Pets enrich people's lives and enhance their well-being in many ways. The importance of the human-animal bond is well-accepted, and the varied benefits of pet ownership are well-recognized. Dogs and cats are found more often in homes with young children, who often have close contact with these animals. Wild animals such as raccoons are very common in urban and suburban areas, and canine infections with raccoon ascarids are possible. Some wild species, such as raccoons, skunks, kinkajous, and coatis, are bred in captivity and sold as exotic pets. Unfortunately, dogs, cats, and wild animals such as raccoons are commonly infected with parasites and other infectious agents, a number of which can produce mild to life-threatening disease in humans, particularly children. Parasitic agents would include a variety of protozoa, helminths and arthropods, some of which cross over to domestic pets from wild cycles. It is important to limit animal-to-human transmission of potentially harmful zoonotic parasites, and one of the best ways to do this is by practicing year-round parasite control.

Ascarids (*Toxocara* and *Baylisascaris*) and hookworms (*Ancylostoma*) continue to be a public health issue across North America and elsewhere. These and other parasites are the target of major awareness efforts by the Companion Animal Parasite Council (CAPC), the Centers for Disease Control and Prevention (CDC), and the Canadian Parasitology Expert Panel (CPEP). Infected pets are common in our society and the main sources of human infection are environmental areas contaminated with pet feces, although often wildlife is also involved. Other zoonotic helminths include a variety of nematodes, tapeworms, and flukes, including *Strongyloides*, heartworm (*Dirofilaria*) and other filarids, *Echinococcus* and certain *Taenia* tapeworms, *Dipylidium*, and *Alaria*, to name a few. None of these are reportable infections in humans or animals, and many exist as sporadic, low-prevalence infections in animals in different areas. Veterinarians and their staff have a very important public health role in the prevention and control of worm parasites in pets, which in turn should help decrease the possibility of human transmission and disease due to these agents.

**ONE HEALTH / ONE MEDICINE**

One health deals with the integration of human and veterinary medicine, public health, and environmental health, through collaborative efforts to attain optimal health for people, animals, plants, and the environment. The concept has been around for centuries, with some very notable collaborations between MDs, DOs, DVM/VMDs, PhDs, and others. These collaborative efforts have accelerated research discoveries, increased scientific knowledge, improved medical care, and
enhanced public health. One Health is also known as “One Medicine”, a term first coined by renowned veterinary epidemiologist Calvin Schwabe, DVM, DSc, who proposed it as a unified medical/veterinary approach to zoonotic diseases. A solidifying concept, this built on several centuries of collaborative work stretching back to the days of Virchow, Osler, and Salmon. With a relative lull in the 20th century, there is now a resurgence of activity in this area, making it one of the most exciting current arenas of public health awareness and policy.

In 1967, recognizing the importance of zoonoses in world health, a joint FAO/WHO expert committee identified more than 150 zoonotic diseases and, by 2000, more than 200 were known. It is estimated that about 75% of recently emerged infectious diseases affecting humans are zoonotic, and that about 60% of all human pathogens are zoonoses. These span the range of bacterial, viral, rickettsial, fungal, and parasitic agents, and include directly transmissible, food-borne, water-borne, and vector-borne diseases. A major step forward in One Health has been the formal establishment of closer ties by the medical and veterinary professions. In order to foster greater awareness and collaboration, formal resolutions were passed in 2007 in both houses of delegates. This resulted in a Task Force and Steering Committee and the establishment of a joint One Health Commission in 2009. In June 2009, the Commission incorporated as a nonprofit and established a Board of Directors representing a diverse group of organizations. Information on the Commission can be accessed at http://www.onehealthcommission.org. Another very active group is the One Health Initiative, a dedicated group of four medical and veterinary professionals working to advance the cause and spread the word on One Health. They serve a major educational function and support a website, newsletter, ProMed links, etc., in support of One Health, and can be accessed at http://onehealthinitiative.com.

ONE HEALTH AND PARASITOLOGY

As listed in numerous sources on public health and zoonoses, a staggering number of zoonotic parasites exists. This stems from the fact that parasites are the most common life forms on earth, far exceeding free-living organisms, and that parasites have evolved over eons of time to develop long-term associations with other animals or plants, their hosts. Humans alone are hosts to dozens of different parasites, and other free-living animals to many, many more. As a consequence of humans also being animals, it is not surprising that many zoonotic parasites also exist. Some of these, like the beef and pork tapeworms or Trichinella, utilize other animals in the food chain of human parasites. There are numerous other food-borne parasitic zoonoses, vector-borne zoonoses such as filarial worms, and others where humans become infected directly, including Cryptosporidium parvum, certain isolates of Giardia, and ectoparasites such as fleas and mites, including canine scabies and others. Some of these parasites are transitory on humans, while others may cause greater problems. Some worms, like Echinococcus spp. and Toxocara spp., are parasites of carnivores that normally use other animals as intermediate or paratenic hosts in their life cycles, and have larvae that can also infect humans if they accidentally become interposed in those cycles.

PET-ASSOCIATED PARASITIC ZOONOSES

There are various common and less common pet-associated parasitic zoonoses, which all have relevance for human disease based on the amount of contact we have with pet dogs, cats and other animals. When one considers the tremendous variety of animals kept as pets, ranging from dogs and cats to exotic and wild mammals, birds and reptiles, it is no wonder that people may be exposed to a
variety of potentially zoonotic parasites and other infectious agents. Certain urban and suburban wildlife also pose a threat, since they often live in close association with humans and contaminate the peridomestic environment. The larva migrans-producing nematodes, including the common ascarids and hookworms of dogs, cats, and raccoons, and several tapeworms are excellent examples of these zoonotic relationships and are dealt with in greater detail below.

The dog and cat ascarids, *Toxocara canis* and *T. cati*, are the most common causes of zoonotic visceral and ocular *larva migrans* (VLM, OLM) in humans, and will also invade the nervous system, causing neural larva migrans (NLM). The raccoon ascarid, *Baylisascaris procyonis*, is the most commonly recognized cause of clinical larva migrans in animals, in which it typically produces fatal or severe neurologic disease (NLM); it is being recognized with increasing frequency as a cause of NLM, OLM, and VLM in humans. Skin-penetrating hookworm larvae produce cutaneous LM, and *Ancylostoma caninum* has recently been shown to cause pneumonitis, myositis, and eosinophilic enteritis in humans. *Strongyloides stercoralis* from dogs poses the potential zoonotic threat of intestinal infection in humans. Children may become infected with adults of the dog flea tapeworm, *Dipylidium caninum*, or the rodent tapeworm *Vampirolepis nana*, and develop mild gastrointestinal disease. Certain taeniid tapeworms cause zoonotic larval infection and some, including various *Echinococcus* spp., can cause serious larval infection in humans. Unfortunately, some other parasites are commonly mistaken as being zoonotic when they are not, the most notorious being the human pinworm *Enterobius*, for which pet dogs and cats do not constitute a source.

The main sources of human infection with ascarids, hookworms and certain taeniid tapeworms are environmental areas contaminated with pet or wild animal feces. Human infection with these parasites is an established public health issue, as the human environment is increasingly shared with infected animals, either pets or wildlife, with the possibility of cross-species transmission. Other zoonotic parasites are acquired through the human food chain or from blood-feeding vectors. It is important that veterinarians, physicians, and public health officials include these parasites in their One Health awareness, being cognizant of their zoonotic significance and the human diseases that they cause. Veterinarians are routinely involved in public health, and they and their staff have an important responsibility to help prevent human infection with these parasites, through proper diagnosis, treatment, and control of these infections in animals, as well as through education of the public about the dangers associated with them.

**PREVALENCE OF INTESTINAL HELMINTHS IN DOGS AND CATS**

The prevalence of intestinal helminths in dogs and cats varies by locale and method used for assessment, i.e., necropsy versus fecal examination; for the latter, it will vary depending on whether centrifugal or passive flotation is used, as well as on the choice of flotation solution. Prevalence is affected by climate, local environment, and characteristics of the animal population, and local pockets of infection may exist or develop. Surveys of shelter animals better reflect “wild-type” prevalence in an area, which is often higher than that seen in well-cared-for pets and is a reflection of what pets can be exposed to if they are not on good parasite control. In a national survey of shelter dogs in the U.S. conducted by Blagburn in 1994, 14.5% of 6,458 dogs were positive for *Toxocara canis*, 19.2% for *Ancylostoma caninum*, and 14.3% for *Trichuris vulpis*, with 36.0% of dogs infected with one or more of these parasites. A repeat survey reported in 2012 found similar or higher values for 6,413 dogs. There is a paucity of data for many areas and prevalence may vary by region or climate zone, but when animals are examined, parasites are usually found at some level,
often much higher than generally believed to occur there. This is especially true for tapeworms since these are notoriously variable and difficult to assess accurately. Despite the fact that prevalence may be lower than in some other areas, the fact that potentially zoonotic parasites occur at even a low level should prompt greater awareness and efforts at control, because sporadic cases of possibly very serious human disease can still occur.

**INFECTION OF HUMANS**

*Toxocara* and *Ancylostoma* may be common in dogs and cats in different areas, and *Baylisascaris* is usually very common in raccoons, leading to considerable human exposure. Patent *Baylisascaris* also occurs in a low percentage of dogs, and occurs in pet kinkajous and probably coatis, which could also expose humans to infection. Humans become infected with ascarid larvae by accidentally ingesting infective eggs from contaminated areas or articles, including soil, hands, food, and fomites such as toys. Humans become infected with hookworm larvae by skin penetration or oral ingestion of infective larvae. Infection takes place from environmental areas previously contaminated with dog, cat, or raccoon feces. Infected pets are a particular problem because they contaminate the immediate home environment with eggs. Since infected animals can shed millions of eggs per day in their feces, they can rapidly and extensively contaminate an area such as a yard. Raccoon latrines in and around domestic environments can contain very large numbers of *B. procyonis* eggs, leading to exposure of pet dogs and children. Dogs may also become infected with *B. procyonis* by predation of wild rodents or rabbits carrying larvae. Ascarid eggs reach infectivity in 2-4 or more weeks and, with adequate moisture, can survive for years in the soil, even through harsh winters. Therefore, areas contaminated with ascarid eggs become long-term sources of human exposure and infection. Infection may also be acquired from contaminated parks and playgrounds where dog owners walk their pets, and from sandboxes and gardens where cats bury their feces. Because of scent-rolling behavior by dogs, there is also the possibility that they may have various parasite eggs, including *Toxocara* spp., in their fur; however, the levels are generally low and do not approach what is seen in highly contaminated soil.

Human infection with *Toxocara* was first recognized in the 1950s, when larvae were identified in the enucleated eyes of children with ocular disease suspected clinically as retinoblastoma, and in the liver of children with eosinophilia and hepatomegaly. Human infection with *Baylisascaris* was first recognized in the 1980s, when larvae were identified in the brains of children dying of neurologic disease and in the eyes of people with OLM. Human toxocariasis is a very common, well-recognized condition worldwide, including in the U.S. where there are ongoing efforts at public health education by the Centers for Disease Control, the American Association of Veterinary Parasitologists (AAVP), and the Companion Animal Parasite Council. Cases are also known to occur in Canada, and in both countries seroprevalence may be surprisingly high in some areas, indicating considerable zoonotic transmission. Human infection with animal hookworm larvae (CLM) was recognized clinically long before a cause was identified; then, in the 1920s, *A. braziliense* of dogs and cats was shown to be a common cause of CLM in the southern U.S. Since then the condition has been shown to be caused by a number of other skin-penetrating nematode species, including several animal *Strongyloides* spp.; however, infection with animal hookworm larvae remains the primary cause. Although larval migration of these parasites is usually restricted to the skin, the common dog hookworm, *A. caninum*, has recently been shown to be capable of deeper migration in humans, producing pneumonitis, myositis, and being capable of development in the intestinal tract, where it produces eosinophilic enteritis. Numerous other helminths of animals, especially wildlife, can also cause larva migrans.
Zoonotic larva migrans is not a reportable disease in the United States or Canada, so the true incidence is unknown. In addition, it is a tertiary level medical condition, with lower general awareness and consideration by the medical profession. However, various serological surveys have indicated that zoonotic toxocariasis is common and widespread, particularly in children. The seroprevalence of zoonotic toxocariasis in the U.S. has been reported at 5-15%, with 5-28% of children being seropositive in various surveys. A recent national survey published by CDC in 2008 found a 14% seroprevalence for Toxocara in the U.S., with a higher seroprevalence (26%) for soil-related occupations. Each year, several thousand presumptive samples are submitted by physicians to the CDC, with 25-33% being seropositive. Several dozen cases of human toxocariasis also have been described from Canada and although few serology studies have been done, 17% of 973 children in Halifax in 1982-1984 were seropositive (14.0% urban and 19.5% rural), as were 10% of approx. 2000 samples in Ontario from 1999-2007. Two of the most important risk factors for toxocaral infection are pica, particularly geophagia, and having dogs, especially puppies, in the home, but there also has been a positive association with soil-related occupation. This is logical, since infected dogs, especially puppies, can contaminate the home environment and elsewhere extensively with eggs. In the United Kingdom, dog breeders and their employees had a significantly higher seroprevalence of infection than did the general population. Veterinarians, on the other hand, have a seroprevalence similar to the general population, probably due to lower contact with infective eggs in their practices and routine sanitary precautions such as fecal cleanup and hand-washing. Contact with contaminated outside environments is most important for contracting toxocariasis and baylisascariasis.

HUMAN DISEASE

Larva Migrans

Human infection with dog, cat, and raccoon ascarid and hookworm larvae is well-recognized and important. It is a common enough problem that the veterinary profession should address it seriously, emphasizing treatment and control of these infections in pets and limiting or preventing contact with infected wildlife and contaminated areas. Larva migrans disease is characterized by the prolonged migration and persistence of larvae in internal organs and tissues, as would normally occur in their paratenic hosts. Larva migrans is separated clinically and pathologically into visceral (VLM), ocular (OLM), neural (NLM), and cutaneous larva migrans (CLM), depending on the main organ systems involved. The type and extent of clinical disease caused by these parasites depends on the infecting dose (e.g., number of infective eggs ingested), the frequency of reinfection, the extent and location of larval migration, and the severity of ensuing inflammatory reactions. Although many infections with these parasites are asymptomatic or result in mild or nonspecific disease, in heavy infections migration of ascarid larvae in internal organs can produce serious if not life-threatening disease. Young children are at the greatest risk of infection with these parasites, because of their intimate contact with contaminated environments as well as their poorer hygiene and propensity for pica and geophagia.

Toxocariasis

Toxocara spp. (T. canis and T. cati) are commonly associated with producing VLM, OLM, and covert disease in humans, especially children, and in heavy infections can also produce NLM.
Humans become infected by accidentally ingesting infective eggs from the environment, from areas or articles previously contaminated with dog or cat feces. VLM is seen primarily in young children 1-4 yrs old and is associated with heavy infection resulting from the ingestion of large numbers of eggs, all at once or repeatedly. Affected children suffer visceral damage and inflammation related to larval migration. Clinically, the disease is characterized by fever, leukocytosis, persistent eosinophilia, hepatomegaly, pneumonitis, and hypergammaglobulinemia. The hepatic and pulmonary reactions in toxocaral VLM have an immunopathologic basis and result in immune trapping of large numbers of larvae in these organs, especially the liver. Toxocaral VLM is rarely fatal unless it involves massive central nervous system (CNS) or cardiac infection or augmented immune responses, however, affected children may be very sick. In heavy primary infections, larvae migrate unimpeded into various somatic tissues, including the nervous system, whereas on reinfection there is a greater likelihood of liver or pulmonary trapping of larvae due to immune reactions. In covert toxocariasis, children have a wide variety of nonspecific symptoms, seen in conjunction with elevated Toxocara antibody titers but often without associated eosinophilia. Clinical findings in seropositive children include fever, abdominal pain, hepatomegaly, anorexia, nausea, vomiting, sleep and behavioral disturbances, respiratory signs (e.g., wheezing, coughing), and limb pain. Because clinical signs are nonspecific, many of these cases go undiagnosed or are misdiagnosed as other conditions.

Toxocara species are also associated with the production of ocular disease in humans. Ocular larva migrans (OLM) usually occurs in children or young adults who ingest fewer eggs and who have no history of pica or geophagia. OLM is related to the chance migration of a single larva into the eye, where it can produce severe complications and visual loss. Ocular examination reveals retinochoroiditis, migration tracks, vitritis, optic neuritis, and retinochoroidal masses caused by the larvae. OLM patients often do not have any other signs of infection, such as those of VLM, and peripheral eosinophilia and Toxocara-specific antibody titers are often low or absent. OLM may also be seen in children following heavy primary infection and larval dissemination, in association with VLM or NLM. Along with hookworm larvae, Toxocara has been implicated as a cause of the small nematode variant of the ocular syndrome, diffuse unilateral subacute neuroretinitis (DUSN) in humans, related to parasite-induced inflammatory changes in the optic disc and retina. Clinically, OLM appears to be more common that VLM or NLM, probably due to the greater number of people exposed to low-level infection. A statewide survey of ophthalmologists and optometrists in Alabama determined a frequency of occurrence of toxocarial OLM of 1 case per 1,000 persons and 11 cases per 1,000 patients. In a group ophthalmology practice in Atlanta, GA, toxocaral OLM accounted for 37% of diagnosed retinal disease in children during an 18-month survey period. A California medical center found OLM accounted for 1% of uveitis cases diagnosed between 1977 and 1996. Probably the most common form of human infection with Toxocara is asymptomatic infection, where people don’t have enough larvae, or larvae in critical locations, to produce clinical disease. Such individuals are recognized because of seropositivity to Toxocara, and may or may not have associated eosinophilia.

People with toxocariasis do not pass eggs or larvae in their feces, therefore O&P examinations on human stool are of no value except to rule out other parasites. Antemortem diagnosis is based on patient history, clinical and laboratory findings, and serology. Computed tomography and magnetic resonance imaging are being used more often to detect granulomatous lesions caused by Toxocara. Serology is used most often to establish a diagnosis in patients with compatible symptoms and signs. The most widely used test is an ELISA using T. canis larval excretory-secretory (ES) antigens, performed at CDC and several commercial laboratories, and several recombinant larval
antigens have also been produced. Patients with OLM usually have serum titers that are much lower than those of patients with VLM, and which may be negative due to low systemic larval burden. Detection of antibody in ocular fluids has greater utility in these cases and may be positive when the serum is negative, but ophthalmologists don’t usually submit it. Ocular cytology to identify eosinophils is also an important adjunct to diagnosis, and occasionally the larva may be visualized in the retina or choroid by direct or indirect ophthalmoscopy. Treatment of toxocariasis is directed at killing larvae that may be present and reducing associated inflammatory reactions using corticosteroids and antihistamines. Anthelmintics recommended most often include albendazole (400-800 mg b.i.d. for 5 days), mebendazole (100-200 mg b.i.d. for 5 days), and diethylcarbamazine (6 mg/kg divided into 3 daily doses for 7-10 days). Some success has been seen with sequential treatment of OLM cases with prednisone and diethylcarbamazine, and in treating DUSN cases with thiabendazole (22 mg/kg b.i.d. for 2-4 days). When larvae are seen in the eye and are away from critical areas, they may be effectively killed using laser photocoagulation.

Baylisascaris procyonis, the raccoon ascarid, is the most commonly recognized cause of clinical larva migrans in animals, in which it typically produces fatal or severe central nervous system disease (NLM). Over 130 species of mammals and birds in North America have been diagnosed with *Baylisascaris* NLM and it is being recognized with increasing frequency in humans, particularly children <2 years old with heavy infections. In addition the parasite is a recognized cause of human OLM and will produce VLM. Most cases of severe infection with encephalitis involve children who become infected by ingesting infective eggs from contaminated areas, especially raccoon latrine sites in or near the domestic environment. However, transmission could also involve infected pets carrying adult worms, be they pet raccoons, other procyonids, or dogs. A related *Baylisascaris* species, *B. columnaris*, occurs in wild and pet skunks and is also a potential cause of both animal and human disease. Recently, pet kinkajous infected with *Baylisascaris* were identified in private collections in Indiana and Tennessee, and contaminated breeder’s facilities found in south Florida. How widespread the infection is in these animals and related procyonids kept as exotic pets (coatis, cacomistles, etc.) is not known and is being investigated. Veterinarians who deal with these animals should be vigilant for this infection and the animals treated regularly with appropriate anthelmintics. Several dozen cases of canine infection with *B. procyonis* adults have also been recognized, and it is likely to be more common and widespread than is presently known, although still at a prevalence far below that seen in raccoons. However, canine infection could also result in domestic contamination with eggs, since dogs are indiscriminate defecators. It is important for veterinary personnel to correctly identify *Baylisascaris* eggs in dogs, so that treatment, control and decontamination can be initiated promptly.

Hookworms

Dog and cat hookworm larvae penetrate and migrate in the skin of humans, producing the condition known as cutaneous larva migrans (CLM). Also known as "creeping eruption" or "ground itch", CLM is characterized by the production of serpiginous migration tracks and/or erythematous papules in the skin. These lesions are intensely pruritic and may become secondarily infected. The primary cause of CLM is *A. braziliense*, which occurs in dogs and cats in the coastal areas of the southeastern U.S. and in the tropics, and produces serpiginous tracks in the skin. In a recent survey, nearly one in three persons seeking medical assistance following return from the Caribbean did so for CLM. Other recent notable cases and outbreaks have occurred in Florida. *Ancylostoma caninum,*
the more widespread hookworm species of dogs, produces erythematous papules or short migration tracks in the skin. Treatment of CLM consists of antipruritics, antihistamines, and oral or topical anthelmintics, including albendazole (400-800 mg daily for 3-5 days), ivermectin (single 12 mg dose), and thiabendazole (15% cream topically t.i.d. for 3-5 days). Recently, it was found that *A. caninum* larvae can also migrate into the deeper tissues of humans, where they may cause pneumonitis and myositis. Some can enter the lower small intestine and establish as young adults, producing clinically-relevant eosinophilic enteritis/enterocolitis. These cases are characterized by acute or chronic abdominal pain, peripheral eosinophilia, small bowel thickening, elevated IgE, and focal areas of inflammation or ulceration in the terminal ileum and colon. Several hundred cases were identified serologically in communities in Australia, and the infection has also been seen in the southern U.S. This is an infection that suffers from poor awareness, which will likely continue due to difficulties in diagnosis. The worms do not mature or shed eggs, and must be visualized in the bowel on colonoscopy, recovered from purged material, or considered based on signs and findings and the patients examined serologically. Based on the ubiquity of this parasite in dogs, it is likely more common and widespread in humans wherever *A. caninum* is found, emphasizing the need for veterinarians to treat and control this common canine parasite. Once it is considered, treatment in humans is easy and straightforward, consisting of oral mebendazole (300 mg once or 100 mg b.i.d. for 3 days) or another effective anthelmintic.

**Strongyloidiasis**

Infected dogs are also potential sources of human infection with *Strongyloides stercoralis*, transmitted by skin penetration by infective larvae from contaminated environments. Most human patients with chronic intestinal infection are asymptomatic or have nonspecific gastrointestinal symptoms, but some develop more severe signs with intermittent diarrhea and recurrent abdominal pain. Because of its ability to undergo internal autoinfection with larval dissemination, *S. stercoralis* may result in massive, life-threatening infections, especially in individuals receiving corticosteroids or other immunosuppressants. The treatment of choice for strongyloidiasis in people or dogs is ivermectin (200 mcg/kg daily for 1-2 days), with alternative therapies including thiabendazole and albendazole. Similar to the situation in humans, because of intermittent or low-level larval shedding, the parasite is more difficult to diagnose in dogs than are roundworms and hookworms, and cases are often missed.

**Tapeworms**

Zoonotic tapeworms consist of species which mature in humans and others which produce larval infection, which is more serious. Pet-associated adult tapeworm infections include the common flea tapeworm of dogs and cats, *Dipylidium caninum*, and the common rodent tapeworm, *Vampirolepis nana*. Both can mature in children who accidentally ingest infected fleas or beetles, respectively, although *V. nana* can also infect directly via ingestion of eggs from rodent feces. Neither is particularly serious, causing minor GI upsets, irritability, and perianal irritation, and both are easily treated with praziquantel (5-10 mg/kg once). With both parasites, proglottids are small and, unless they are carefully examined, may be mistaken for pinworms, confounding the diagnosis. Zoonotic infection with tapeworm larvae is of much greater importance because they migrate and develop in various internal organs and tissues. Infection with taeniid tapeworm larvae is most important and occurs through ingestion of eggs shed in the feces of infected dogs, cats and wild canids. Taeniid eggs are fully embryonated and directly infective when shed, so pets infected with zoonotic species pose an immediate threat to people who have contact with them or their feces. Unfortunately, it is
basically impossible to distinguish the proglottids and eggs of zoonotic and non-zoonotic *Taenia* species, and also impossible to distinguish their eggs from those of *Echinococcus* species, the most dangerous of zoonotic taeniids. Sporadic cases of zoonotic taeniid larvae (*T. crassiceps, T. serialis, etc.*) and hydatid disease occur across North America.

Larvae of taeniid tapeworms are small to large, fluid-filled cysts that grow slowly, may asexually proliferate, and produce scolecis or protoscolecis. They are most dangerous when located in the nervous system or other critical locations. The most serious larval infections are due to *Echinococcus* spp., which produce hydatid cysts in the liver and other locations. *Echinococcus granulosus* produces thick-walled, spherical, unilocular hydatid cysts, whereas *E. multilocularis* produces thin-walled, pleomorphic, alveolar hydatid cysts, which invade tissue, proliferate, and metastasize like malignant neoplasms. Both types of hydatid cysts are slow-growing and it may take years before clinical signs of infection become apparent. *Echinococcus granulosus* is restricted primarily to Alaska, Canada, northern Michigan, and the northwestern and southwestern U.S., where it exists as sylvatic and domestic strains. *Echinococcus multilocularis* occurs in Alaska, Canada, and in a large endemic focus in central North America, encompassing many of the north-central and midwestern states. In these areas, it occurs primarily in wild foxes and coyotes, but will also infect dogs and cats that hunt and consume wild rodents containing larvae. Treatment of hydatid disease in humans is difficult, consisting of surgical removal of the cysts followed by suppressive anthelmintic therapy.

### Other Helminth Zoonoses

Numerous food-borne zoonotic helminths occur in the U.S. and Canada, most involving ingestion of wild animals. Sporadic cases of infection (e.g., OLM) with *Alaria* larvae (mesocercariae) have occurred in people consuming undercooked frogs, snakes, or some wild game. People may also contract larval *Spirometra* (sparganosis) cestodes from similar food sources. Zoonotic lung fluke infection, *Paragonimus kellicotti*, has occurred following ingestion of raw or undercooked crayfish containing metacercariae. Intestinal infection with *Nanophyetus salmincola* occurred following ingestion of metacercariae in raw or undercooked salmonid fishes, and liver fluke infection with *Metorchis conjunctus* followed ingestion of raw white suckers. Intestinal penetration and peritoneal migration are possible whenever certain nematode larvae (anisakids, *Eustrongylides*, etc.) are consumed in raw or undercooked fish. Trichinosis is still common in a variety of North American wild carnivores including bears, canids, raccoons, walrus, etc., with the possibility of transmission via raw or undercooked meat. Canine heartworm, *Dirofilaria immitis*, is a well-known zoonosis with dozens of human cases reported from N. America; it usually presents as a large granuloma occluding a pulmonary artery. Numerous sporadic cases involving subcutaneous and connective tissue masses have been linked to infection with various filarids of wildlife, including *Dirofilaria tenuis* of raccoons, *D. ursi* of bears, and similar parasites from porcupines, rabbits, etc.; all are transmitted by blood-sucking vectors such as mosquitoes.

### PREVENTION AND CONTROL ARE IMPORTANT RESPONSIBILITIES

Veterinarians, their staff, and other health professionals have an important responsibility to protect children and other family members from zoonotic helminths transmitted from pets and wildlife. The primary focus should be on those common helminths of dogs, cats, and wildlife with direct
transmission to people, including *Toxocara* and *Baylisascaris* species, *Ancylostoma*, *Strongyloides*, and tapeworms such as *Echinococcus*. Veterinarians are the first line of defense between infected pets and the family and, as such, have an important responsibility to diagnose, treat, and control these parasites in dogs and cats. Veterinarians should also provide accurate information and counseling concerning these parasites and the potential dangers of transmission from pets and wildlife, and serve as a resource for other medical professionals. As a matter of One Health, together with pediatricians and other health professionals, veterinarians and their staff should emphasize the importance of good sanitation and hygiene concerning pets and children, including fecal cleanup, handwashing, and monitoring or modifying childhood behaviors (e.g., pica and geophagia) that lead to infection. All should emphasize high quality preventive veterinary care for families that have pets. Following are the most important aspects of prevention and control of these zoonotic helminths.

### Reduce environmental contamination with infective eggs and larvae
- implement strategic deworming of dogs, cats, and wildlife/exotic pets
- reduce the number of stray dogs and cats and nuisance wildlife
- enforce leash laws and promote responsible pet ownership
- recommend regular fecal cleanup, and enforce fecal cleanup laws for dogs

### Limit or prevent contact between children and contaminated areas
- exclude dogs from playgrounds and areas of parks where children play
- keep children away from contaminated environments
- teach children to recognize and avoid raccoon latrines
- keep sandboxes covered when not in use

### Educate the public, especially pet owners, about the dangers associated with these parasites
- emphasize personal hygiene and hand-washing when dealing with animals or their feces
- emphasize prevention of infection through routine veterinary care and common sense practices

The goal of **strategic deworming** is to prevent environmental contamination with eggs or larvae, by removing intestinal helminths with strategically timed treatments. This is usually directed at eliminating intestinal ascarids and hookworms from puppies, kittens, and lactating dams, since they are major sources of environmental contamination and zoonotic transmission. However, adult dogs and cats may also have patent infections with *Toxocara* and *Ancylostoma* species and are potential sources of *Baylisascaris* (dogs) and *Echinococcus* eggs, so targeted deworming of adult animals is also indicated. Unless anthelmintic treatment is combined with sanitation, fecal cleanup, and environmental decontamination, contaminated areas will remain a source of reinfection for both animals and humans.

### Companion Animal Parasite Council (CAPC) and Canadian Parasitology Expert Panel (CPEP)

Formed in 2002, CAPC is an independent council of U.S. veterinarians, parasitologists, physicians, public health personnel, and others whose mission is to create and update guidelines for the optimal control of internal and external parasites of companion animals and serve as an educational resource for the above groups and others. CAPC’s guidelines recommend: (1.) year-round treatment with
broad-spectrum heartworm preventives with activity against intestinal parasites of zoonotic concern; (2.) administration of flea and/or tick products year-round; (3.) conducting annual heartworm testing on dogs and periodic testing on cats; (4.) conducting fecal exams 2-4 times during the first year of life and 1-2 times/year in adult animals; (5.) deworming animals as outlined below; (6.) use of the best diagnostic methods, including centrifugal flotation of an adequate fecal specimen; and (7.) daily to weekly fecal cleanup and other means of environmental control of parasite transmission stages (see below). These and other CAPC recommendations and related parasite information can be accessed at www.capcvet.org. CAPC also has a consumer website available at www.petsandparasites.org. The CPEP was organized to develop Canadian-specific recommendations, which for puppies and kittens essentially mirror CAPC guidelines. Canadian guidelines deviate somewhat by not being as stringent concerning year-round parasite control for older animals as in the U.S.

**Treatment and Control of Ascarids and Hookworms**

A large number of safe and effective anthelmintics are presently available for the treatment of ascarids and hookworms in dogs and cats. Individual compounds vary in their spectrum of activity, some being fairly specific and others broad-spectrum. Various products will also treat whipworms in dogs, and several combination products will remove both nematodes and cestodes. Historically, ascarids and hookworms have been easier to treat than whipworms and more compounds were available for treatment of the former parasites; however, this situation has improved. Because migrating or developing larval parasites may not be affected by routine treatment, and will subsequently complete their development, mature and lay eggs, it is generally recommended that animals be given at least two additional treatments at 2 week intervals to insure that the entire infection has been eliminated. Chronic or refractory cases of hookworm infection in dogs may be related to the "larva leak" phenomenon, i.e., reactivation of arrested larvae in the somatic tissues with subsequent migration into the intestine where they mature. Since reinfection from environmental sources is a common problem with all of these parasites, a strategic deworming program with periodic retreatment is recommended, along with good sanitation (fecal cleanup, etc.) and environmental control.

In the U.S., several heartworm preventive products are available which are broad spectrum endectocides or combination anthelmintics, providing additional efficacy for the treatment/removal and/or control of ascarids, hookworms, or whipworms in dogs and cats. For dogs, these include monthly milbemycin oxime/lufenuron, also approved for the removal and control of adult ascarids (*T. canis, T. leonina*) and whipworms (*T. vulpis*) and control of adult *A. caninum*; milbemycin oxime/lufenuron/praziquantel, also approved for the treatment and control of the above plus *Taenia pisiformis* and two *Echinococcus* species; monthly milbemycin oxime/spinosad, also approved for the treatment and control of ascarids (*T. canis, T. leonina*), whipworms (*T. vulpis*) and hookworms (*A. caninum*); monthly ivermectin/pyrantel pamoate, also approved for the treatment and control of ascarids (*T. canis, T. leonina*) and hookworms (*A. caninum, A. braziliense, Uncinaria stenocephala*); monthly ivermectin/pyrantel pamoate/praziquantel, also approved for the treatment and control of ascarids (*T. canis, T. leonina*), hookworms (*A. caninum, A. braziliense, Uncinaria stenocephala*) and tapeworms (*Taenia pisiformis* and *Dipylidium caninum*); and monthly topical moxidectin/imidacloprid, also approved for the treatment and control of ascarids (*T. canis* adults and L4, *T. leonina*), hookworms (*A. caninum* and *U. stenocephala* adults, immature adults and L4), and whipworms (*T. vulpis*). For cats, these include monthly milbemycin oxime, approved for the removal of adult *A. tubaeforme* and *T. catt* in cats and kittens; monthly ivermectin, approved for the
removal and control of adult and immature hookworms, *A. tubaeforme* and *A. braziliense*; monthly topical moxidectin/imidacloprid, approved for the treatment and control of *T. cati* (adults and L4) and *A. tubaeforme* (adults, immature adults and L4); and monthly topical selamectin, also approved for the treatment and control of *T. cati* and *A. tubaeforme*. One of CAPC’s strongest recommendations is the year-round use of monthly heartworm preventive products that also remove GI helminths of zoonotic importance, even in areas where year-round treatment for heartworm alone may not be justified. It is important to consider this a paradigm shift within the profession, from viewing these products primarily as heartworm preventives to seeing them as broad-spectrum parasite control products. These recommendations have been endorsed by a number of organizations, including the American Animal Hospital Association, the Association of Feline Practitioners, and the American Heartworm Society.

**Strategic Deworming of Puppies and Kittens**

Because of their zoonotic significance, major efforts should be directed toward the elimination of intestinal ascarids and hookworms in puppies, kittens, and their lactating dams. Many safe and effective anthelmintics are available for treatment of these infections, including pyrantel pamoate, fenbendazole, piperazine salts (for ascarids only), praziquantel/pyrantel pamoate/febantel combination, praziquantel/pyrantel pamoate, milbemycin oxime, and moxidectin. Topical emodepside/praziquantel and selamectin are available for use in cats. The labels should be consulted for information on contraindications and/or limitations of use based on host age, etc.

Treatments should begin early, before environmental contamination with eggs commences; waiting to treat puppies at 6-8 weeks of age, as is commonly done, is clearly too late to prevent contamination. Current recommendations of the Centers for Disease Control, the American Association of Veterinary Parasitologists, the Companion Animal Parasite Council, and the Canadian Parasitology Expert Panel are to deworm all puppies and kittens for ascarids and hookworms starting at 2 weeks of age whenever possible, with additional treatments at 4, 6, and 8 weeks of age. Optimally, this should be extended with monthly treatments until the pet is at least 6 months old, to insure elimination of all developing intestinal parasites. It is important that young puppies and kittens be treated regardless of the results of fecal examinations, since they may harbor prepatent infections. Bitches and queens should be treated at the same time, since they too are often infected. Newly acquired puppies and kittens should be dewormed immediately, with at least 2 additional treatments at 2 week intervals, and monthly treatment until 6 months old. As soon as age-appropriate for the product, they should be started on a broad-spectrum monthly heartworm preventive that removes intestinal nematodes, which preferably is given year-round. While they are being treated, access to the yard should be restricted, and a strict fecal cleanup policy should be in place. Any roundworms expelled should be collected and properly disposed of, e.g., put in the trash, flushed down a toilet, or destroyed by burning. Adjustments may be made in well-cared for animals based on local parasite prevalence, the pet's exposure and infection history (e.g., totally indoor cats, etc.), and results of fecal exams, bearing in mind that adult dogs and cats can be infected with intestinal parasites and that infection/reinfection can always occur. CAPC recommends the extended use of monthly heartworm preventives known to be effective against intestinal nematodes as an optimum protocol, but other parasites (stomach worms, lungworms, *Giardia*, etc.) must also be considered, sought through appropriate diagnostics, and dealt with through additional targeted treatment and control.
Prevention of Perinatal Transmission

It is possible to treat pregnant bitches in order to prevent transplacental and transmammary transmission of somatic *T. canis* and *A. caninum* larvae to puppies. Several treatment regimens have been recommended. These include: (1.) daily doses of fenbendazole at 50 mg/kg body weight from day 40 of gestation to day 14 of lactation [↓Tc 89-100%; ↓Ac 99-100%]; (2.) topical selamectin (6-12 mg/kg) approx. 40 and 10 days before and after parturition [↓Tc 98%]; (3.) ivermectin 0.5 mg/kg i.m. 8-10 days or 1.0 mg/kg i.m. 2-8 days before parturition [↓Ac 97% & 99%]; (4.) ivermectin 0.5 mg/kg i.m. twice, 4-9 days before parturition and 10 days later [↓Ac 100%]; (5.) ivermectin (1 mg/kg) on days 20 and 42 of gestation, or 0.5 mg/kg on days 38, 41, 44, and 47; (6.) moxidectin or doramectin 1 mg/kg s.c. on day 55 of gestation [↓Ac 100%]; (7.) topical moxidectin-imidacloprid 2.5%/10% on day 56 of gestation [↓Ac 100%]. In queens, topical selamectin (6 mg/kg) approx. 40 and 10 days before and after parturition was found to decrease *T. cati* to kittens by 100%.

Treatment of Baylisascaris

Raccoons kept as pets or in wildlife rehabilitation, pet kinkajous or coatis, and pet skunks should be on a strict deworming program for intestinal *Baylisascaris*. Although no products are approved for this purpose, anthelmintics effective against *B. procyonis* include fenbendazole, piperazine, pyrantel pamoate, praziquantel/pyrantel pamoate/febantel, milbemycin oxime, and high-dose ivermectin and moxidectin. *Baylisascaris* has a long prepatent period (7-11 weeks) in young raccoons and skunks and presumably kinkajous and other hosts, during which time the animals will be false-negative based on fecal exams for eggs. Newly acquired raccoons, kinkajous, coatis, and skunks less than 3 months old should be dewormed every two weeks for five or six treatments, beginning at 5 to 6 weeks of age. Older animals should be quarantined and dewormed immediately, with at least 2-3 retreatments at 2 week intervals. After this, they can be dewormed on a monthly schedule and checked by fecal exams. In dogs, anthelmintics with efficacy against adult *Toxocara* should also work well against *Baylisascaris*. Two studies conducted in dogs found that monthly milbemycin oxime and ivermectin/pyrantel pamoate products were both highly effective.

Treatment of Tapeworms

Several anthelmintics are available for treatment of adult tapeworms in dogs and cats. The most broad spectrum is praziquantel, which is 100% effective against *Dipylidium caninum*, various *Taenia* species, and *Echinococcus*, and effective against pseudophyllidean tapeworms at higher dosages. Praziquantel is now being included in various monthly heartworm preventive products, allowing for monthly treatment of tapeworms. Other drugs available for treatment of tapeworms include epsiprantel and fenbendazole, the latter showing efficacy against *Taenia* spp. in dogs.

Environmental Control of Ascarids and Hookworms

Fecal cleanup, i.e., removal of dog, cat, raccoon, or other feces with proper disposal at least weekly will remove most ascarid and other eggs before they can develop. It should be noted that taeniid tapeworm eggs are fully developed thus potentially infective for humans when shed. Regular fecal removal is both important and strongly recommended by CAPC and others. Dealing with established environmental contamination is more problematic, because of the longevity and resistance of ascarid and whipworm eggs. Because of the zoonotic importance of ascarids and
hookworms, veterinarians have a responsibility to deal with this aspect of control and inform clients about the problem of environmental contamination so that they can take appropriate precautions and remedial action. This is especially important for clients with new puppies or kittens in the household, and easily accomplished during new puppy/kitten examinations in the clinic. Several companies have information packets that are useful in this regard. Environmental contamination of public parks, playgrounds, beaches, and other areas can be decreased by enforcing leash laws, fecal cleanup laws, exclusion of dogs from these areas, and controlling strays, including feral cats. Sandboxes, a potential source of *Toxocara cati* and *Baylisascaris* eggs as well as hookworm larvae, should be kept covered when not in use. Young children should be kept away from potentially contaminated environments, and pica and especially geophagia should be discouraged. Parents should teach children to recognize and avoid animal feces in general, and especially raccoon latrines they may encounter near their home or in public areas. The importance of routine hand-washing should be stressed, particularly after playing outside or having contact with animals.

*Toxocara, Baylisascaris,* and *Trichuris* eggs are very resistant and long-lived in the environment. Commonly used disinfectants will not kill ascarid eggs, and those chemicals that will kill them are unsafe or impractical for routine use. The eggs are susceptible to elevated temperatures (their thermal death point is approx. 62°C [144°F]) and to desiccation, although death from drying may take about 7 months. 20% bleach (1% sodium hypochlorite) decoats the eggs, making them non-adherent and allowing them to be rinsed away, but does not kill them (they will survive at least 90 minutes in 100% bleach). Heat is by far the best method for killing ascarid and whipworm eggs in the environment. Commonly used methods include scalding (150-160°F) or boiling water, a steam cleaner, propane flame gun, burning straw, or other means. Various hand-held and larger steam cleaners and propane flame guns are readily available and easy to use for this purpose. For heavily contaminated areas, it may be necessary to remove, discard, and replace the top several inches of soil in order to remove the eggs, or entomb the area under a slab of concrete or asphalt. Unlike the eggs of *Toxocara* or *Baylisascaris,* *Ancylostoma* eggs and larvae are killed off by freezing. Hookworm larvae can also be killed using desiccants such as sodium borate (0.5 kg/m²) on gravel dog runs and other areas; however, this will also destroy vegetation, making it unsuitable for use on lawns. After the removal of organic debris and routine cleaning, concrete surfaces, cages, etc., can be treated with 1% sodium hypochlorite or ammonia, which will kill hookworm larvae or cause them to exsheath, making them more susceptible to adverse conditions such as drying.

The prevalence of common zoonotic helminths in pets and wildlife emphasizes the need for strategic deworming and other aspects of prevention and control. Most cases of human infection with these parasites are preventable through simple, straightforward means, but these will not be taken unless people understand and appreciate the problem. Veterinarians and their staff are in an excellent position to educate the public about these infections, and should implement treatment and control strategies designed to reduce environmental contamination with eggs and larvae. In this way, they can play an important role in preventing human infection with these parasites from pets and wildlife.

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