to the parasite.69 Contamination of water sources and soil with the feces of wild or domestic cats is an important source of exposure as well. Infection may occur following ingestion of oocysts on unwashed, uncooked vegetables or in contaminated water.696,699,700 Geophagia, contact with soil or sand (e.g., from a children’s sandbox or gardening), and poor hand hygiene have also been associated with toxoplasmosis.676,701,702 Dogs could also act as mechanical vectors if their hair coat becomes contaminated with sporulated oocysts.703

*T. gondii* is transmitted through ingestion of sporozoites in sporulated oocysts in feline feces or the environment, bradyzoites within cysts in the tissues of latently infected individuals, and trophozoites in the tissues of acutely infected individuals.676,704 Oocysts are shed only in the feces of cats. Epidemiologically, oocysts are an extremely important means of transmission because, when sporulated, they are the most environmentally resistant life stage of the parasite. At that stage, as few as 10 cysts may infect an intermediate host such as a pig,704 while 100 or more cysts can cause a patent infection in a cat, which may ultimately shed tens to hundreds of millions of oocysts.675,676

Ingestion of oocysts from cat feces can occur; however, because of the time required for oocysts to become infective after defecation, fresh feces pose no risk. Risk of exposure is from old cat feces in litter boxes, in the outdoor environment (especially gardens and sandboxes), and potentially on the hair coat of debilitated or long-haired cats that have difficulty properly grooming themselves.

Carnivorous or omnivorous animals (and people) are often infected through ingestion of encysted bradyzoites in the tissues of their prey. Tachyzoites can be shed in the milk of acutely infected animals.

Vertical transmission of *T. gondii* is a particular concern in humans but may also occur in dogs and cats.704,705 In humans, the main concern is exposure of immunologically naive women during pregnancy. Previous exposure is adequate to protect against subsequent infection in immunocompetent individuals. Under normal circumstances, a naive female that has been exposed to *Toxoplasma* 4–6 months prior to pregnancy will develop sufficient immunity to protect herself and the fetus for the rest of her life.676 In naive individuals, parasitemia with tachyzoites results in placentitis and subsequent infection of the fetus. In humans, the risk of the infection being passed on to the fetus is lower in the first trimester (10–25%) than during the third trimester (60–90%), though the consequences and potential congenital defects are more severe with earlier infections.706

While previous infection is typically considered to be protective in humans, there may be situations where reinfection is possible. If the immune response is suppressed by drug therapy or disease such as HIV/AIDS in humans, both the mother and the fetus become susceptible to infection once again. Additionally, transplacental infection with subsequent fetal deaths has been reported in experimentally infected dogs that had previous Toxoplasma exposure.707 Care should be taken in extrapolating this study to natural infection and infection in other species, but it does raise concerns that prior infection may not be completely protective, at least in dogs. Infection through milk has been documented in kittens.708,709 Transmission to bitches has also been reported via semen of experimentally infected dogs;710 however, the clinical relevance of this is likely minimal. In humans, *T. gondii* has also been transmitted by organ trans-
plants and blood transfusions, but this is uncommon.  

Animals 

Clinical presentation 

In healthy, immunologically naive cats, primary infection with *T. gondii* is typically either subclinical or causes mild diarrhea that persists for up to 10 days.  

Though severe disease may occur in healthy, naive cats, it is most common in immunosuppressed cats, as well as in transplacentally or lactationally infected kittens.  

Reactivation of chronic encysted infection can also occur in older cats that become immunosuppressed.  

Signs of systemic disease may include fever, lethargy, anorexia, pneumonia, hepatitis, stiff gait with shifting lameness, or neurological signs from encephalitis. 

Pancreatic, cardiac, and ocular tissues are also commonly affected. Dermatitis, vomiting, and diarrhea have been reported. Kittens may exhibit fever, cough, dyspnea, icterus, and leukopenia. Chronic infection may result in diarrhea, emaciation, nausea, ataxia, and ocular lesions. The onset of signs may be slow, though the disease may be rapidly fatal, particularly with lung or brain involvement. Neurological and ocular signs without systemic illness occur more commonly with reactivated infections than with primary infection. 

Congenitally or lactationally infected kittens are often severely affected due to uncontrolled replication of tachyzoites and subsequent tissue damage. Kittens may be stillborn or die before weaning, typically with signs related to pulmonary or hepatic disease, or encephalitis. However, in some cases, the only signs of disease may be choroiditis and, occasionally, concurrent anterior uveitis. 

Clinical signs and tissue involvement can be similar in dogs, with respiratory, neurological, gastrointestinal, or generalized infection. Generalized disease is mainly seen in young (<1 year) dogs. The most apparent clinical signs in older dogs are associated with encephalitis and myositis, and appear very similar to *Neospora caninum* infection, which is more common than toxoplasmosis. 

Because of *Toxoplasma*’s opportunistic nature, infection may be associated with other diseases such as distemper or ehrlichiosis in dogs, hemotrophic mycoplasma infection, FIV or feline infectious peritonitis (FIP) in cats, or immunosuppressive therapy in any species. 

Diagnosis 

Definitive antemortem diagnosis of clinical toxoplasmosis is difficult. The diagnosis should be made based on a fourfold or greater change in antibody titer or high IgM titer, response to anti-*Toxoplasma* therapy, and exclusion of other diagnoses. *Toxoplasma*-specific antibody may also be detected in the aqueous humor or CSF of cats with ocular or neurological signs, respectively, but the titer must be compared with that of a non-ocular or non-neurological pathogen to determine if the antibody was produced locally, as opposed to leakage of antibodies through a compromised blood-ocular barrier or blood-brain barrier. Changes in the CSF of encephalitic cats are inconsistent but may include increased protein and lymphocytic or mixed inflammatory cells. 

In acute infection, tachyzoites may rarely be seen in peripheral blood, CSF, or lung or tracheal wash fluid, but are more commonly found in thoracic or abdominal effusions. Detection of the organism in tissues or body fluids can be done using either PCR or bioassays in mice. Due to the potentially high sensitivity of PCR, the test may be positive in both healthy (i.e., latently infected) and diseased cats, and therefore cannot be used to distinguish acute from chronic infection. 

Serological testing is commonly used for diagnosis, but there is currently no test that can definitively diagnose toxoplasmosis. An IgM titer of >1:64 by indirect FAT or ELISA, with or without concurrent IgG, or demonstration of seroconversion (fourfold or higher increase IgG as determined by indirect FAT, ELISA, or modified agglutination test), is supportive of active infection. 

Serological testing is not useful for determining whether there is a risk of *T. gondii* shedding. Most cats are seronegative during the short period of time they are shedding *T. gondii*. A cat that is seronegative is unlikely to be shedding oocysts at any given time, but poses the most significant public health risk because it is most likely to develop a patent infection and shed large numbers of oocysts over a short period of time if it is exposed to *T.
**Management**

Clindamycin is the drug of choice for the treatment of clinical toxoplasmosis in dogs and cats. The dose is higher than is used for treatment of anaerobic bacterial infections and can cause anorexia, vomiting, and diarrhea. A response should be seen within 48 hours, but feline immunodeficiency virus (FIV)-infected cats may be more difficult to treat. Cats with ocular inflammation should be treated either topically (ideally) or systemically with anti-inflammatory doses of glucocorticoids as well. The second-choice treatment for toxoplasmosis is a combination of pyrimethamine and a sulfonamide. Newer macrolides such as azithromycin and clarithromycin also have efficacy against *Toxoplasma*, but their role in treatment is unclear. Doxycycline or minocycline could be considered if there is concurrent infection with an agent susceptible to tetracyclines.  

Oocyst shedding in cats is reduced by use of the therapeutic dose of clindamycin, or high doses of a sulfonamide/pyrimethamine combination. Other anticoccidials that can be used for this purpose include monensin and toltrazuril, if given within 1–2 days of exposure or administration of immunosuppressive therapy to the animal (which could cause recrudescence of infection). Routine use of these is not recommended because of the short duration of shedding and the ability to use basic infection control and hygiene measures to reduce the risk of human exposure. An oral vaccine to reduce oocyst shedding in cats has been developed but is not currently commercially available.

**Humans**

**Clinical presentation**

Only 10–15% of human cases of toxoplasmosis are associated with clinical signs. These are typically mild and include fever, malaise, sore throat, myalgia, and lymphadenopathy. In some cases, disease may mimic mononucleosis, with macular rash and hepatosplenomegaly. Signs may persist for 1–12 weeks, but the clinical course is typically mild and self-limited. Severe manifestations are very rare in immunocompetent individuals that acquire the infection postnatally, but potential problems include myocarditis, pericarditis, and pneumonitis.

Ocular toxoplasmosis can occur with acute infection or reactivation of latent infection. Chorioretinitis is uncommon following clinical toxoplasmosis, occurring in 0.2–0.7% of infections, but this small percentage is not insignificant considering the high rate of infection. Severe toxoplasmosis is a serious problem in immunocompromised persons, particularly those with AIDS. It is estimated that 4000 AIDS patients develop *Toxoplasma* encephalitis each year in the United States, although this number is decreasing because of highly active antiretroviral therapy. In the past, the condition was estimated to affect up to 40% of AIDS patients worldwide. Most cases are thought to develop from reactivation of latent infections, not new infections, so zoonotic infection from pets is of limited relevance in this population. Individuals with low CD4+ counts (<100 cells/mm³) and high *Toxoplasma* titers may be treated prophylactically for the disease with trimethoprim– sulfamethoxazole.

Clinical signs in congenitally infected neonates are not apparent at birth in the majority of cases. A cat that is IgG seropositive was presumably infected some time in the past and is unlikely to be actively shedding oocysts. If reexposed to the parasite, seropositive cats may shed some oocysts, albeit in low numbers, and thus they remain a potential risk for human exposure. Fecal examination is unreliable because a single negative sample cannot rule out the possibility that the cat is shedding or will do so in the near future.

Fecal examination for oocysts is of limited use since shedding tends to occur for only 1–2 weeks after exposure, and usually occurs in the absence of clinical signs. If present, the oocysts are best detected using a centrifugal fecal flotation technique with Sheather’s sugar solution (500 g sugar, 300 mL water, 6.5 g melted phenol crystals). The oocysts are unsporulated with no distinct internal structures and approximately 10 μm in diameter (one-fourth the size of *Isospora* cysts and one-eighth the size of *T. cati* eggs). They are indistinguishable from the oocysts of some species of *Hammondia* and *Besnoitia*, which also occur in cats. Any identified oocysts should be considered *Toxoplasma* until proven otherwise.
(67–90%), but eye (e.g., blindness, retinchoroiditis), ear (e.g., deafness), and CNS (e.g., mental retardation, learning difficulties, psychomotor deficiencies) problems can develop later.\textsuperscript{2,676,706} Approximately 10% of cases result in abortion or neonatal death.\textsuperscript{676} If signs of toxoplasmosis are apparent at birth (10–23% of cases), they may include generalized lymphadenopathy, maculopapular rash, hydrocephalus, chorioretinitis, intracranial calcifications (which can also be detected on prenatal ultrasonography), hepatosplenomegaly, thrombocytopenia, microcephaly, convulsions, fever, and small size for gestational age.\textsuperscript{2,676,706} Ocular toxoplasmosis may occur in up to one-third of children who survive congenital infection and is the most common manifestation of the disease in these individuals.\textsuperscript{676} It is possible for a person to develop clinical toxoplasmosis from a congenital infection up to 20–30 years of age.\textsuperscript{706} Congenital toxoplasmosis has been estimated to occur in 1:1000 to 1:10,000 live births in the United States.\textsuperscript{2}

**Diagnosis**

Once infected with *T. gondii*, people usually develop an antibody titer that lasts indefinitely,\textsuperscript{721} possibly because the tissue cysts that form also persist for the lifetime of the host. Therefore, serological testing is a reliable indicator of previous exposure. Severely immunocompromised individuals may be unable to mount or sustain an appropriate humoral immune response, and serological testing is less reliable in this subgroup.

Serological testing is the main component of diagnosis, but results must be interpreted carefully because of the high seroprevalence in the population. Serum IgG titers typically indicate previous infection and therefore are of limited use for diagnosis of acute infection or reactivation of latent infection. Serum IgM titers are an important component of diagnosis since they indicate more recent, acute infection. Both types of antibodies are usually detectable within 1–2 weeks of infection.\textsuperscript{706} If IgG is present without IgM, then infection likely took place 6–12 months earlier.\textsuperscript{2,706} The avidity of the IgG can also be measured, and this is used in situations where the determination of the timing of infection is critical (e.g., infection of a pregnant woman). The presence of high avidity IgG indicates that the infection likely took place 3–4 months prior to testing.\textsuperscript{2,706} Further identification of timing can sometimes be accomplished by testing for IgE and IgA, both of which decline faster than IgM.\textsuperscript{2}

Diagnosis of in utero infection is most commonly accomplished by testing amniotic fluid for the presence of *T. gondii* DNA by PCR or by isolation of the parasite by mouse inoculation or tissue culture.\textsuperscript{2,706} Testing of fetal blood (by cordocentesis) is less sensitive and a higher-risk procedure.\textsuperscript{706} If test results are positive, ultrasonography should be used to check the fetus for abnormalities such as intracerebral calcifications, microcephaly, hydrocephalus, or excessively small size, which are consistent with toxoplasmosis.\textsuperscript{706}

Congenital toxoplasmosis can present in several ways: severe neonatal disease, disease presenting over the first few months of life, disease (either as the sequelae of infection or relapse) presenting in later childhood or adolescence, and subclinical disease. The challenge is recognizing subclinical disease in infants as toxoplasmosis can cause later, potentially devastating, sequelae including CNS abnormalities and eye lesions. Diagnosis is confirmed by the isolation of *T. gondii* in blood (from the infant or cord blood) or tissue, including the placenta. PCR of peripheral white blood cells, CSF, or placenta is also an option. It should be noted that PCR testing for *T. gondii* has not been standardized. There is no universal protocol regarding when, or whether, to screen pregnant women or women considering becoming pregnant. In some countries, pregnant women are regularly screened during gestation to detect infection and allow for early intervention.\textsuperscript{706,725} In others, screening may be sporadic or rare. Regardless of the approach to screening, general preventive measures outlined below are the key for reducing the risk of infection during pregnancy.

**Management**

Most clinical infections in immunocompetent persons are mild and self-limited, and do not require treatment.\textsuperscript{2} Treatment is most often considered in pregnant women or immunocompromised individuals. Antimicrobials, if used, are directed against tachyzoites and do not eradicate encysted bradyzoites.\textsuperscript{725} Pyrimethamine is considered to be the most effective agent and should be included as part of the treatment in adults,\textsuperscript{725} usually in
Measures should be taken to reduce the risk of exposure of cats to *T. gondii* and thus decrease the risk that they become infected and shed oocysts. The two main measures that can be used are keeping cats inside so they do not ingest infected small prey and not feeding them raw meat. Avoiding contact with old (as opposed to fresh) cat feces that may contain sporulated oocysts is critical. Oocysts take longer to sporulate under cooler conditions. At room temperature, sporulation may occur within 1–3 days, but this can take 3 weeks at 11 °C. Litter box management is a critical component of avoiding exposure to *T. gondii* from pet cats. Ideally, feces should be removed from litter boxes on a daily basis to prevent sporulation of oocysts. This is particularly true in households with seronegative women (or women of unknown serological status) who are pregnant or may become pregnant, as well as households with immunocompromised individuals. Litter boxes should not be cleaned by high-risk people if possible, but the lack of someone else to clean the litter box should not be taken as an indication that cat ownership is inappropriate. If a high-risk person must handle used litter or feces, gloves should be worn and hands should be washed thoroughly immediately after completing the task. Litter boxes, scoops, and any other objects or surfaces that have come in contact with cat feces should, on a regular basis, be thoroughly cleaned and immersed in hot water (>70 °C). This must not be done in kitchen or washroom sinks. Chemical disinfection can be achieved but requires high concentrations of chemicals such as ammonia (5% ammonia for at least 1 hour or 10% ammonia for at least 10 minutes) and may not be practical. Cat feces or contaminated cat litter should not be composted because backyard composting may not produce sufficient heat to destroy oocysts.

Prevention

In the majority of studies, no direct association has been found between cat ownership and clinical toxoplasmosis. However, cats are the primary definitive host for this organism, serious disease can occur in humans, and some studies have implicated contact with cats as a risk factor for exposure, so consideration of the possible risks is warranted. Given the emotional benefits associated with owning a cat, and the minimal risk of transmission if appropriate hygiene is practiced, even pregnant and immunocompromised individuals do not need to give up their cats. If a cat in a household with a naïve pregnant woman or other high-risk individual is found to be shedding oocysts, it could be removed from the premises temporarily and either treated to eliminate shedding or monitored to determine when shedding ceases naturally. As cats are usually meticulous groomers, it is very unlikely that oocysts will be found on their fur, so regular handling is not a significant risk. Care should be taken with debilitated cats that are unable to groom themselves adequately and long-haired cats that might be more prone to fecal staining of perineal hair.

Once sporulated, oocysts can survive in the environment for prolonged periods of time and are combination with sulfadiazine and folinic acid. Combination of pyrimethamine and clindamycin is another option. Other drugs such as azithromycin, clarithromycin, atovaquone, dapsone, and trimethoprim–sulfamethoxazole can be considered, but their role in treatment is unclear. Spiramycin is one of the current drugs of choice for treatment of pregnant women with toxoplasmosis to reduce the risk of transmission to the fetus. It is ineffective for acute therapy, maintenance therapy, or prevention of *Toxoplasma* encephalitis in AIDS patients. It has been suggested that such treatment decreases the severity of congenital toxoplasmosis, but not the risk of transmission, yet there is evidence to support both possibilities. It remains unknown if treatment of a pregnant woman reduces transmission, reduces congenital disease, or reduces long-term sequelae in vertically infected children; the cost-effectiveness of such therapy is often debated. Early treatment of prenatally infected children has been shown to reduce or prevent long-term sequelae later in life.
highly resistant to environmental effects and disinfectants.\textsuperscript{675} Sporulated oocysts can survive up to 4.5 years in water at 4°C, up to 18 months in moist soil or sand, and at least 200 days in water at 10–25°C.\textsuperscript{576}

In any species other than cats, \textit{T. gondii} infection is not patent. However, it is possible for sporulated oocysts from cat feces to survive passage through the intestine of a dog. Dogs that eat cat feces could therefore have infective oocysts in their feces,\textsuperscript{730} but given the extremely low incidence of \textit{Toxoplasma} oocysts in dog feces,\textsuperscript{689} the risk is probably inconsequential.

There is a small risk of oocyst shedding in any cat that may be immunosuppressed due to illness or medication, and greater care should perhaps be taken with this group. Keeping the cat inside, not feeding it raw meat, and proper litter box management largely negate the potential added risks.

\textbf{Trichuris vulpis}

The canine whipworm, \textit{T. vulpis}, is a nematode that is found in dogs, foxes, and coyotes, where it can cause disease ranging from inapparent to severe bloody diarrhea. Whipworm eggs can be found in the feces of 0–23% of healthy dogs.\textsuperscript{157,158,537,634}

Adult whipworms live mainly in the cecum, but may also be present in the distal small intestine or colon. Unembryonated eggs are laid and passed with feces. Eggs embryonate and become infective in 1–2 months. After ingestion by a susceptible host, larvae hatch in the small intestine, migrate further along the intestinal tract, and mature, thereby completing the life cycle.

There are few reports of human infections with \textit{T. vulpis}.\textsuperscript{731–736} One report described infection of 19 individuals, all of whom had mental illness or physical disabilities.\textsuperscript{733} Another described detection of \textit{T. vulpis} from two children from urban slums in India.\textsuperscript{736} Both had abdominal pain and one had diarrhea. Severe diarrhea and detection of \textit{T. vulpis} eggs were reported in a woman who owned multiple dogs, though apparently, her dogs were not tested for whipworms to determine if they may have been the source of infection.\textsuperscript{731} Adult \textit{T. vulpis} were identified incidentally in the cecum of a person in a postmortem examination.\textsuperscript{735} \textit{T. vulpis} eggs were also identified in 6.1% of healthy individuals in an Indian ethnic group.\textsuperscript{737} There are also rare reports of VLM attributed to \textit{T. vulpis}.\textsuperscript{738,739} However, in one of these reports, the two individuals had “almost asymptomatic” infections, and diagnosis was based on immunoelectrophoretic studies\textsuperscript{739} with the accuracy of diagnosis having been challenged.\textsuperscript{740}

In none of these reports was the source of the infection clearly identified. Given the time required for eggs to become infective, inadvertent ingestion of eggs from contaminated environmental surfaces is most likely. \textit{T. vulpis} eggs can be found in the soil in various environmental sites, including playgrounds.\textsuperscript{10,356}

Diagnosis is based on the identification of characteristic eggs in feces by centrifugal fecal flotation.\textsuperscript{731} Eggs must be measured when evaluating human specimens, since eggs from the human whipworm, \textit{Trichuris trichiura}, have a similar appearance to \textit{T. vulpis}, but are smaller (50 – 56 by 21 – 26 μm for \textit{T. trichiura} compared with 72 – 89 by 37 – 40 μm for \textit{T. vulpis}) (Figure 1.16).\textsuperscript{731} Misidentification of \textit{T. vulpis} as \textit{T. trichiura} in human feces is possible if adequate care is not taken by the microscopist.\textsuperscript{731} Care should be taken in extrapolating the limited reports of human infections in specific populations (e.g., slum residents, institutionalized individuals, certain ethnic groups) to the broader population. \textit{T. vulpis} is likely of limited zoonotic risk given the small number of reports and the rarity of clinical infections. Nevertheless, these
reports indicate that some thought should be given to this parasite as a potential cause of human infection. Measures taken to avoid infection from other, more relevant gastrointestinal parasites, particularly avoiding contact with feces and hand hygiene, would be effective at reducing any risk that might be present from Trichuris spp. Routine deworming with milbemycin, milbemycin/lufenuron, or fenbendazole, febantel, or oxantel is effective at controlling T. vulpis in dogs. Prompt removal of feces will help reduce the prevalence of infective eggs in the environment.

*Tritrichomonas foetus*

**Introduction/life cycle**

*T. foetus* is a trichomonad parasite that is an emerging cause of enteric disease in cats.\(^{741}\) It is characterized morphologically by three anterior flagella and a single recurrent flagellum that acts as an undulating membrane.\(^{296,742}\) Reproduction occurs in the intestinal tract by binary fission, and there is no cyst stage.\(^{296}\) In addition to cats and cattle, *T. foetus* can be found in many other animal species, including pigs and rarely dogs.\(^{743,744}\)

**Geographic distribution/epidemiology**

*T. foetus* shedding and disease can be common in cats in breeding colonies and shelters, with reported prevalences of 0–31%.\(^{322,745,746}\) Dense housing is likely the most important risk factor.\(^{296,322}\) Purebred cats are often overrepresented,\(^{296,747}\) but this is more likely a function of housing and management rather than a true breed predisposition. Colonization is rare in nondiarrheic household cats.\(^{746,748}\) Transmission is via the fecal–oral route, with the litter box a prime source of infection of cats.\(^{741}\)

**Animals**

**Clinical presentation**

Diarrhea is more common in younger (<1 year of age) cats,\(^ {749-751}\) and is mainly large bowel in character, with occasional blood and mucus.\(^ {749}\) Chronic diarrhea is common.

**Diagnosis**

Diagnosis requires specialized methods. Routine fecal flotation is not adequate for diagnosis. Microscopic evaluation of fecal wet mounts in saline has a poor sensitivity and can also result in misdiagnosis of Giardia as *T. foetus*. Culture of feces in specialized media followed by microscopic evaluation of the sample can be a sensitive and specific test if performed properly and is commonly used.\(^ {752}\) PCR has excellent sensitivity and specificity with a lower detection threshold than culture.\(^ {322}\) Cost and availability are the main current limitations.

**Management**

While up to 90% of cats with *T. foetus* diarrhea will resolve without treatment, they may continue to shed the organism for prolonged periods of time, potentially for life.\(^ {741}\) Ronidazole is the drug of choice and is usually administered because, while spontaneous resolution of clinical signs is common, it may take up to 2 years.\(^ {753}\) Care must be taken since ronidazole administration can be associated with adverse neurological effects.\(^ {296}\) Even with clinically successful treatment, persistent shedding of *T. foetus* is common\(^ {753}\) with one study reporting a median posttreatment shedding duration of 39 months.\(^ {753}\)

**Humans**

The broad range of animal species that *T. foetus* can infect and the close association between people and pet cats has raised questions about the potential for zoonotic transmission.\(^ {741,754}\) However, the risk of transmission of *T. foetus* from cats to humans (or at least transmission with the development of clinical disease) is presumably very low because of the apparent rarity of human infections and lack of reported cases of transmission of *T. foetus* from a cat to a person. There is a report of detection of “*T. foetus*-like organisms” from a bronchoalveolar lavage sample of a person with AIDS and Pneumocystis pneumonia.\(^ {754}\) The role of the *T. foetus*-like organism in disease was unclear, and there was no reported link to animals. While the potential for zoonotic transmission should not be dismissed, there is limited evidence indicating any risk.
Prevention

Routine screening of cats for *T. foetus* shedding is difficult to justify from a zoonotic disease prevention standpoint considering the extremely low incidence of human disease and the low prevalence of shedding by healthy pet cats. Detection of *T. foetus* in nondiarrheic animals is also challenging, and optimal recovery is obtained by inducing diarrhea in the cat by pretreating with lactulose.\(^{741}\) Given the low likelihood of zoonotic risk and the potential for environmental or hair coat contamination with various pathogens from induced diarrhea, this is not recommended. Even if a cat was shedding *T. foetus* and if a susceptible person was in the household, the main recommendation would be to avoid direct and indirect contact with feces through proper litter box management and other general infection control measures, the same approach that should be taken in any household. There is no evidence that treatment of carriers is indicated. Even in a household with an immunocompromised owner, the need for treatment of a nondiarrheic cat is debatable, as many other potentially zoonotic pathogens could still be shed in feces and the approach to management of the cat in the household would not change. Because *T. foetus* does not have a cyst stage, it is very susceptible to environmental conditions, particularly drying. Therefore, the highest risk in terms of feces containing *T. foetus* is wet diarrheic stool or fresh, wet feces.

**Trypanosoma cruzi**

Introduction

*T. cruzi* is a protozoal parasite and the cause of Chagas’ disease (also known as American trypanosomiasis). Humans and dogs are accidental hosts and are not required for maintenance of the transmission cycle, but infections in both are common. It is a leading cause of cardiomyopathy in humans and has a greater disease burden than any other parasite in the New World.\(^{755}\) It is also a cause of cardiomyopathy in dogs.\(^{756}\) The overwhelming majority of human infections are not associated with dogs; however, dogs can be part of the transmission cycle.

Etiology

There are approximately 20 different *Trypanosoma* species, all of which are flagellated protozoa that pass through different morphological stages in their vertebrate and insect hosts.\(^{757}\) *T. cruzi* is adapted to infect a wide range of hosts, including more than 150 wild and domestic mammal species.\(^{757}\) This, combined with the ability to produce long-term (including lifelong) parasitemia, creates the opportunity for the development of a large reservoir.

Life cycle

There are three morphological forms. The trypomastigote is found in circulation in the host. It is 15–20\(\mu\)m long, with a flattened, spindle-shaped body (Figure 1.17). The amastigote form is the intracellular form. It is smaller (1.5–4.0\(\mu\)m) and roughly spheroid.\(^{756}\) The epimastigote is the third form and is found in the reduviid insect vector (subfamily Tritominae).\(^{756}\) These large (up to 2.5 cm in length) insects, commonly known as “kissing bugs” or “assassin bugs” in South America, become infected by ingesting circulating trypomastigotes from infected humans or animals. In the insect, trypomastigotes transform to epimastigotes and multiply by binary fission before transforming back into metacyclic trypomastigotes in the insect’s hindgut.\(^{756}\) In humans, infection typically occurs.

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*Figure 1.17 Trypanosoma cruzi* (public domain, Centers for Disease Control and Prevention).
when the insect vector deposits feces containing trypomastigotes at the bite site. The individual becomes infected by rubbing contaminated insect feces into the bite wound or by transferring it to the mucous membranes of the eyes or mouth. Transfusion of infected blood is another possible route, as is organ transplantation. Transplacental infection occurs in approximately 5% of infants born to infected mothers. Laboratory-acquired infections can also occur from needlestick injuries involving blood from an infected subject. Outbreaks have also been described in association with the consumption of sugarcane juice and the consumption of Acai palm fruit juice or paste. The presumption is that infected insect vectors were inadvertently crushed and mixed into the juice during production.

Dogs can be infected similarly, including by ingestion of infected vectors, with release of the parasite in the mouth. Infection from ingestion of infected meat has been considered, but evidence from raccoons fed infected meat suggests that this route is unimportant. The greater role of ingestion of insects in canine infections compared with human infections means that there can be disproportionate prevalences of infection in humans and dogs in certain regions. Specifically, in areas where insect vectors tend not to defecate shortly after feeding and are therefore at lower risk of causing bite-associated infections, canine infections (from ingesting insects) may be much more common than human infections.

Regardless of the route of entry, trypomastigotes either enter macrophages where they transform to amastigotes and multiply by binary fission, or remain free in circulation. Circulating trypomastigotes may infect myocardial cells, where they transform into amastigotes, multiply, transform back to trypomastigotes, and are released back into circulation following myocardial cell rupture.

Geographic distribution/epidemiology

This parasite is endemic in many regions in South and Central America, and appears to be increasing in Mexico. It is estimated that 8 million people are infected in the Americas. Large numbers of infected people have been identified in the United States, but the overwhelming majority is associated with travel to or immigration from endemic regions (or previously via transfusion of contaminated blood). It has been estimated that over 300,000 people with T. cruzi infection live in the United States, with 30,000–450,000 cases of cardiomyopathy and 63–315 congenital infections occurring annually. Only a small number of autochthonous infections have been identified in the United States, such as a case that occurred in New Orleans in 2006 after an influx of vectors following hurricane Katrina. There is a similar distribution of canine cases, with endemic infection in regions of Central and South America, increasing reports in Mexico, and sporadic cases in the United States, most often in southeastern Texas. Infected dogs have been identified in other parts of the United States, including as far north as Virginia.

The geographic distribution is largely related to the presence of competent insect vectors and susceptible hosts in close proximity. Social aspects also play a role, particularly keeping animals in.
The role of dogs in human infection is poorly quantified, and identification of the risks posed by one species in a pathogen with a complex cycle involving many potential reservoir hosts is difficult. Regardless, it is suspected that domestic animals, including dogs, play a crucial role in *T. cruzi* transmission in developing countries, particularly in rural regions with poor housing standards and cohabitation with other species like chickens. Chickens, while not susceptible to infection themselves, can encourage the presence of the insect vector. The presence of infected dogs has been associated with a much greater likelihood that infected insect vectors are also present in the household. As well, a correlation between the presence of infected dogs and infected humans has been reported. The risks are probably highly variable geographically even within endemic regions, and dogs probably play a limited role in human infection in some endemic areas, particularly urban areas.

The risks associated with pet dogs in developed countries are probably minimal because of housing and hygiene standards. Risks may be greater in areas with less insect control, where many dogs live closely with people and where other animals are also living in the house. The potential role of dogs in *T. cruzi* transmission has been modeled using households in rural Argentina, in households where people, dogs, and chickens cohabitated and where people slept outdoors during a part of the year. This model indicated that keeping two infected domestic dogs was the worst thing people could do in terms of promoting the prevalence of *T. cruzi*. It also reported that eliminating infected dogs from the household was nearly sufficient for eliminating *T. cruzi* transmission, in the absence of reintroduction of infected dogs, children, or insects. Similar data are not available for other household situations, and the risk of dog–human transmission is presumably lower in the absence of conditions such as those that were modeled. The serious nature of the infection and difficulty of treating infected individuals means that the potential for transmission from dogs should not be ignored, even if the risk is low.

**Animals**

**Clinical presentation**

The acute phase of infection is characterized by vague signs such as lethargy, lymphadenopathy and weakness, or overt signs of right-sided heart failure. Sudden death may be the only sign in some cases, particularly in dogs less than 1 year of age. Neurological abnormalities, including ataxia, profound weakness, and hyperreflexia, have been found in natural and experimental infections.

The acute stage may not be identified and an unknown percentage of dogs surviving acute infection will progress to the chronic stage, which progresses over 1 or more years. Cardiomyopathy with associated lethargy, ascites, arrhythmias, and heart failure may develop in chronic cases. Sudden death may occur.
Diagnosis

Diagnosis is difficult and may be missed if trypanosomiasis is not considered. This disease should be considered in any dog that has ever lived in or near an endemic region.\textsuperscript{756} During acute infection trypomastigotes may be seen on blood smears. Parasitemia levels are often low, and the parasite may not be seen without careful observation or the use of special techniques. Examination of the buffy coat stained with Wright’s or Giemsa’s stain is more sensitive than blood smear examination.\textsuperscript{756} There are also techniques for centrifugation of plasma that can concentrate trypomastigotes. PCR, best done on concentrated samples, is available. Occasionally, trypomastigotes can be seen on lymph node aspirates or from abdominal effusion.

Serology is useful and, in combination with appropriate clinical signs, is considered the gold standard.\textsuperscript{760} However, cross-reaction with \textit{Leishmania} is a problem in areas that these two pathogens overlap, and further exploration in positive cases is required to interpret seropositive results. Xenodiagnosis, testing of insect vectors that have fed from the animal’s blood for the presence of trypomastigotes, can also be performed.\textsuperscript{777}

Management

Treatment of the acute phase is difficult, and little objective information is available, partly because this stage is uncommonly recognized. A combination of corticosteroids and benznidazole can be used.\textsuperscript{756} Most cases are identified in the chronic stage, but treatment of this stage is rarely successful. Supportive therapy for heart failure and arrhythmia is the mainstay of treatment. Euthanasia is often elected because of the poor prognosis and advanced state of disease by the time a diagnosis is made.

Humans

Clinical presentation

Acute and chronic forms of disease may be present, with the acute form often not being recognized. In acute infection, a red nodule (chagoma) that becomes indurated and later, hypopigmented, may develop at the site of infection, usually on the face or arms.\textsuperscript{2,757} If the conjunctiva is the site of inoculation, firm eyelid edema (Romana’s sign) may be present. Fever, malaise, and generalized lymphadenopathy may then occur. Muscles, including myocardial muscle, are the most heavily parasitized tissues.\textsuperscript{757} Rarely, myocarditis, hepatosplenomegaly, or meningoencephalitis is seen. In most patients, the acute phase of the disease resolves in 1–3 months and an asymptomatic (indeterminate) period follows.\textsuperscript{2} In 10–30% of cases, chronic disease develops over the course of years to decades, most often presenting with cardiomyopathy, megaesophagus, or megacolon.\textsuperscript{2,757} There seems to be a wide variation in the incidence and types of severe sequelae among different regions.\textsuperscript{757} Cardiomyopathy is the most common and concerning sequela and may lead to embolic disease, intractable congestive heart failure, complete heart block, and other arrhythmias including ventricular arrhythmias leading to sudden death. Congenital infections are usually asymptomatic but can result in low birth weight, hepatosplenomegaly, and/or meningitis.\textsuperscript{2} Reactivation of latent infection can occur in people that become immunsuppressed, and the disease may be more severe than is typically encountered otherwise.\textsuperscript{2,757} The incidence of this is unknown.\textsuperscript{757}

Diagnosis

During the acute phase of infection, \textit{T. cruzi} may be detected using Giemsa staining of blood smears, buffy coat preparation, or after a concentration technique.\textsuperscript{2} The indeterminate and chronic phases have low-level parasitemia and detection requires the use of special media, with negative results being common. Isolation of \textit{T. cruzi} from a triatomine insect that has been allowed to feed on patient blood (xenodiagnosis) is sometimes performed in South and Central America.\textsuperscript{2} Because of the low level of sensitivity of these procedures, serological testing is the primary test for chronic disease.

Management

Current treatment options are far from ideal. Nifurtimox can reduce the duration and severity of disease and decrease mortality, but it only results in parasitological cure (complete elimina-
infected dog should result in prompt consultation.

Other measures for the reduction of *T. cruzi* transmission include control of insect vector populations (e.g., insecticide spraying), measures to exclude insects from the house (e.g., screens), and screening blood donors from endemic areas. Insect control has been shown to have a dramatic impact on the incidence of disease in dogs in endemic areas.

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