CANADIAN PARASITOLOGY EXPERT PANEL GUIDELINES

for the Management of Parasites in Dogs & Cats





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1 : GUIDELINES	FOR THE MANAGEMENT OF PARASITES IN DOGS AND CATS	03
2 : PARASITE D	IAGNOSTIC, TREATMENT, AND PREVENTION PROTOCOLS FOR CANADA	07
3 : CANADIAN I	PARASITE PREVALENCE DATA BY REGION	19
Regions »	Altantic Canada / 20	
	Quebec / 25	
	Ontario / 27	
	Western Canada / 31	

4 : SUPPLEMENTAL INFORMATION

Part A »

Protozoa / 38 Ticks and Mites / 41 Nematodes / 44 Heartworm / 47 Metastrongyloid Lungworms / 51 Cestodes and Trematodes / 54

Part B »

Managing *Ixodes scapularis* and Lyme disease in a risk area / 58 Emerging issues with *Echinococcus* spp. cestodes in Canada / 60 Anthelmintic Resistance in Companion Animal Parasites / 61 Northern, Rural and Remote Dogs / 64 Imported Pets : Protozoal Parasites / 66

5 : REFERENCES, CONFLICT OF INTEREST STATEMENT & ACKNOWLEDGEMENTS 67

37



GUIDELINES FOR THE MANAGEMENT OF PARASITES IN DOGS AND CATS





GUIDELINES FOR THE MANAGEMENT OF PARASITES IN DOGS AND CATS

These guidelines are the consensus opinion of the Canadian Parasitology Expert Panel (CPEP) which is comprised of Canadian and Canadian-based veterinary parasitologists and veterinarians in general practice with specific interest or expertise in parasitology in their region.

The guidelines are intended to provide Canadian veterinarians and dog and cat owners with information about the diagnosis, treatment and prevention of parasitic infections including gastrointestinal helminths, heartworm, fleas, and ticks. These guidelines replace the first edition, developed in 2009. As an additional resource, short summaries of the most common parasites found in Canada have been provided. This new supplemental section presents an overview of life cycle, diagnosis, and treatment options, and includes parasites (e.g. protozoa, mites) not covered in the general management guidelines. Also included are special considerations for specific populations, such as northern, rural and remote dogs, and specific parasites that may be emerging (ticks, tapeworms) or require special management.

In preparing the guidelines, CPEP took into account the most recent Canadian data - and informed opinions where data do not exist - on the prevalence and distribution of parasites of veterinary and public health importance. Where possible, we considered regional differences in parasite transmission when determining the optimal frequency for antiparasitic treatments. Transmission of vectors and vector-borne parasites (such as fleas and heartworm) is seasonally limited for many regions of Canada. For many gastrointestinal parasites, the potential for transmission is greatly reduced during the winter months. Therefore, treatment and control measures for ectoparasites, vectorborne parasites, and directly transmitted gastrointestinal parasites are often focused on spring, summer, and fall in Canada. We recognize that environmental change may be altering the length of seasonal transmission periods, and that continued surveillance (diagnostic testing) and

predictive modeling are needed to detect and proactively address such changes.

Veterinarians should use the available data together with their local knowledge to apply and align these guidelines to the realities of their practice. Veterinarians may recommend altered treatment schedules based on an assessment of a pet's risk factors such as age, lifestyle, location, health status, and individual needs, as well as the composition of the household (children, pregnant, or immunocompromised people) and the risk tolerance of the client. We continue to emphasize the importance of a good history and diagnostic testing to guide appropriate and individualized treatment plans, to detect the emergence of new parasites or anthelmintic resistance, and to incentivize owners to see their vet at least annually.

The major objectives of all treatment and control programs are to remove harmful parasites, to prevent their establishment, to reduce environmental contamination with life cycle stages that can infect other animals and people, and to minimize the development of drug resistance in parasites. Veterinarians should follow label instructions for parasite treatment and control when approved products are available.

Evidence-based parasite diagnostic and control programs have positive effects on pet health and play an important part in the prevention of zoonoses. These guidelines will aid veterinarians to inform pet owners about the health implications for their pets, and, in some cases, for human health. Ongoing discussion with clients is key to compliance and implementation of prevention, treatment and control programs that can reduce parasite burdens in dogs and cats and transmission of zoonotic parasites. This can be incorporated into annual health examinations, which should include regular diagnostic monitoring for vector-borne and fecal parasites.



Veterinarians can also reinforce public health messages such as:

- Washing hands (particularly children's) with soap and water after outdoor activities, handling pets, pet feces disposal and before meals.
- + Wearing gloves while gardening.
- + Thoroughly washing produce from backyard gardens prior to consumption.
- + Promptly removing and properly disposing of pet feces.
- + Limiting pet defecation areas.
- + Reducing pet interaction with stray and wild animals.
- + Preventing wildlife access to buildings used by pets and people.
- + Covering sandboxes when not in use.
- + Checking for ticks after being outdoors in endemic areas.

Parasite control also requires broader public education as some parasites can be both public and animal health problems. While the veterinarian's role is central, ideally parasite management should take a One Health approach involving many people, including breeders, pet owners, urban planners, wildlife managers, environmental health specialists, physicians, and public health officials.

CPEP encourages veterinarians to share information from these Guidelines for the Management of Parasites in Dogs and Cats with pet owners. This document is intended to be useful in educating pet owners about the importance of parasite diagnostic, prevention, and treatment programs, and it may help to reassure pet owners that the recommended protocols are consistent with the consensus opinion of veterinary experts.



PARASITE DIAGNOSTIC, TREATMENT, AND PREVENTION PROTOCOLS FOR CANADA





PARASITE DIAGNOSTIC, TREATMENT, AND PREVENTION PROTOCOLS FOR CANADA

TREATMENT

Treat puppies and kittens every 2 weeks starting at 2 weeks of age. At 8 weeks, switch to a monthly schedule. From 6 months of age onward, monthly or regular targeted treatments can be given based on the pet's individual risk.

PUPPIES AND KITTENS LESS THAN SIX MONTHS OF AGE:

Puppies and kittens should ideally be treated with an anthelmintic with activity against *Toxocara* spp. at two, four, six and eight weeks of age, and then monthly to six months of age. This early start schedule ensures removal of *Toxocara* spp. acquired prenatally and/or through the milk. Because most puppies and kittens do not have contact with a veterinarian until six to eight weeks of age, it may be necessary to provide anthelmintics to breeders for earlier treatments.

Nursing bitches and queens should be treated concurrently with their offspring since they often develop patent infections along with their young (Sprent 1961, Lloyd et al 1983).

When puppies or kittens are first acquired by their owner, they should be dewormed for a minimum of two treatments spaced two weeks apart and then monthly up to six months of age; three initial treatments at 2-week intervals may be used to synchronise deworming with vaccination programs.

Fecal parasitological examinations should be performed twice in the first 6 months of the animal's life (e.g. at 2-3 months and 6 months of age). The choice of product and scheduling of future treatments should be based on the parasites detected and their prevalence in a given geographic area.

DOGS AND CATS OVER SIX MONTHS OF AGE:

All dogs and cats over six months of age should have at least 1-2 fecal parasitological examinations per year and be assessed for risk of parasitic infection. Decreased anthelmintic use can be justified for pets who are regularly tested and are considered low risk animals.

Veterinarians should consider the pet's lifestyle, location, health status, composition of the household, and ask pet owners the following questions to assess the animal's risk level:

- + Are there young children in the house? In regular contact with the animal?
- + Are there individuals with compromised immune systems in the house? In regular contact with the animal?
- + Are there any pregnant women, or women who could be pregnant, in the house? In regular contact with the animal?
- + Is the dog or cat a service animal?
- + Do pets frequently come into contact with highly contaminated environments (e.g. dog parks, kennels)?
- + Do pets have access to wildlife such as rodents, rabbits, birds, or carcasses of livestock or wild cervids?
- + Do pets ever roam freely?
- + Are pets fed raw meat or organs?



ASSESSMENT AND TREATMENT RECOMMENDATIONS FOR DOGS AND CATS OVER SIX MONTHS OF AGE:



LOW RISK HOUSEHOLD¹

(If answer is "no" to all of the above questions)

- + Conduct fecal examinations² one to two times per year.
 - + Treat based on fecal examination results.

HIGH RISK HOUSEHOLD

(If answer is "yes" to one or more of the above questions)

- Conduct fecal examinations² at least two times per year.
- Tailor control program according to parasite species of concern in your area and risk tolerance of the client. At a minimum, 3-4 treatments should be given per year.²

FOOTNOTE:

1) Dogs that receive a heartworm preventive treatment with activity against *Toxocara* should be managed as for low-risk households, unless they are at risk of acquiring cestodes. 2) Fecal examinations may be performed at convenient times. For example, at the time of the first examination, spay or neuter, heartworm antigen testing, or annual health exam. Information on properly conducting a fecal examination is available at *www.capcvet.org/articles/why-fecal-centrifugation-is-better*. Techniques that include centrifugation have a higher sensitivity. New coproantigen and fecal PCR techniques are increasingly becoming available for a wide range of gastrointestinal parasites and have higher sensitivity and specificity than traditional flotation based methods.

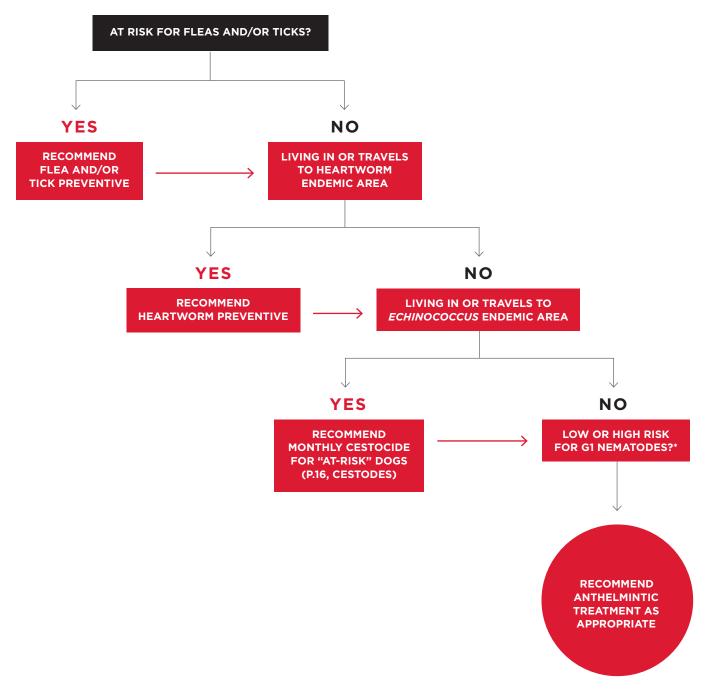
Veterinarians may sometimes choose to forgo fecal diagnostic testing because their patient is already on an anthelmintic regimen (e.g. monthly heartworm preventive) or because of client financial constraints, among other reasons. However, it is important to recognize that regular fecal monitoring (at least annually) is still indicated because fecal testing:

- + Can help tailor the choice of anthelmintic treatment and prophylaxis for individual animals and regions.
- + Can detect developing anthelmintic resistance (as is already seen with heartworm and gastrointestinal nematodes of large animals).
- + Can reduce the unnecessary use of anthelmintics in low risk animals, low risk households, and low risk regions.
- + Can help detect other parasites, including cestodes such as *Echinococcus*, *Dipylidium*, and *Taenia* spp., and protozoans such as *Cystoisospora*, *Giardia*, *Cryptosporidium*, and *Sarcocystis* species.
- + Can help detect emergence of new parasites in new regions, key in an increasingly globalized world and an increasingly permissive climate.
- + Is most useful if done well (centrifugation methods), performed by trained personnel, and interpreted by diagnosticians familiar with regional parasite fauna and accompanied by a detailed history including travel (even locally), animal behavior (risk factors such as diet, coprophagia) and detailed parasiticide treatments (type, frequency, compliance).
- + Will become increasingly sensitive and specific as new PCR-based and coproantigen technologies are emerging.

{» For more information see supplemental section on Anthelmintic resistance / pg. 61}

All dogs and cats should be assessed for risk of parasitic infection, including gastrointestinal helminths, heartworm, fleas, ticks and protozoans **{> FOR MORE INFORMATION SEE SUPPLEMENTAL SECTION ON** Protozoan Parasites / pg. 38 and Imported Pets / pg. 66} based on regional knowledge of parasites, interviewing clients, and, whenever possible, by using appropriate diagnostic testing.

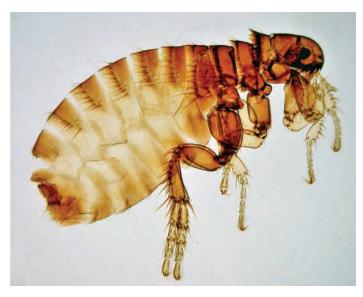
The following flowchart will help veterinarians determine the most appropriate treatment and prevention regimen for their patients based on an individual patient risk assessment.



* See nematode section below to determine level of household risk

FLEAS

Due to climate variations across the country, Canada has highly variable distributions and abundance of fleas, and multiple species of fleas, some of which primarily infest dogs and cats, while others only temporarily infest dogs and cats in contact with wildlife. Infestations of dog and cat fleas are primarily maintained in the environment. These include areas well protected from temperature fluctuations and the sun, and areas with high humidity that maximize development of environmental stages of fleas (larvae and pupae). Dogs and cats in multi-pet households and those that spend a great deal of time outdoors in areas frequented by a large number of potentially untreated pets (e.g. at dog day cares, off-leash areas, etc.) are at greatest risk. Flea infestations may be introduced into neighbourhoods through wildlife, particularly in much of western Canada where wildlife are the major source of fleas. Do not allow pets to roam in areas where they can contact animal dens or nest sites, and prevent contact with wildlife (e.g. raccoons, coyotes, foxes, skunks, weasels) by keeping wildlife out of yards used by pets.



Ctenocephalides canis, the dog flea

Dogs and cats in areas endemic for fleas or that might come into contact with fleas via infested animals or environments should receive regular preventive treatment during the at-risk season, which is typically late spring, summer, and early fall, but could be year-round in some regions. In particular, flea-allergic pets or those susceptible to flea allergy should be treated regularly with an adulticide. There are a wide range of oral and topical flea preventive products. Note that over the counter products containing pyrethroids are generally not safe for use in cats and should not be used on dogs in households with cats.

When fleas are diagnosed on a dog or cat, all pets in the household should be treated to remove adult fleas and to prevent re-infestation. Using a product that has residual activity is recommended and typically does not require treatment of the household environment. To establish realistic expectations, pet owners should be educated by their veterinarian on flea life cycles and how various products work (e.g. adulticides vs. insect growth regulators). It is also important to identify and address the origin of the infestation. Eliminating flea infestations may require five to six months of treatment, especially if a non-residual product is used or if the environment is not addressed. Environmental treatment may be required for a heavy infestation or when there are flea-allergic pets and/or people in the household.

TICKS

<u>{» For more information, see supplemental</u> section on Mites and Ticks / pg. 41}

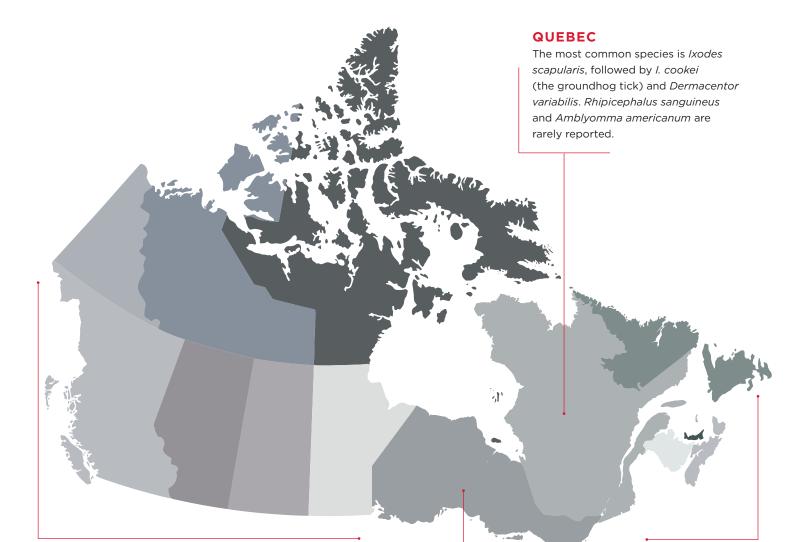
The distribution and abundance of tick species varies widely in Canada, and the geographic range of some species is expanding. In many regions, an increasing number of ticks have been observed on people and pets. This is likely due to a combination of an actual increase in tick abundance along



Dermacentor sp. female with eggs

with greater awareness of tick-borne illnesses and therefore greater surveillance effort. Dogs and cats at greatest risk are pets with access to suitable tick habitat (brush, long grass) in areas with high abundance of suitable wildlife maintenance hosts.

THE FOLLOWING ILLUSTRATION GIVES A GENERAL OVERVIEW OF THE DISTRIBUTION OF TICK SPECIES IN THE VARIOUS REGIONS OF CANADA.



WESTERN CANADA

Dermacentor andersoni and D. variabilis are the most common ticks found on dogs and cats. Ixodes scapularis is endemic in southern Manitoba and I. pacificus in coastal BC. Rhipicephalus sanguineus is occasionally found on dogs with a history of travel.

ONTARIO

The most common ticks on dogs are Dermacentor variabilis and lxodes scapularis. I. cookei (the groundhog tick) is occasionally reported, Amblyomma americanum and Rhipicephalus sanguineus are occasionally found on dogs with a history of travel.

ATLANTIC CANADA

Ixodes scapularis has been found on dogs and occasionally cats in all provinces and is the primary tick in P.E.I. Dermacentor variabilis is the primary tick in Nova Scotia and New Brunswick, along with a small amount of Rhipicephalus sanguineus. rarely reported. In areas of Canada endemic for Ixodes scapularis, >15% of *I. scapularis* (sometimes > 50%) are typically infected with Borrelia burgdorferi, the causative agent of Lyme disease (Bouchard et al 2015) {» See supplemental section on Ixodes and Lyme disease / pg. 58}. Ixodes scapularis may transmit other pathogens, such as Anaplasma. Outside endemic areas, cases of Lyme disease and anaplasmosis in dogs are rare and are thought to be due to either travel or seasonal introduction of *I. scapularis* by migratory birds. Because it takes years to confirm the establishment of an endemic population of ticks, Public Health Ontario has adopted risk area mapping to provide up-to-date information on the distribution of *I. scapularis* and the associated public health hazards. An estimated risk area is defined as a 20-km radius around a locality where adult ticks have been found in two consecutive tick seasons.

The prevalence of tick-borne disease in Canada's dog population remains quite low and dogs are generally at very low risk of becoming infected and of developing clinical disease. *B. burgdorferi* seroprevalence in a population of 115,636 Canadian dogs tested from 2013-2014 (Herrin et al 2017) is compared below to data from 94,928 samples tested in 2007 (as determined by the IDEXX SNAP® 3Dx® and 4Dx® Tests – 2007 National Incidence Study Results, IDEXX, Markham, ON). The following data do not distinguish travel acquired cases and indicate only the province of testing.

» See data table on the right hand side.

Seroprevalence for B. burgdorferi appears to be on the rise for some provinces, although these results are difficult to interpret due to lack of statistical significance, travel history, denominators for testing, and denominators for total dog and cat populations in the province. As well, these data indicate exposure and not necessarily current infection. Many dogs that seroconvert for B. burgdorferi do not develop clinical signs. In addition, the true prevalence of exposure within Canada is likely to be lower than the reported estimates for several reasons: there is no evidence that confirmatory tests were done for any of the samples; the travel history of dogs is not given; and, in light of the very low prevalence of infection in most areas, some positive results may be false positives. A useful reference on this topic is the ACVIM consensus update on Lyme borreliosis in dogs and cats (Littman et al 2018).

	B. burgdorferi seroprevalence	
PROVINCE	2007	2013-2014
British Columbia	0.53%	N/A
Alberta	0.35%	N/A
Saskatchewan	0.58%	0.5%*
Manitoba	2.1%	2.4%
Ontario	0.58%	2.3%
Quebec	0.6%	2.8%
New Brunswick	2.24%	3.7%
Nova Scotia	2.38%	15.7%*
Prince Edward Island	4.55%	NO DATA

*based on small sample sizes

At the time of publication, there is no evidence of established populations of *Ixodes scapularis* in BC, AB, SK, and the northern territories. At the time of publication, there is also no evidence to suggest that there are established populations of *Amblyomma americanum* in Canada. This tick is encountered sporadically in eastern Canada and may be associated with a travel history, or a tick that has fallen off a migratory bird. However, vigilance is recommended along the US border in eastern Canada. All veterinarians should be comfortable identifying the main genera of ticks commonly encountered on pets in their area, to assess risk of tick-borne illness and to detect introductions of exotic tick species.



In tick-endemic regions, veterinarians should remind pet owners of the following measures to avoid ticks and tick-borne diseases, in the following order, according to risk of the pet and risk perception of the owner.

- + The first line of defense is avoidance; litter under forest canopies, overgrown grass and brush in yards, especially during periods of high tick activity (seasonally and diurnally).
- + Second is regular checking and removal of ticks from pets and people within 6-24 hours of being in tick-infested areas.
- + Wearing protective clothing such as long pants, long sleeves and socks will help prevent tick attachment to people.
- + To remove an attached tick, use tweezers to grasp its "head" and mouth parts as close to the skin as possible. Pull slowly until the tick is removed. Do not twist or rotate the tick and try not to damage or crush the body of the tick during removal. After removing the tick, wash the site of attachment with soap and water and/or disinfect it with alcohol or household antiseptic. (Reference: www.canada.ca/ en/public-health/services/diseases/lymedisease.html)
- + Third, there are a wide range of tick control products for high risk dogs and repellents for people. Permethrin treated clothing may also be an option for high risk people.
- + Finally, high risk dogs can also be vaccinated against *B. burgdorferi*, consistent with recommendations of the ACVIM.
- + Treatment and management of *B. burgdorferi* positive dogs should be conducted in accordance with the ACVIM Consensus Update on Lyme borreliosis in Dogs and Cats (2018) in conjunction with the original ACVIM Consensus Statement on Lyme Disease in Dogs: Diagnosis, Treatment, and Prevention (2006).

The tick season varies depending on regional climate and tick species of concern. Dermacentor spp. adults are most commonly active in the late spring and summer, when they are found on pets and people. In regions where I. scapularis nymphs are introduced via migratory birds, adult I. scapularis are generally found on pets and people in the fall. In endemic regions, I. scapularis are most active in spring and fall (adults) and early summer months (nymphs). I. scapularis (adults) can be active any time the ambient temperature rises above 4°C. Between 2010 and March 2018, in Ontario, only the month of February 2015 failed to see ambient temperatures reach 4°C, and in Quebec, only January and February 2015 failed to reach this threshold. In Nova Scotia, all months since 2010 have seen at least 1 day >4°C. Therefore, it is recommended that a tick preventive be administered even during winter months if temperatures rise above this threshold level in regions endemic for I. scapularis.



Dermacentor sp. on a dog's ear

Many products with rapid action against ticks are available for preventing infestation. Tick control products should be prescribed based on a regional, seasonal, and individual risk assessment that includes knowledge of tick species and tick-borne illnesses endemic in the region. There are numerous tick treatment and preventative products that may be used. Tick species vary widely across Canada, and not all products are effective against all tick species so carefully read the label when selecting a product to fit your patient's needs. Products containing pyrethroids are generally not safe for use in cats and should not be used on dogs in households with cats (see exception in flea section above). Note that tick preventives do not always provide 100% protection for the entire inter-treatment period and may need to be applied more frequently to maintain efficacy in areas where ticks are plentiful. Pet owners should also be advised that they may see a low number of ticks on an animal even after treatment, particularly near the end of the efficacy period.

HEARTWORM

<u>{» For more information, See supplemental</u> section on Heartworm / pg. 47}

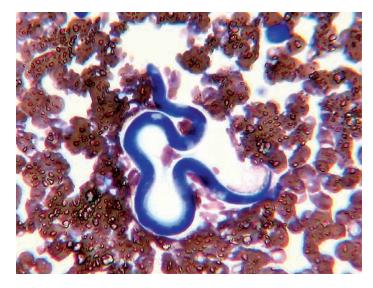
Heartworm prevalence is, overall, low in Canada, with endemic transmission occurring seasonally only in regions of southern British Columbia, Manitoba, Ontario, Quebec, and New Brunswick. Testing and preventives are necessary in these areas of Canada where heartworm is endemic, or for pets traveling to or through endemic areas during transmission season. Transmission seasons vary across Canada, but generally range from May to October.

Antigen testing is the primary screening test for heartworm infection in dogs. These serological tests detect antigen produced by adult female nematodes in established infections, about 6-7 months after exposure to the infective mosquito. Veterinarians in endemic areas should evaluate the risk of infection on an annual basis (e.g. compliance in previous year, travel to high risk areas) and make the decision

Annual testing may be indicated in highly endemic areas even if the dog was on a heartworm preventive during the previous season because:

- All products have reports of lack of efficacy, and resistant heartworm strains may make their way into Canada via importation of dogs (Bourguinat et al 2011).
- There may be compliance issues, missed doses, or undetected vomiting.
- + Annual testing ensures early and timely detection of a positive case.
- There is a risk of adverse reaction following administration of some preventives to a heartworm-positive dog.
- + Pharmaceutical companies will not cover the cost of adulticidal treatment if pets are not tested annually.

on whether or not to test on a case by case basis.



In non-endemic areas, dogs should only be tested if they have a history of travel to or through endemic areas more than seven months previously, bearing in mind that false positives may constitute a large proportion of the positive results. In endemic areas, testing should be performed prior to beginning preventive treatment, and 6-7 months after the last possible exposure to infected mosquitoes in the previous year. Therefore, in Canada, antigen testing should ideally be conducted in spring (April-May). Microfilarial concentration techniques may help confirm infection; however they will not detect occult infections (non-patent infections, i.e. during the pre-patent period, with same sex worm infections, or with senescent worms) and may not detect low levels of microfilaremia. Animals that test positive for antigen but have no microfilaria and no suggestive history (e.g. travel to, or residence in, an endemic region, clinical signs, lack of prophylaxis) should be retested in six months. False negatives are also possible on the antigen test, due to testing too early, or infections with only male nematodes. Heartworm preventives target third stage larvae (L3) acquired from mosquitos and developing fourth stage larvae in the early stages of infection.

Dirofilaria immitis microfilaria

Heartworm preventive products are generally macrocyclic lactones administered monthly that kill larvae acquired in the month prior (one month reachback, or retroactive efficacy). Thus, dogs and cats living in or traveling to endemic regions should receive a heartworm preventive starting one month after transmission begins and finishing within one month following the end of the transmission season. For animals residing in Canada that do not travel abroad, this means six treatments per year from June 1st to November 1st. Puppies and kittens in endemic regions should begin heartworm prevention by 8 weeks of age if born during the transmission season. Heartworm preventives are safe and, with good compliance, are usually highly efficacious. However, there have now been multiple reports demonstrating resistance to macrocyclic lactone heartworm preventives in various parts of the USA - most notably the Mississippi Delta region - as well as in one dog imported from Louisiana into Ontario (Bourguinat et al 2011, Wolstenholme et al 2015).

Dogs diagnosed with active heartworm infections (ideally with an antigen test plus/minus a microfilarial concentration test) should be treated with the adulticide melarsomine dihydrochloride as well as a microfilaricide plus/minus doxycycline (to inactivate symbiotic bacteria), as recommended by the American Heartworm Society. CPEP strongly advises against use of the "slow kill" method (i.e., administering a monthly preventative as a microfilaricide) as it creates the optimal conditions for generating resistance to macrocyclic lactones, which is known to be emerging in canine heartworm. Monthly preventives are designed to kill L3, and may be at a lower dose than that recommended to kill microfilaria (first stage larvae produced by adult heartworms in established infections). Microfilaricides prevent ongoing transmission to mosquitoes. This is important because once heartworm is endemic in a region, it is very difficult to eliminate because not all dogs are on preventive medications. In addition, wildlife such as coyotes, wolves, and foxes can serve as reservoir hosts of heartworm.

The heartworm antigen test and microfilarial recovery techniques do not work reliably in cats due to low heartworm burdens, failure to develop fully to adult nematodes, and transient microfilaremia. Antibody-based serology is an option. Cats may experience respiratory disease, ectopic migration of heartworms with severe neurological signs, and



even sudden death. Therefore heartworm prevention for cats should be considered in endemic areas.

Further information on heartworm testing and interpretation is available in the supplemental section of these guidelines and from the American Heartworm Society at *www.heartwormsociety.org.*



CESTODES



{» FOR MORE INFORMATION SEE SUPPLEMENTAL SECTION ON Cestodes / pg. 54} and Emerging Issues With Echinococcus in Canada / pg. 60}

Risk of exposure to cestodes should be assessed through a good history (focusing on flea control, diet, and access to wildlife and fish intermediate hosts) and through fecal diagnostic testing (although false negatives are common using fecal flotation methods, there are new fecal PCR and coproantigen methods that offer potentially higher sensitivity). Pets at high risk for cestodes are those that may consume fleas, raw fish, rodents, or the organs of cervids and domestic livestock. Taeniid egg

Of particular concern are the zoonotic cestodes Echinococcus granulosus and E. multilocularis. E. granulosus (strains G1-G3) is not present in livestock in Canada. Strains of *E. granulosus* established in Canada (G8 and G10) are known as *E. canadensis*, and are present wherever cervids (moose, caribou, elk, and deer) and wolves/coyotes can maintain the life cycle (most of Canada except the Atlantic provinces). *E. multilocularis* is present in most of western Canada and in southern Ontario. In high risk dogs in areas endemic for *Echinococcus* spp., monthly cestocidal treatments



are recommended for the protection of public health.



Products used for the prevention of heartworm, fleas, ticks, or gastrointestinal nematodes have no efficacy against



cestodes (except for those in combination with praziquantel in cats and dogs), so a separate cestocidal drug must be



CANADIAN PARASITE PREVALENCE DATA BY REGION

03



CANADIAN PARASITE PREVALENCE DATA BY REGION

Echinococcus multilocularis Echinococcus multilocularis and E. canadensis

administered. The only anthelmintic with approved efficacy against adult cestodes of Echinococcus spp. is praziquantel (note: not all products containing praziguantel are specifically labeled for Echinococcus treatment, so be sure to read the label carefully). Dogs with the larval stage of E. multilocularis should be treated with both an adult cestocide (praziquantel) and a larval cestocide (such as albendazole).

GASTROINTESTINAL NEMATODES (GIN)

{» For more information see supplemental section on Nematodes / pg. 44}

There are a wide range of gastrointestinal nematodes,

including ascarids (Toxocara, Toxascaris, and Baylisascaris spp.), hookworms (Uncinaria and Ancylostoma spp.), and whipworms (Trichuris spp.), present in companion animals across Canada, and there are strong regional differences in prevalence. Toxocara spp. ascarids are the most common

GIN in pets in Canada and may pose a zoonotic risk. Because

of this, most treatment and prevention guidelines target

Toxocara spp. Veterinarians should conduct regular fecal diagnostic testing and follow label instructions for parasite treatment and control when approved products are available. Trichuris vulpis eggs

LEFT: Hookworm egg / RIGHT: Ancylostoma caninum anterior end

LEFT: Toxocara canis egg / RIGHT: Toxocara cati anterior end

This section contains regional prevalence data for gastrointestinal provinces, Quebec, Ontario and Western Canada.

Veterinarians should note that in some areas these Expert Panel (CPEP) members have provided their discussions with local veterinarians. Therefore, the da measure of parasite occurrence. In addition, parasite r a pet's lifestyle and its level of veterinary care. Veterin with their own local knowledge when making decisic

NOTE: Heartworm transmission start and end times are taken

fleas, and ticks for the Atlantic

😞 Canadian Parasitology eir diagnostic experience and delines fo a precis osition can L ocation. the informatic

that

inconjunction

heartworm microfilariae require 14 days at the minimum threshold temperature of 14°C to complete development to the infectious third larval stage within mosquitoes. An assumption is also made that infected mosquitoes are not able to survive the winter. These regional transmission dates can be used to provide general guidelines on choosing start and end times for preventive use. However, these dates are based on temperature data for 1963-1992, now considered a baseline period for current climate projections. Canada continues to experience warming due to climate change (a mean annual warming trend of 1.7°C nationally since 1948, with the most rapid warming in northwestern Canada); therefore, the transmission season likely begins earlier and ends later than the dates presented below

		% PREV	ALENCE	
PARASITE	Newfoundland and Labrador (n = 18)	Nova Scotia (n = 25)	New Brunswick (n = 35)	Prince Edward Island (n = 23)
Toxocara canis	0.0	16.0	5.7	17.4
Toxascaris leonina	0.0	0.0	0.0	0.0
Ancylostoma caninum	0.0	4.0	5.7	0.0
Uncinaria stenocephala	5.6	8.0	0.0	0.0
Taeniid	0.0	0.0	0.0	0.0
Trichuris vulpis	5.6	8.0	0.0	4.3
Capillarid	0.0	0.0	0.0	4.3
Cystoisospora	5.6	0.0	17.1	8.7
Giardia	0.0	4.0	5.7	0.0
Cryptosporidium	5.6	0.0	8.6	4.3
Sarcocystis	5.6	0.0	5.7	4.3
All parasites	16.7	28.0	37.1	39.1

ATLANTIC CANADA

REGION-SPECIFIC PARASITES:

- » Angiostrongylus vasorum (French heartworm)
- » Crenosoma vulpis (fox lungworm)
- » Aelurostrongylus abstrusus (feline lungworm)

	% PREVALENCE			
PARASITE	Newfoundland and Labrador (n = 28)	Nova Scotia (n = 6)	New Brunswick (n = 16)	Prince Edward Island (n = 31)
Toxocara cati	14.3	16.7	43.8	22.6
Ancylostoma tubaeforme	0.0	0.0	0.0	0.0
Taeniid	3.6	0.0	18.8	6.5
Capillarid	0.0	0.0	18.8	0.0
Cystoisospora	7.1	0.0	12.5	6.5
Giardia	0.0	0.0	0.0	0.0
Cryptosporidium	0.0	0.0	0.0	0.0
Sarcocystis	0.0	0.0	0.0	0.0
All parasites	21.4	16.7	56.3	32.3

	HEARTWORM POSITIVE/NO. TESTED (%)		
PROVINCE	2002	2010	2013-2014
New Brunswick	2/1,729 (0.12%)	2/1,125 (0.18%)	2/1,631 (0.12%)
Nova Scotia	1/3,023 (0.03%)	1/560 (0.18%)	1/210 (0.48%)
Prince Edward Island	1/83 (1.20%)	0/63 (0.00%)	N/A
Newfoundland & Labrador	0/126 (0.00%)	0/11 (0.00%)	N/A
Total	4/4,961 (0.08%)	3/1,759 (0.17%)	3/1,841 (0.16%)

GASTROINTESTINAL PARASITES

The tables below show fecal flotation data from shelter animals and are therefore not representative of the expected parasite prevalence in pet populations that receive regular veterinary care. However, they do provide information on the types of parasites that pets may be exposed to in this region.

Based on sugar flotations and centrifugation of fecal samples collected from 101 shelter dogs, the most commonly observed parasites in dogs in Atlantic Canada are *Toxocara canis, Cystoisospora*, and *Cryptosporidium* (Villeneuve et al 2015). The complete fecal examination results are shown below, with the total number of dogs sampled per province provided in parentheses.

In a study of Prince Edward Island dogs < 1 year old, the prevalence of parasites in client-owned dogs (n=78) was 38% for *Giardia*, 13% for *Cystoisospora*, 10% for *Cryptosporidium*, and 9% for *T. canis* (Uehlinger et al 2013). The higher prevalence of *Giardia* and *Cryptosporidium* noted in these pet dogs compared to the shelter dogs above is likely due to the greater sensitivity of the immunofluorescent detection method used. Three quarters of the *Giardia*-positive samples belonged to the dog-specific assemblages C and D, while one sixth of samples contained zoonotic assemblage A or B. All *Cryptosporidium*-positive samples that were sequenced were identified as the host-adapted *C. canis*.

Based on sugar centrifugal flotations of fecal samples collected from 81 shelter cats, the most commonly observed parasites in cats in Atlantic Canada are *Toxocara cati*, taeniid tapeworms, and *Cystoisospora* spp. (Villeneuve et al 2015). The complete fecal examination results are shown below, with the total number of cats sampled per province provided in parentheses.

A study of parasite prevalence in feral cats on Prince Edward Island showed similar results, with *T. cati* (34%), taeniid tapeworms (15%), and *Cystoisospora* (14%) being most common in the 78 samples examined (Stojanovic and Foley 2011). A single cat (1.3%) in this study was shedding *Toxoplasma gondii* oocysts, though seroprevalence was much higher (29.8% of 96 cats).

HEARTWORM & LUNGWORMS

Heartworm has been endemic in and localized to the Tracadie area of New Brunswick for some time and has not spread, although prevalence monitoring should occur. Monthly preventive should be administered from June 1st to November 1st.

The last systematic postal survey of heartworm in Canada was carried out in 2010. Of the 564 canine cases diagnosed, three cases were in the Maritimes: one dog in Nova Scotia, and two dogs in New Brunswick. The survey data for Atlantic Canada

3 : CANADIAN PARASITE PREVALENCE DATA BY REGION

are presented below alongside the postal survey from 2002 and IDEXX SNAP 4Dx data from 2013-2014 (Herrin et al 2017). Because the 2013-2014 SNAP 4Dx test results are not accompanied by information on confirmatory testing, we cannot draw firm conclusions when comparing this data to veterinarian-diagnosed cases from prior years. However, it does provide an estimate of heartworm prevalence that can help to establish a temporal trend.

While the total number of heartworm cases diagnosed in Canada has increased since 2002, prevalence within the Atlantic provinces has remained relatively steady. There is an apparent rise in prevalence in Nova Scotia, however, the single case diagnosed in 2010 was an imported dog, and the travel history of the case from 2013-2014 is unknown. Veterinarians are advised to remain vigilant, particularly for dogs imported from heartworm-endemic regions.

Dogs in Atlantic Canada can also be infected with *Crenosoma vulpis* (the fox lungworm) and *Angiostrongylus vasorum* (the French heartworm). <u>{» for more information see the supplemental section on Metastrongylid</u>

<u>lungworms / pg. 51}</u> The prevalence of *C. vulpis* in dogs in Nova Scotia, New Brunswick and Newfoundland is unknown, but the parasite is highly prevalent in the red fox population (50% to 90%). On Prince Edward Island, post-mortem data from Humane Society cases shows that 3% of the general dog population has this lungworm (Bihr and Conboy 1999). A similar rate is likely in Newfoundland. Based on fecal diagnostics, about 20% of dogs in Atlantic Canada suffering from chronic coughing are infected with *C. vulpis* (Conboy 2004).

Reports of *A. vasorum* in dogs are mainly restricted to southeastern Newfoundland, where 11% of shelter dogs had adult worms in their pulmonary arteries upon necropsy (Bourque et al 2008). Roughly a quarter of dogs with chronic cough in this region are infected with *A. vasorum* (Conboy 2004). Recently, a case of *A. vasorum*-associated paradoxical vestibular syndrome was reported from Codroy, on the western coast of Newfoundland (Jang et al 2016). This dog had no history of travel outside of western Newfoundland, suggesting that *A. vasorum* has now spread across the island. This hypothesis is supported by the results of an unpublished survey showing *A. vasorum* infection in foxes throughout Newfoundland, even northern regions. *A. vasorum* is a potentially serious pathogen that causes permanent damage, and as such, warrants regular anthelmintic prophylaxis while the mollusc intermediate hosts are active (typically from mid-April through October, sometimes up to December). Monthly moxidectin or milbemycin are suitable for this purpose.

	B. burg	Idorferi	Anaplasma spp.	Ehrlichia spp.
PROVINCE	2007	2013-2014	2013-2014	2013-2014
New Brunswick	2.24%	3.7%	0.43%	0.12%
Nova Scotia	2.38%	15.7%*	0.95%	0.0%
Prince Edward Island	4.55%	N/A	N/A	N/A

In a recent study, researchers from Acadia University and provincial wildlife biologists found *A. vasorum* infection in coyotes in 4 different counties in Nova Scotia indicating that French Heartworm has successfully spread to the mainland (Priest et al,

2018). Presumably after a period of expansion within the wild canid population (especially red fox) infections are expected to occur in dogs. As with *C. vulpis*, the large red fox population and the abundance of gastropod intermediate hosts will likely result in a significant exposure risk to dogs in the Maritime provinces and beyond.

Cats in Atlantic Canada can also be infected with *Aelurostrongylus abstrusus* (the feline lungworm). This parasite was previously reported from Newfoundland and Labrador. More recently, in an investigation of anesthesia-related feline deaths in New Brunswick and Nova Scotia, *A. abstrusus* was diagnosed in one cat (unpublished).

FOOTNOTE: Priest JM, Stewart DT, Boudreau M, Power J, Shutler D. First report of *Angiostrongylus vasorum* infection in coyotes in mainland North America. Vet Rec December 2018 (doi: 10.1136/vr.105097)

FLEAS

There has been only a single published report of flea prevalence on Prince Edward Island, where 9.6% of feral cats showed

evidence of flea infestation (Stojanovic and Foley 2011). Based on their own experience, veterinary practitioners in Atlantic

Canada assess the prevalence as relatively high.

Fleas are not typically a problem year round. The risk period is typically May to October. However, some households have

experienced flea problems throughout the year (e.g. unoccupied and infested apartments).

PARASITE	% PREVALENCE (N = 270)
Toxocara canis	12.6
Toxascaris leonina	3.0
Ancylostoma caninum	3.0
Uncinaria stenocephala	0.7
Taeniid	0.0
Trichuris vulpis	0.7
Capillarid	0.0
Cystoisospora	4.8
Giardia	5.2
Cryptosporidium	3.3
Sarcocystis	1.9
All parasites	27.8



Ticks are encountered in most of Atlantic Canada. *Ixodes scapularis* have been recovered from dogs and occasionally cats, as well as from people, in all Atlantic provinces. *I. scapularis* is the primary tick in Prince Edward Island, although the overall risk of ticks is low. Other *Ixodes* spp. ticks have been recovered from both dogs and cats. *Dermacentor variabilis* is

PARASITE	% PREVALENCE (N = 114)
Toxocara cati	12.3
Ancylostoma tubaeforme	3.5
Taeniid	2.6
Capillarid	2.6
Cystoisospora	9.6
Giardia	2.6
Cryptosporidium	0.0
Sarcocystis	0.0
All parasites	27.2

the primary tick in Nova Scotia, particularly in the Annapolis Valley, and in New Brunswick, in areas with the right habitat. *Rhipicephalus sanguineus*

is present at low levels. *I. scapularis* and *D. variabilis* activity follows a bimodal pattern with peaks in May/June and again in

TICKS

October/November. Realistically, tick control programs should be used for the whole season.

Maps of Lyme disease risk areas are generated by public health agencies and are available through the links below.

NEW BRUNSWICK:

www2.gnb.ca/content/gnb/en/departments/ocmoh/cdc/content/vectorborne_andzoonotic/lyme/risk.html

NOVA SCOTIA:

www.novascotia.ca/dhw/CDPC/lyme.asp

Data from a total of 115,636 Canadian dogs tested in 2013-2014 (Herrin et al 2017), compared to 94,928 samples in 2007 (from Incidence of Heartworm, *Ehrlichia canis*, Lyme Disease, Anaplasmosis in dogs across Canada as determined by the IDEXX

	HEARTWORM POSITIVE/NO. TESTED (%)		
PROVINCE	2002	2010	2013-2014
Quebec	21/34,508 (0.06%)	41/48,301 (0.09%)	71/23,701 (0.30%)

SNAP[®] 3Dx[®] and 4Dx[®] Tests – 2007 National Incidence Study Results, IDEXX, Markham, ON) indicate that seroprevalence of tick-borne agents was as follows:

*A hyperendemic focus exists in Pictou county, where seroprevalence is 40.6%.

These data should be interpreted carefully as they indicate exposure and not current infection. Many dogs that seroconvert for *B. burgdorferi* do not develop clinical signs. The true prevalence of exposure may be lower than the reported estimates for several reasons: there is no evidence that confirmatory tests were done for any of the samples; the travel history of dogs is not given; and, in light of the very low prevalence of infection in most areas, some positive results may be false positive.

QUEBEC

GASTROINTESTINAL PARASITES

The tables below show fecal flotation data from

shelter animals and are therefore not representative of the expected parasite prevalence in pet populations that receive regular

	B. burgdorferi		Anaplasma spp.	Ehrlichia spp.
PROVINCE	2007	2013-2014	2013-2014	2013-2014
Quebec	0.6%	2.8%*	O.19%	0.16%

veterinary care. However, they do provide information on the types of parasites that pets may be exposed to in this region.

Based on sugar flotations and centrifugation of fecal samples collected from 270 shelter dogs, the most commonly observed parasites in dogs in Quebec are *Toxocara canis, Giardia,* and *Cystoisospora* (Villeneuve et al 2015). The complete fecal examination results are shown below.



PARASITE	% PREVALENCE IN DOGS (N = 70)
<i>Toxocara</i> spp.	14.2
Coccidia	11.4
<i>Giardia</i> spp.	7.1
Hookworms	2.9
Trichuris sp.	2.9
Taenia sp.	1.4
Dipylidium caninum	0.0
All parasites	40.0

Based on sugar centrifugal flotations of fecal samples collected from 114 shelter cats, the most commonly observed parasite in cats in Quebec are *Toxocara cati* and *Cystoisospora* (Villeneuve et al 2015). The complete fecal examination results are shown below.

The above prevalences in shelter animals are likely higher than what would be seen in the companion animal population, as these were largely young animals, and prevalence of helminths is expected to be lower in pets that receive regular veterinary care.

PARASITE	% PREVALENCE IN CATS (N = 41)
<i>Toxocara</i> spp.	12.2
Coccidia	9.7
Dipylidium caninum	7.3
<i>Taenia</i> sp.	4.9
<i>Giardia</i> spp.	2.4
Hookworms	0.0
All parasites	36.6

HEARTWORM

The heartworm endemic area is in southwestern Quebec. Monthly preventive should be administered from June 1st to November 1st.

The last systematic postal survey of heartworm in Canada was carried out in 2010. Of the 564 canine cases diagnosed, 41 (7%) were in Quebec. The survey data for Quebec are presented below alongside the postal survey from 2002 and IDEXX SNAP 4Dx data from 2013-2014 (Herrin et al 2017). Because the 2013-2014 SNAP 4Dx test results are not accompanied by information on confirmatory testing, we cannot draw firm conclusions when comparing this data to veterinarian-diagnosed cases from prior years. However, it does provide an estimate of heartworm prevalence that can help to establish a temporal trend.

The prevalence of heartworm infection appears to have increased in Quebec since 2002. Only 6 of the 41 diagnosed cases in 2010 were imported dogs or dogs that had traveled outside Canada. Once heartworm is successfully cycling in a region it is

	HEARTWORM POSITIVE/NO. TESTED (%)			
PROVINCE	2002	2010	2013-2014	
Ontario	268/256,249 (0.10%)	431/289,229 (0.15%)	385/77,143 (0.50%)	

very difficult to eliminate because not all dogs will be placed on preventive medications and wildlife such as coyotes, foxes, and wolves are appropriate hosts and can act as a reservoir of infection. Climate change may be allowing for the geographic expansion of mosquito vectors as well and thus enhancing heartworm transmission. Since no patient history is provided for the 2013-2014 SNAP 4Dx data, it is unknown if the dogs testing heartworm positive were imported from other countries or had traveled to endemic countries. Regardless of original location of infection, the fact remains that a higher prevalence of heartworm-infected dogs in a region will increase the risk of transmission to other dogs in that area, making it crucial to detect and treat infections as soon as possible. This will also help to reduce zoonotic transmission of heartworm to people, which has been reported on 3 occasions – twice in Quebec and once in Ontario (Lagrotteria et al 2003, Kokta 2008).

FLEAS

There are no prevalence data for fleas in Quebec, though based on experience, veterinary practitioners assess the prevalence as relatively high.

Fleas are not typically a problem year round. The at-risk period is generally May to October, though some households have experienced flea problems throughout the year.

TICKS

The tick season typically starts at the end of April and concludes by early December, but recall that *Ixodes scapularis* will be active any time the ambient temperature reaches 4°C, which occurs in many areas on some days throughout the winter. The most commonly found species in a passive tick surveillance program was *I. scapularis* by far (294/382), followed by *I. cookei* (the groundhog tick; 70/382) and *Dermacentor variabilis* (11/382) (Koffi et al 2017). Of the *I. scapularis* ticks recovered from companion animals, 193/2,044 (9.4%) on dogs and 122/892 (13.7%) on cats were infected with *B. burgdorferi* (Ogden et al 2010).

A map of Lyme disease risk areas in Quebec is available at: www.inspq.qc.ca/zoonoses/maladie-de-lyme

Data from a total of 115,636 Canadian dogs tested in 2013-2014 (Herrin et al 2017), compared to 94,928 samples in 2007 (from Incidence of Heartworm, *Ehrlichia canis*, Lyme Disease, Anaplasmosis in dogs across Canada as determined by the IDEXX SNAP[®] 3Dx[®] and 4Dx[®] Tests – 2007 National Incidence Study Results, IDEXX, Markham, ON) indicate that seroprevalence of tick-borne agents was as follows:

*A hyperendemic focus exists in southern Quebec, where seroprevalence is > 5%.

These data should be interpreted carefully as they indicate exposure and not necessarily current infection. Many dogs that seroconvert for *B. burgdorferi* do not develop clinical signs. In addition, the true prevalence of exposure within Canada may be lower than the reported estimates for several reasons: there is no evidence that confirmatory tests were done for any of the samples; the travel history of dogs is not given; and, in light of the very low prevalence of infection in most areas, some positive results may be false positive.

ONTARIO

REGION-SPECIFIC PARASITES:

» Echinococcus multilocularis

GASTROINTESTINAL PARASITES

Few studies have been conducted in recent years on the prevalence of intestinal parasites in dogs and cats in Ontario. Findings from the fecal examination of 70 owned dogs in the Niagara region are summarized below (Shukla et al 2006). Overall, parasite prevalence for all species detected was higher in dogs 6 months of age or younger compared to dogs > 6 months of age, with the exception of *Taenia* and *Trichuris*. *Cryptosporidium* antigen was detected in 5/68 dogs (7.4%) based on an enzyme-linked immunosorbent assay that does not differentiate between species (Shukla et al 2006). A separate investigation identified *Giardia* spp. in 16/251 (6.4%) fecal samples collected from dog parks in southwestern Ontario (Procter et al 2014),

	B. burgdorferi		Anaplasma spp.	Ehrlichia spp.
PROVINCE	2007	2013-2014	2013-2014	2013-2014
Ontario	0.58%	2.3%*	0.22%	0.19%

consistent with the prevalence observed in the first study. Giardia cysts

shed by pet dogs were determined to be mainly of the non-zoonotic C and D assemblages in one study, though 1 sample out of 75 contained a potentially zoonotic B

assemblage (McDowall et al 2011).

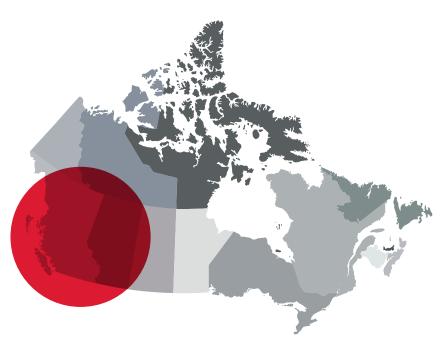
Dogs can also be infected with *Echinococcus granulosus* and *E. multilocularis*, although rarely diagnosed in part because the eggs are indistinguishable from each other and from the eggs of *Taenia* species. It is important to note that both species of *Echinococcus* are zoonotic. *E. granulosus* /

E. canadensis eggs were detected by PCR in the feces of a small number of dogs from Ontario shelters (Villeneuve et al 2015). Of note, canine alveolar hydatid disease due to

E. multilocularis – with dogs acting as the intermediate host rather than the definitive host – has been diagnosed in Ontario's Golden Horseshoe area in recent years (Peregrine 2015). This parasite is highly prevalent in the fox and coyote population in Ontario, and with coyotes becoming increasingly urban, the risk of exposure for dogs and people is likely to rise. In order to mitigate the danger of alveolar hydatidosis, dogs should not be allowed access to fox or coyote feces. Dogs that ingest rodents are at risk of developing intestinal infections with *E. multilocularis* and constitute a public health concern. High-risk dogs with rodent access should be treated monthly with praziquantel, year-round. Owners should

practice good general hygiene.

Findings from the fecal examination of 41 owned cats in the Niagara region are summarized below (Shukla et al 2006). Toxocara and coccidia were much more commonly detected in cats 6 months of age or younger compared to cats > 6 months of age. Cryptosporidium antigen was detected in 3/41 cats (7.3%) based on an enzyme-linked immunosorbent assay that does not differentiate between species (Shukla et al 2006). Unlike dogs, 13/13 pet cats in a Giardia genotyping study were infected with potentially zoonotic assemblages A or B (McDowall et al 2011). Another zoonotic protozoan parasite infecting cats is Toxoplasma gondii. Its short period of oocyst shedding (just 1-2 weeks), along with limited access to prey for indoor cats, may explain why it was not detected in the pets examined above. Though uncommon, extraintestinal toxoplasmosis causing pneumonia and various



other

manifestations does occur in cats. From 2008-2014, nine cases of disseminated toxoplasmosis were confirmed by the Animal Health Laboratory in Guelph, most of them in young male cats (Cohen et al 2016).

	% PREVALENCE			
PARASITE	British Columbia (n = 135)	Alberta (n = 122)	Saskatchewan (n = 46)	Manitoba (n = 60)
Toxocara canis	18.5	11.5	13.0	11.7
Toxascaris leonina	5.9	8.2	6.5	3.3
Ancylostoma caninum	1.5	0.8	2.2	3.3
Uncinaria stenocephala	0.7	3.3	4.3	6.7
Taeniid (Taenia and Echinococcus)	0.7	4.1	0.0	3.3
Trichuris spp.	3.0	0.8	0.0	1.7
Capillarid	1.5	0.8	0.0	0.0
Cystoisospora	16.3	12.3	15.2	10.0
Giardia	2.2	3.3	4.3	3.3
Cryptosporidium	1.5	2.5	2.2	1.7
Sarcocystis	3.0	16.4	4.3	8.3
All parasites	33.3	39.3	39.1	35.0

HEARTWORM

The heartworm endemic area is in southern Ontario. However, the risk of infection is greatest south of the 403/402/401 highways that run between Sarnia and Hamilton where 80% of all the Ontario cases occur. Monthly preventives should be administered from June 1st to November 1st. The overall prevalence of heartworm in Ontario dogs appears to be approximately 0.5%. However, in a few discrete areas within southern Ontario the prevalence of infection in dogs not on a heartworm

preventive can be as high as 5% to 10%.

The last systematic postal survey of heartworm in Canada was carried out in 2010. Of the 564 canine cases diagnosed, 431 (76%) were in Ontario. The survey data for Ontario are presented below alongside a similar survey from 2002 and IDEXX SNAP 4Dx data from 2013-2014 (Herrin et al 2017). Because the 2013-2014 SNAP 4Dx test results are not accompanied by information on confirmatory testing, we cannot draw firm conclusions when comparing these data to veter-inarian-diagnosed cases from prior years. However, it does provide an estimate of heartworm prevalence that can help to establish a temporal trend.

The prevalence of heartworm infection in Ontario appears to have increased since 2002. Part of this rise can be attributed to infected dogs being imported from other countries or Ontario dogs traveling abroad (approximately 25% of heartworm cases in 2010). However, half of the dogs diagnosed with heartworm infection in 2010 had never left their local area. Climate change may be allowing for the geographic expansion of mosquito vectors and thus enhancing heartworm transmission. Since no patient history is provided for the 2013-2014 SNAP 4Dx data, it is unknown if the dogs testing heartworm positive were imported from other countries or had traveled to endemic countries. While not all heartworm cases may be the result of local transmission, the fact remains that a higher prevalence of heartworm-infected dogs in a region will increase the risk of transmission to other dogs in that area.

Of note, there has been at least one report of a heartworm-infected dog in Ontario – imported as a rescue dog from

New Orleans after Hurricane Katrina – whose microfilariae were highly resistant to the macrocyclic lactone class (Bour-

guinat et al 2011); other such resistant strains of heartworm may be out there and veterinarians should remain vigilant in monitoring their patients for heartworm infection, even those receiving monthly preventives. In particular, when treating heartworm infections, veterinarians should ensure that microfilariae are eliminated following successful adulticide treatment.

Ontario veterinarians should follow The College of Veterinarians of Ontario (CVO) Veterinarian's Act and recommendations from CVO Update Volume 23(4), December 2007 pgs. 8-9, 18-19 on heartworm testing and dispensing of heartworm preventives (*www.cvo.org*).

FLEAS

There are no prevalence data for fleas in Ontario, though based on their experience, veterinary practitioners assess the prevalence as relatively high.

	% PREVALENCE			
PARASITE	British Columbia (n = 95)	Alberta (n = 106)	Saskatchewan (n = 34)	Manitoba (n = 35)
Toxocara cati	9.5	12.3	8.8	22.9
Ancylostoma tubaeforme	0.0	0.0	0.0	0.0
Taeniid	2.1	5.7	5.9	8.6
Capillarid	2.1	0.0	5.9	2.9
Cystoisospora	10.5	9.4	11.8	11.4
Giardia	0.0	2.8	0.0	0.0
Cryptosporidium	2.1	4.7	0.0	0.0
Sarcocystis	1.1	0.0	0.0	0.0
All parasites	21.1	25.5	32.4	37.1

Fleas are not typically a problem year-round. The at-risk period is typically May to October, though some households in the Toronto area have experienced flea problems throughout the year.

TICKS

The most common tick seen on dogs is highly dependent on region and may be either *Dermacentor variabilis* (the "American dog tick") and/or *Ixodes scapularis* (the "deer" or "black-legged" tick). The peak season for preventive treatment for adult ticks is typically May to July for both ticks, and also September to November for *I. scapularis*. Nymphs are active during the summer months and are considered an important source of *B. burgdorferi* infections in people. In areas endemic for *I. scapularis*, prevention is recommended any time the temperature is above 4°C, which may be year-round.

Annual maps of estimated Lyme disease risk areas are generated by Public Health Ontario and are available at *www.publichealthontario.ca/lymedisease*. The range of *I. scapularis* is progressively extending northward and along the coasts of Lake Ontario and Lake Erie (Nelder et al 2014). The current risk map shows areas of risk throughout eastern Ontario, in addition to the endemic foci of Point Pelee, Rondeau, Long Point, Turkey Point, Prince Edward County, and the Thousand Islands. For regions close to enzootic areas of the United States that are not yet enzootic for *B. burgdorferi* themselves, the main source of *I. scapularis* is adventitious ticks (e.g. ticks dropping from migrating birds) – mainly nymphs.

Amblyomma americanum (the "lonestar tick") has not yet become established in Ontario, but these ticks are occasionally

reported on dogs that have not traveled outside of the province (Herrin et al 2017). It is anticipated that this tick will become established in the province in the near future.

	HEARTWORM POSITIVE/NO. TESTED (%)				
PARASITE	2002	2010	2013-2014		
Manitoba	53/12,338 (0.43%)	77/23,192 (0.33%)	26/12,765 (0.20%)		
British Columbia	4/4,573 (0.09%)	8/1,943 (0.41%)	N/A		
Alberta	4/4,439 (0.09%)	2/2,218 (0.09%)	N/A		
Saskatchewan	0/197 (0.00%)	2/743 (0.27%)	0/186 (0.00%)		
Total	61/21,547 (0.28%)	89/28,096 (0.32%)	26/12,951 (0.20%)		

Over the years, Public Health Ontario Laboratory (PHOL) has carried out passive surveillance of Ixodes scapularis that have

been submitted to them by the public. Submitted ticks are examined for the presence of both *Borrelia burgdorferi* and *Anaplasma phagocytophilum* using molecular diagnostic tests. From 2008-2012, PHOL received 5,763 *I. scapularis* adults. The percentage infected with *B. burgdorferi* increased steadily from 8.4% in 2008 to 19.1% in 2012 (overall average of 15.1%), while the percentage infected with *A. phagocytophilum* remained relatively unchanged with an overall average of 0.3% (Nelder et al 2014). Of the *B. burgdorferi*-infected ticks, 146 were fed to the point where transmission would have occurred. Therefore, only 146 (2.5%) of 5,763 tick encounters could have resulted in exposure to *B. burgdorferi*, suggesting the risk of dog exposure to ticks infected with *B. burgdorferi* is low in non-endemic areas of Ontario. The risk of exposure is higher in tick-endemic areas such as Long Point and the Thousand Islands. A recent report documented a 73% *B. burgdorferi* infection prevalence in *I. scapularis* ticks on Corkscrew Island – in northwestern Ontario's Lake of the Woods – the northernmost location in Ontario where black-legged ticks have become established (Scott et al 2016).

The incidence of tick-borne diseases in dogs that have not traveled outside Ontario is very low. Data from a total of 115,636 Canadian dogs tested in 2013-2014 (Herrin et al 2017), compared to 94,928 samples in 2007 (from Incidence of Heartworm, *Ehrlichia canis*, Lyme Disease, Anaplasmosis in dogs across Canada as determined by the IDEXX SNAP[®] 3Dx[®] and 4Dx[®] Tests – 2007 National Incidence Study Results, IDEXX, Markham, ON) indicate that seroprevalence for tick-borne agents was as follows: **A hyperendemic focus exists in eastern Ontario, where seroprevalence reaches 5.1%.*

Because travel history and confirmatory testing were not provided for these dogs, the true prevalence of antibodies to these two pathogens in non-traveling dogs is likely lower than these figures. Furthermore, since many dogs seroconvert to tick-borne pathogens and do not develop clinical disease, the overall incidence of disease in Ontario caused by these agents is likely much lower. It is worth noting, however, that *B. burgdorferi* seroprevalence in dogs has increased almost four-fold in the span of 7-8 years, likely reflecting the increasing infection prevalence in *I. scapularis* ticks during this period. Over time, as *I. scapularis* populations become more established in previously non-endemic areas and more commonly infected with *B. burgdorferi*, the risk to dogs is expected to rise.

The Ontario Animal Health Network has generated a useful infographic to help veterinarians explain Lyme disease risk to pet owners: *www.oahn.ca/resources/companion-animals/ticks-and-lyme-disease-in-ontario-whats-the-real-risk-infographic-and-references/*

For guidelines on screening dogs for Lyme disease and management of cases, see the latest ACVIM consensus statement (Littman et al 2018).

WESTERN CANADA

REGION-SPECIFIC PARASITES:

- » Ixodes pacificus (Western black-legged tick)
- *» Pulex simulans* (wildlife flea) more common than *Ctenocephalides felis* (cat flea)
- » Echinococcus multilocularis

	B. burgdorferi		Anaplasma spp.	Ehrlichia spp.
PROVINCE	2007	2013-2014	2013-2014	2013-2014
British Columbia	0.53%	N/A	N/A	N/A
Alberta	0.35%	N/A	N/A	N/A
Saskatchewan	0.58%	0.5%	0.0%	1.6%
Manitoba	2.1%	2.4%	0.86%	0.24%

SUPPLEMENTAL INFORMATION: PART A

PROTOZOA

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/ CYSTOISOSPORA SPP.

("coccidia"; formerly *Isospora* spp.)

Species of veterinary importance include *Cystoisospora* canis, *C. ohioensis, C. neorivolta*, and *C. burrowsi* in dogs, and *C. felis* and *C. rivolta* in cats; these species are not zoonotic.

HOST RANGE: Dogs and cats serve as definitive hosts. A wide range of mammalian paratenic hots (mice, rats, cows, etc.) can carry an encysted form of this parasite that is infective for the cat or dog upon consumption.

GEOGRAPHIC RANGE: *Csytoisospora* spp. are found worldwide where dogs and cats are present.

LIFE CYCLE: Dogs and cats are infected by ingestion of sporulated oocysts or encysted stages in paratenic host tissues. Sporozoites that are released from oocysts invade intestinal epithelial cells where they develop through several asexual and sexual stages. Oocysts are released in feces and undergo sporulation in the environment.

DIAGNOSIS: Oocysts can be observed by microscopy after fecal flotation. Clinical disease is more frequent in young animals housed in stressful and/or crowded environments.

MANAGEMENT: Cats usually eliminate infection naturally without treatment. Trimethoprim-sulfonamide or toltrazuril is recommended for clinically affected cats. In kennels, prophylaxis (amprolium) and sanitation must be prioritized. In severe cases, sulfonamides or toltrazuril coupled with supportive fluid therapy should be used as treatment of choice. Consumption of raw meat should be avoided.

/ TOXOPLASMA GONDII

T. gondii is the causative agent of toxoplasmosis and one of the most important zoonotic parasites.

HOST RANGE: Cats are the only definitive host.

However, *T. gondii* is capable of infecting a broad range of warm-blooded paratenic hosts (humans, livestock, companion animals and wildlife).

GEOGRAPHIC DISTRIBUTION: Worldwide.

LIFE CYCLE: Transmission occurs by three routes: (1) Ingesting meat from a paratenic host carrying bradyzoite tissue cysts, (2) Ingesting sporulated oocysts (fecal-oral), and (3) transplacental and transmammary transmission. Asexual and sexual development occurs in the intestine, and oocysts are shed in the feces, sporulating in 1-5 days. Infected cats shed oocysts for just 1-2 weeks, which minimizes the risk of direct zoonotic transmission from cats. However, millions of oocysts are produced during this period, resulting in significant environmental contamination. Extraintestinal replication of *T. gondii* can lead to disseminated toxoplasmosis in dogs and sometimes cats.

DIAGNOSIS: Oocysts can be observed by microscopy after fecal flotation. Antibody assays are useful to detect current and past exposure to *T. gondii* in cats, but most cats are seronegative at the time of oocyst shedding. Cats with intestinal infection are typically asymptomatic.

MANAGEMENT: There is no approved treatment for toxoplasmosis in cats or dogs. Several medications including clindamycin hydrochloride, pyrimethamine and trimethoprim-sulfonamide can be used in cases of disseminated toxoplasmosis. Prevention protocols should emphasize avoidance of hunting by cats, elimination of raw or undercooked meat or viscera from the diet, and daily cleaning of litterboxes to remove oocysts before they have a chance to fully sporulate.

/ SARCOCYSTIS SPP.

Species of interest include *Sarcocystis cruzi, S. tenella, S. wenzeli, S. camelicanis* and *S. neurona* in dogs and at least 11 named species in cats.

HOST RANGE: A variety of vertebrate animals serve as intermediate or definitive hosts for *Sarcocystis spp.*, with specific predator/prey (definitive host/intermediate host) pairings identified for each species.

GEOGRAPHIC RANGE: Worldwide. Especially common in

areas where livestock is raised or where companion animals have contact with wildlife.

LIFE CYCLE: Cats and dogs are infected by ingesting tissue cysts (sarcocysts) in intermediate host tissues. Sexual replication occurs in the intestine and infective sporocysts are shed in the feces. Sporocysts ingested by intermediate hosts release sporozoites that replicate asexually in vascular endothelia and eventually muscle fibers.

DIAGNOSIS: Sporocysts can be observed by microscopy after fecal flotation. Infections are typically asymptomatic.

MANAGEMENT: Infections in dogs and cats are typically asymptomatic. Rarely, acute myositis, hepatitis, and neurological complications have been reported in dogs, potentially leading to death. Experimental treatment with clindamycin and decoquinate can be useful in dogs presenting with extraintestinal infection. Dogs and cats should not be fed raw meat or offal.

/ GIARDIA SPP.

Giardia duodenalis (formerly *G. intestinalis* and *G. lamblia*) is molecularly classified into several assemblages, which vary in their infectivity for animals and humans. Dogs have mainly assemblages C, D, and A1, while cat isolates fall mainly into assemblages F and A1. Assemblages A1, A2, and B are infectious to people.

HOST RANGE: The total number of *Giardia* strains and host infectivity ranges is unknown. Canine assemblages (C, D) are not known to infect cats, and feline (F) assemblages are not known to infect dogs. Transmission of *Giardia* from pets to humans appears to be rare, and is of most concern in households with immunocompromised people.

GEOGRAPHIC DISTRIBUTION: Worldwide.

LIFE CYCLE: Cats and dogs are infected by ingestion of cysts present in the environment (water, food or fomites) or through self-grooming. Cysts release trophozoites that reside on the mucosal surface of the small intestine. Trophozoites replicate by binary fission and will ultimately encyst prior to being released in the feces as infectious cysts.

DIAGNOSIS: Presence of Giardia spp. can be detected by

different complementary methods: (1) direct smear of diarrheic stools revealing motile trophozoites, (2) 33% ZnSO4 centrifugal flotation demonstrating cysts, (3) Fecal ELISA for antigen, and (4) PCR assay. Due to intermittent shedding, it may be necessary to perform tests over multiple days to confirm infection. Infected animals may or may not exhibit diarrhea.

MANAGEMENT: Asymptomatic dogs and cats do not require treatment. Treatment is recommended for pets living with or in frequent contact with immunocompromised people; in these cases, genotyping to determine if the *Giardia* belongs to an assemblage infectious to people may bring owners peace of mind. In the absence of an approved treatment, fenbendazole (with or without metronidazole) is commonly used as extra-label therapy. Treatment should be combined with disinfection of surfaces as well as shampooing of the animals to remove fecal debris containing cysts. A second, longer course of treatment may be necessary for infections that are not successfully cleared the first time.

/ CRYPTOSPORIDIUM SPP.

Species of interest include *C. canis* in dogs and *C. felis* in cats. Human cryptosporidiosis is predominantly caused by *C. hominis* and *C. parvum*; zoonotic infections by *C. canis* and *C. felis* have only been reported in immunocompromised individuals.

HOST RANGE: A wide variety of vertebrate hosts. However, most *Cryptosporidium* spp. are highly adapted to specific hosts.

GEOGRAPHIC DISTRIBUTION: Worldwide.

LIFE CYCLE: Cats and dogs get infected by ingestion of oocysts present in the environment (water, food or fomites). The parasites undergo asexual and sexual reproduction in the small intestine, releasing sporulated oocysts into the feces. Oocysts are immediately infectious when shed. They may survive in the environment for extended periods of time.

DIAGNOSIS: Presence of *Cryptosporidium* spp. can be
detected by: (1) acid-fast stain or fluorescent antibody tests
on fecal smears, (2) Sheather's sugar centrifugal flotation,
(3) ELISA for detecting fecal antigen, and (4) PCR assay,

which also allows for genotyping and subtyping. Infected animals exhibit a self-limiting diarrhea.

MANAGEMENT: Extra-label treatment of highly diarrheic animals has shown some success. Paromomycin and azithromycin are currently used for both dogs and cats, while tylosin is only recommended for cats. Environmental decontamination requires heat treatment (over 70°C) or ammonia-based disinfectants.

/ LEISHMANIA SPP.

Species of interest include *L. infantum*, *L. mexicana*, *L. donovani*, and *L. braziliensis* in dogs. *Leishmania* spp. has been infrequently reported in cats. *L. infantum* is an important zoonotic agent and dogs are considered the primary reservoir host.

HOST RANGE: Vertebrate hosts include a wide variety of mammals e.g. rodents, dogs, foxes and humans. Insect hosts (vectors for transmission) are mainly small blood-sucking sandflies.

GEOGRAPHIC DISTRIBUTION: *L. infantum* has an almost global distribution, being endemic in the Mediterranean basin, the Balkans, much of Asia, Africa and Central and South America. Canine leishmaniasis is currently documented in foxhounds from many kennels in the U.S. and Canada.

LIFE CYCLE: In addition to classical vector-mediated transmission, *L. infantum* can be transmitted directly from dog to dog, either vertically (i.e. transplacental) or horizontally (through blood and secretions). Dog-to-dog transmission is believed to be the route of infection in North American foxhound kennels.

DIAGNOSIS: Diagnosis should be guided by clinical signs in combination with antibody tests (indirect fluorescent antibody assay, direct agglutination assay, and enzyme immunoassay). Presence of *Leishmania* parasites can be confirmed by Wright-Giemsa staining or *in vitro* culture of biopsies from target organs (spleen, liver, lymph nodes, etc.). PCR assays are also available. Not all dogs develop clinical disease. Signs, when present, may include regional alopecia and dermatitis, cachexia, epistaxis, conjunctivitis, lameness, diarrhea, etc. **MANAGEMENT:** Leishmanicidal drugs used in dogs include pentavalent antimonials, allopurinol, and sometimes miltefosine. However, no drug is able to consistently cure canine leishmaniasis and relapses are very common.

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Toxoplasma gondii: history and diagnostic test development. Animal Health Research Reviews 2015; 16:150-162.

LeishVet guidelines for the practical management

TICKS & MITES

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/ TICKS DERMACENTOR SPP.

Species of veterinary importance for dogs and cats in Canada are *D. variabilis* and *D. andersoni*.

HOST RANGE: Dogs and cats serve primarily as hosts for the adult stage of these ticks. Occasionally domestic pets will be infested with tick nymphs. A wide range of wildlife hosts sustain larvae, nymphs and adults of these ticks and serve as a reservoir for domestic animals and people.

GEOGRAPHIC RANGE: Widespread with *D. variabilis* found in Alberta and east and *D. andersoni* found Alberta and west into British Columbia.

LIFE-CYCLE: *D. variabilis* and *D. andersoni* are both three-host ticks, feeding on three unique hosts in the course of their lifespan, with moulting or egg laying occurring in the environment post feeding. Tick larvae and nymphs tend to prefer smaller hosts, rodents and birds, with adults having a preference for larger animals including dogs, cats and people.

DIAGNOSIS: Observing one or more of these large ornate reddish brown ticks attached to a host is the primary method of diagnosis. Dogs and cats with moderate to heavy infestations may have irritated skin, hair loss and possibly anemia. These ticks have been associated with tick paralysis.

MANAGEMENT: Preventing access to semi-wild to wild areas during the seasons these ticks are active can be helpful. As well there are numerous highly efficacious topical and oral tick treatments available. These ticks are known to transmit numerous pathogens including Rocky Mountain Spotted Fever, Colorado Tick Fever and tularemia. These ticks are not associated with the transmission of Lyme disease.

/ IXODES SPP.

Species of veterinary importance for dogs and cats in Canada are *I. scapularis* and *I. pacificus*. There are other *Ixodes* species found in Canada but these are primarily found on wildlife and only rarely cross to domestic animals.

HOST RANGE: Dogs and cats serve as hosts for both nymph and adult life stages of this tick. A wide range of wildlife hosts sustain the larvae, nymphs and adults of these ticks and which then serve as a reservoir for domestic animals and people.

GEOGRAPHIC RANGE: *I. pacificus* is found on the lower mainland and Vancouver Island in British Columbia. *I. scapularis* is found in endemic populations in southern Manitoba, in much of southern Ontario and Quebec and into New Brunswick and Nova Scotia. *Ixodes scapularis* is found in other parts of the country on a regular basis. These ticks in non-endemic areas are thought to be brought in by migrating birds. The *I. scapularis* population size and geographic distribution in Canada is increasing, likely due in part to climate change causing environmental conditions to become more suited to their requirements.

LIFE-CYCLE: These are three host ticks, feeding on three unique hosts in the course of their lifespan, with a moult or egg-laying occurring in the environment post feeding. Tick larvae prefer smaller hosts while the nymphs and adults will feed on a variety of larger hosts including dogs, cats and people.

DIAGNOSIS: Observing one or more of these small inornate ticks attached to a host is the primary method of diagnosis.

MANAGEMENT: Preventing access to semi-wild to wild areas during the seasons these ticks are active can be helpful. As well there are numerous highly efficacious topical and oral tick treatments available. These ticks transmit the pathogens associated with Lyme disease and with the pathogens associated with tularemia, ehrlichiosis, and anaplasmosis.

/ RHIPICEPHALUS SANGUINEUS

HOST RANGE: Dogs are the preferential host for all life stages of *R. sanguineus*. This tick will only rarely feed off other hosts including people.

GEOGRAPHIC RANGE: *Rhipicephalus sanguineus*, is probably the most cosmopolitan tick in the world but is relatively rare in Canada. It is found mainly in Quebec and Ontario. There has been an increased incidence of this parasite as more dogs are traveling with their owners to tropical and semi-tropical destinations and then bringing the ticks back home.

LIFE-CYCLE: This is a three host tick with each stage leaving the host to moult prior to finding another host. Dogs are the preferential host and all three life stages, larva, nymph and adults may be found on a single dog. *Rhipicephalus sanguineus* is able to complete its life-cycle outdoors in warmer areas of the world, but it can also complete its life-cycle indoors in regions with cooler climates.

DIAGNOSIS: Finding these medium sized brown ticks on dogs is the primary diagnostic method. Dogs generally do not display clinical signs when infested.

MANAGEMENT: Keeping pet dogs away from places where infested dogs may be or have been present is an effective control measure. This may include kennels and houses. As well there are numerous highly efficacious topical and oral tick treatments available. As well, premise treatment may be required if the infestation is severe. This tick is a vector for canine piroplasmosis (*Babesia canis* and possibly *Babesia canis gibsoni*) and canine pancytopenia (*Erlichia canis*).

/ MITES CHEYLETIELLA SPP.

HOST RANGE: Dogs and cats each have their own species of the mite *Cheyletiella*, which appear to be host-specific – *C. yasguri* in dogs and *C. blakei* in cats.

GEOGRAPHIC DISTRIBUTION: *Cheyletiella* occurs on these hosts around the world. Distribution in Canada is not well documented but there is probably variation in occurrence in different regions of the country.

LIFE-CYCLE: The entire life cycle of the mites, adults, eggs and larval stages, occurs on the host.

DIAGNOSIS: The mites can be easily seen moving around in the haircoat – "walking dandruff". In general, dogs are more likely to show clinical signs (primarily pruritis, scaliness and

eczema-like skin lesions around the face), than are cats. *Cheyletiella* transmits readily to people, who can show clinical signs in the absence of signs in the pet, or before such signs develop.

MANAGEMENT: Infestations can be acquired from other animals but mites may survive for some time in the environment so may be present even if infested animals are not. It is important to thoroughly clean bedding etc. once a treatment regime has started. Although there are no products labelled for treatment of these mites in dogs, some insecticides and topical and oral acarcides have been found to be effective.

/ DEMODEX SPP.

HOST RANGE: *Demodex* mites are common in the hair follicles and sometimes sebaceous glands of the skin of dogs and cats.

GEOGRAPHIC DISTRIBUTION: The mite is found worldwide.

LIFE-CYCLE: The entire life-cycle of the mite occurs on the host. Probably most dogs and cats are infested and they acquired the mites from their dams while nursing.

DIAGNOSIS: The mites can often be found using a deep skin scraping. Very few infested animals will display symptoms of mange of which there are three clinical presentations 1) localized (one or more isolated lesions) – often resolves spontaneously; 2) generalized (some, most, or all of the skin surface affected) – does not resolve spontaneously and can be difficult to treat successfully; and 3) pododemodecosis – affects the feet.

MANAGEMENT: Demodectic mange in dogs is most common in young animals and has three main clinical presentations: Generalized demodectic mange in an older dog often signals underlying disease. Pruritus is not a common feature of demodectic mange unless there is secondary bacterial infection, which is common with the generalized form of the disease. Moxidectins and isoxazolines seem to be effective in resolving demodectic mange in dogs. Treatment in cats involves the use of macrocyclic lactones or lime-sulfur dips.

/ OTODECTES CYNOTIS

HOST RANGE: The ear mite *Otodectes cynotis* infests dogs and cats and several free-ranging carnivores.

GEOGRAPHIC DISTRIBUTION: This parasite is found worldwide.

LIFE-CYCLE: The entire life-cycle occurs on the host. Transmission is via direct contact with other infected animals and possibly fomites

DIAGNOSIS: Clinical signs include intense pruritus, scratching and rubbing at the ears, head shaking and sometimes severe behavioural disturbances and seizures. Examination of the ear canals reveals a waxy then crusty exudate. Ear swabs examined under a microscope may reveal the presence of mites.

MANAGEMENT: Numerous treatments are available. Ear cleaning is advised

/ SARCOPTES SCABIEI

HOST RANGE: Adult mites of the genus *Sarcoptes* live in the stratum corneum of the skin of mammals. Specific subspecies (or strains) are found on dogs.

GEOGRAPHIC DISTRIBUTION: This parasite is found worldwide.

LIFE-CYCLE: The entire life-cycle occurs on the host. Transmission is via direct contact with other infected animals and possibly fomites. The infestation is highly contagious

DIAGNOSIS: Clinically, sarcoptic mange (scabies) is characterised initially by intense pruritus and erythema and papulocrustous eruptions, and later by a range of pathological changes in the skin including particularly epidermal hyperplasia. Deep skin scraping and microscopic examination may reveal the mites.

MANAGEMENT: Macrocyclic lactones and isoxazalines may be used to treat and control this parasite.

NEMATODES

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/ TOXOCARA SPP.

Species of veterinary importance include *Toxocara canis* and *Toxocara cati*. Both species are zoonotic, and infection can lead to ocular, visceral and cerebral larva migrans in people. Human toxocariasis due to *T. canis* is widely reported and studied, with fewer reports and investigations for *T. cati*.

HOST RANGE: Definitive hosts for *T. canis* are dogs and wild canids (coyotes, wolves, foxes). Definitive hosts for *T. cati* are cats and wild felids. Many animals can act as paratenic hosts (e.g. rodents, pigs, birds, earthworms).

GEOGRAPHIC RANGE: *T. canis* and *T. cati* have a worldwide distribution, although prevalence rates vary significantly between regions.

LIFE CYCLE: Adult worms live in the small intestine. In the case of *T. canis*, there are four routes of infection: (i) Ingestion of eggs containing third-stage (L3) larvae from the environment, (ii) Ingestion of a paratenic host containing somatic L3 larvae, (iii) Transplacental infection of pups by migrating somatic larvae from the pregnant bitch, and (iv) Transmammary infection of neonatal pups by somatic larvae present in the milk of the lactating bitch. In dogs less than 2 months of age, larvae released from ingested eggs or paratenic host tissues undergo a hepatic-tracheal migration ending up as adult worms in the small intestine. In dogs older than 3 months of age, the majority of larvae arrest in somatic tissues. Somatic larvae reactivate during late gestation in pregnant bitches and migrate to the placenta and mammary glands. The prepatent period following T. canis infection is usually 4-5 weeks. However, following transplacental infection, puppies can shed eggs as soon as 2 weeks after birth. In the case of *T. cati*, the same routes of infection occur as T. canis except that transplacental transmission does not occur. The prepatent period is about 8 weeks, or as soon as 3 weeks after birth for transmammary infections.

DIAGNOSIS: Ascarid-type eggs are detected by microscopy after fecal flotation, or coproantigen can be detected by an ELISA test. The fecal ELISA can detect *Toxocara* infections prior to patency, detect single-sex infections, and distinguish between active infection and eggs being present in feces due to coprophagy. Young puppies and kittens with heavy infections can present with a combination of poor condition, poor growth, pot-bellied appearance, and sometimes vomiting and diarrhea; very occasionally intestinal impaction can occur. Respiratory signs may also be apparent in puppies or kittens in heavily contaminated environments due to migrating larvae.

MANAGEMENT: Puppies and kittens should be treated with pyrantel pamoate at two, four, six and eight weeks of age and then monthly to six months of age using febantel, fenbendazole, pyrantel pamoate. Nursing bitches and queens should be treated at the same time as puppies and kittens. To prevent vertical transmission, pregnant bitches can be treated off-label with fenbendazole or high-dose ivermectin. For dogs and cats over 6 months of age, anthelmintic treatment should be based on the results of fecal examinations. Prevention of hunting and scavenging are important to prevent ingestion of larvae from paratenic hosts.

/ TOXASCARIS LEONINA

HOST RANGE: Definitive hosts are domestic and wild canids and felids. Paratenic hosts include rodents and birds.

GEOGRAPHIC RANGE: Worldwide distribution, but prevalence generally lower than for *Toxocara* species.

LIFE CYCLE: Adult worms live in the small intestine and eggs are shed in the feces. Dogs and cats are infected by ingestion of larvated eggs from the environment or larvae in paratenic host tissues. Development to the adult stage occurs entirely within the small intestinal tract with no somatic migration. The pre-patent period is ~10 weeks following ingestion of eggs or larvae.

DIAGNOSIS: Detection of smooth-shelled eggs following fecal flotation and microscopy, or detection of coproantigen by fecal ELISA. Clinical impacts are similar to *Toxocara*, but infection intensities are generally lower and so clinical disease is less common.

MANAGEMENT: Measures recommended to control *Toxocara* spp. should also control *Toxascaris*. Since somatic migration does not occur, vertical transmission is not a concern.

/ BAYLISASCARIS SPP.

Baylisascaris procyonis is the main species of veterinary importance due to its potential for causing particularly severe clinical disease in young children (cerebral and ocular larva migrans).

HOST RANGE: The natural host and main reservoir of infection for *B. procyonis* is the raccoon, but dogs are also a competent definitive host. Over 100 different species of mammals and birds have been described as paratenic hosts, with rodents considered the most important reservoir host among them.

GEOGRAPHIC RANGE: Follows the range of the raccoon host. It is endemic throughout North and Central America and is present in raccoons in BC, AB, SK, MN, ON, QB, NB and NS, with prevalence rates of over 50% in some regions (BC,QB and ON). It has been introduced into Europe and Asia with raccoons.

LIFE CYCLE: Adult worms (up to 20 cm in length) reside in the small intestine, and eggs are passed in the feces. Definitive hosts are infected by ingestion of larvated eggs from the environment or somatic larvae within a paratenic host. Paratenic hosts can be infected by these same routes.

DIAGNOSIS: Detection of ascarid-type eggs by microscopy following fecal flotation, or detection of coproantigen by fecal ELISA. Eggs are similar to those of *Toxocara* but are slightly smaller, more finely pitted, and darker in colour. Infections with adult worms in definitive hosts are asymptomatic. Migration of L3 in paratenic hosts, including humans, can cause a range of signs varying from mild behavioural changes to severe disability, coma, and death.

MANAGEMENT: Routine fecal examination and treatment of dogs as applied for *Toxocara*. Preventing dogs from hunting, scavenging, and encountering raccoon latrines will greatly reduce risk of exposure. Prevention of human disease is focused on public education of the dangers of contact with raccoons or their feces, particularly for young children who are prone to geophagia.

/ ANCYLOSTOMA SPP.

Species of veterinary importance include *Ancylostoma caninum*, *Ancylostoma braziliense*, and *Ancylostoma tubaeforme*. *A. braziliense* and, to a lesser degree, *A. caninum* are zoonotic parasites causing cutaneous larval migrans in people. *A. caninum* is also rarely reported to cause eosinophilic enteritis in people.

HOST RANGE: Definitive hosts of *A. caninum* are dogs and wild canids. Definitive hosts of *A. tubaeforme* are cats and wild felids. Both canids and felids serve as definitive hosts of *A. braziliense*.

GEOGRAPHIC RANGE: Mainly occur in warmer tropical and subtropical climates, although *A. caninum* and *A. tubaeforme* are endemic in parts of North America including Canada – particularly in the eastern provinces, albeit at a low prevalence. Animals at highest risk in Canada are imported dogs or cats or those returning from travel to warmer regions. In North America, *A. braziliense* occurs in the southeastern and southcentral US coastal states.

LIFE CYCLE: Ancylostoma adults are 1-2 cm in length and attach to the small intestinal mucosa, feeding off blood. Eggs are shed in the feces and develop in the environment, with a first-stage larva hatching out and moulting two times. Infective L3 enter the host by ingestion or by skin penetration. In the latter case, larvae migrate via the bloodstream to the lungs and then to the small intestine via the respiratory tract. The prepatent period is 14-21 days. In the case of *A. caninum*, a proportion of L3 pass from the lungs to skeletal muscle and can remain dormant for many years, reactivating in pregnant bitches to infect puppies through the transmammary route.

DIAGNOSIS: Detection of strongyle-type eggs on fecal flotation or coproantigen by ELISA. Eggs are very similar to *Uncinaria* but smaller in size. *A. caninum* can cause anaemia and bloody diarrhea which is generally seen in animals less than 1 year of age or in young puppies following transmammary transmission; infection can be fatal in severe cases. Lower worm burdens can cause chronic malaise and poor condition. Other *Ancylostoma* species are considered to be milder pathogens. Migrating larvae can cause skin lesions, particularly pedal dermatitis. **MANAGEMENT:** Measures recommended to screen and control *Toxocara* species should also control *Ancylostoma* infection. Deworming of dogs and cats following importation or travel to an endemic region is recommended.

/ UNCINARIA STENOCEPHALA

HOST RANGE: Domestic and wild canids and felids.

GEOGRAPHIC RANGE: *U. stenocephala* is often called the "northern hookworm" as it is endemic in temperate and cooler regions. It is present in all Canadian provinces, albeit at a low prevalence.

LIFE CYCLE: Adults (up to 1 cm in length) attach to the small intestinal mucosa and feed on blood. Eggs are shed in the feces and develop in the environment, with a first-stage larva hatching out and moulting two times. The definitive host is generally infected via ingestion of L3. Skin penetration by infective L3 can cause dermatitis but doesn't generally result in a patent infection.

DIAGNOSIS: Detection of strongyle-type eggs on fecal flotation or coproantigen by ELISA. Eggs are similar to *Ancylostoma* but larger in size. Adult worms are of low pathogenicity but migrating larvae can cause pedal dermatitis and, more rarely, a more generalised dermatitis.

MANAGEMENT: Measures recommended to screen and control *Toxocara* species should also control *Uncinaria* infection.

/ TRICHURIS VULPIS

HOST RANGE: Domestic and wild canids; coyotes are considered to be an important reservoir.

GEOGRAPHIC RANGE: Worldwide.

LIFE CYCLE: Adult worms (up to 8 cm in length) reside in the cecum and colon with their anterior end embedded in the mucosa. Eggs are shed in the feces and develop to first-stage larvae within the egg.

After ingestion by the dog, larvae hatch out and develop in the distal small intestinal and large intestinal mucosal glands. The prepatent period is around 3 months. **DIAGNOSIS:** Detection of characteristic eggs in fecal flotation (small "lemon-shaped" eggs with bipolar mucus plugs); the long prepatent period and low egg output of adult worms can lead to false negatives. A fecal ELISA test for coproantigen can detect infection prior to patency. Heavily infected dogs have been reported to have colitis leading to mucus and blood in stools. Reduced growth has been reported in puppies.

MANAGEMENT: Measures recommended to screen and control *Toxocara* species should also control *Trichuris* infection.

HEARTWORM

(Dirofilaria immitis)

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HOST RANGE: Dogs, cats, ferrets and wild canids serve as definitive hosts. Once established in wild canids, the parasite is essentially endemic in that area (e.g. parts of Ontario).

GEOGRAPHIC RANGE: The parasite is focally distributed across Canada; dependent on the presence of definitive hosts and the duration of activity of mosquito vectors. Approximately one half of the mosquitoes found in North America are possible vectors. However, to date, significant vector roles have only been demonstrated for a few. In the most recent review of heartworm cases diagnosed in dogs in Canada (2013-2014), 79.4% were diagnosed in Ontario, 14.6% in Quebec, 5.4% in Manitoba, 0.4% in New Brunswick and 0.2% in Nova Scotia. Usually there are also a few cases in the greater Vancouver area. Cases diagnosed elsewhere (e.g. Alberta) are travel associated. Furthermore, across the country, at least one third of all cases appear to be travel associated. Within the USA, heartworm has been diagnosed in all States, however, the risk is greatest in the eastern half of the USA, especially the southeastern USA, where practices may diagnose more than 100 canine cases a year.

LIFE CYCLE: Adult parasites reside within the arterial blood vessels of the lungs. In low burdens, the caudal lobar artery may be the only place that parasites are found. When moderate/high burdens are present, the parasites will also be found in the pulmonary artery and the right side of the heart. When fully mature, adult female and male parasites mate. Subsequently, microfilariae (early first-stage larvae) are released by female parasites into the bloodstream. If ingested by mosquitoes, the microfilariae mature to third-stage larvae over a period of 1-4 weeks, depending on temperature. Only when third-stage larvae are present can parasites be transferred to a definitive host during a blood meal; larvae enter the animal via the mosquito's bite wound on the skin. Within a few days the parasites moult to fourthstage larvae; after 2-3 months they moult to immature adult parasites. Throughout this time they reside within connective tissue. After the final moult to immature adults, the parasites migrate to the pulmonary arteries via the venous circulation. Once at this location, the parasites mature to adults then release microfilariae and antigen in to the bloodstream. Typically, this begins 6-7 months following infection. In dogs, adult parasites live 5-7 years. In cats, the life span is typically 2-3 years.

On the basis of 30 years of climate data from southern Ontario, the heartworm transmission season conservatively lasts from the first week of June to the second week in October (i.e. 4.5 months). These dates are used across Canada where transmission occurs but are likely overestimates for many places. At the moment, there is no evidence that the transmission season has lengthened. However, climate change will very likely result in lengthening of the transmission season and an increase in the geographic area of endemic transmission.

DIAGNOSIS: In Canada, approximately 88% of heartworm infections in dogs are subclinical, due to low parasite burdens. Clinical signs include exercise intolerance, coughing, dyspnea, loss of condition, hemoptysis, ascites and hydrothorax. Heartworm antigen tests are the primary diagnostic and screening tests for heartworm. All detect a uterine antigen produced by reproductively active female parasites. Thus, since the pre-patent period (i.e. the time from infection to presence in blood) for antigen and microfilariae is 6-7 months, antigen tests for the purposes of detecting heartworm antigens should never be performed on animals under 6 months of age. Whenever a positive test result is obtained, the test should always be repeated using a different blood sample, ideally with a different antigen test, to ensure the test was carried out correctly.

In general, heartworm antigen tests are extremely good tests with very high levels of sensitivity and specificity. However, in low prevalence areas (i.e. almost all of Canada) one has to be careful to interpret the result correctly. For example, the most recent data on heartworm in Canada (Herrin et al 2017) indicated that the nationwide proportion of dogs testing positive for heartworm using 4Dx Plus Tests (Idexx Laboratories) was 0.42% (485/115,636 dogs tested); in no province was the proportion of positive dogs greater than 0.5%. How does one interpret a positive or a negative result when the prevalence of infection is this low?

4 : SUPPLEMENTAL INFORMATION » PART A

The following table should be constructed which makes the following assumptions:

- (a) Prevalence of heartworm in dog population = 0.42%
- (b) Sensitivity of 4Dx Plus Test = 99.0% (as reported by Idexx)

(c) Specificity of 4Dx Plus Test = 99.3% (as reported by Idexx)

	INFECTED WITH HEARTWORM	NOT INFECTED WITH HEARTWORM	TOTAL
Test positive	415.8 ^b	697	1112.8
Test negative	4.2	98,883°	98,887.2
Dog population	420ª	99,580	100,000

° = 0.42% of 100,000; ° = 99.0% of 420; ° = 99.3% of 99,580

Thus, *if a negative result is obtained*, the negative predictive value is 98,883/98,887.2 x 100 = 99.99%. In other words, one is 99.99% sure the dog is not infected with heartworm.

If a positive result is obtained, the positive predictive value is 415.8/1112.8 x 100 = 37.4%. Thus, there is only a 37.4% chance the dog is genuinely infected with heartworm. As such, the following additional diagnostic information also needs to be considered to determine if the dog is likely genuinely infected with heartworm:

(a) Does the dog have clinical signs consistent with heartworm?

(b) Are *D. immitis* microfilariae present in the blood sample when examined with a concentration method (e.g. Knott's test)?

(c) Has the dog traveled to an area(s) of higher heartworm risk since last tested with an antigen test?

(d) Has the dog been on a heartworm preventive since last tested? If so, how good was the compliance?

In dogs with clinical signs consistent with heartworm, the following are additional useful diagnostic tests:

(a) Thoracic radiographs. Changes consistent with heartworm are (i) enlargement of pulmonary blood vessels, (ii) tortuosity of pulmonary vasculature, and (iii) right-sided heart enlargement. Changes (i) and (ii) are highly specific for heartworm; change (iii) is not specific. Generally, none of these changes occur in dogs with subclinical heartworm infections. Thus, thoracic radiographs are typically only useful diagnostic tests when dogs have clinical signs consistent with heartworm.

(b) Cardiac ultrasound. The presence of double echoic lines ("equals signs") within the pulmonary arteries or right ventricle/ atrium is highly specific for heartworm. However, visualisation of the parasites is typically only possible in dogs with significant parasite burdens. Thus, in dogs with subclinical heartworm infections, cardiac ultrasound is generally not a useful diagnostic test.

ROUTINE TESTING FOR HEARTWORM: The American Heartworm Society recommends annual testing for heartworm. Likewise, the licensed use of heartworm preventives in Canada requires annual testing. However, the problem with annual testing in low risk areas is that little is gained by carrying out the test. For example, in the above example, when the prevalence of infection is 0.42%, there is a 99.58% chance a dog is not infected before a test is carried out. If one then obtains a negative antigen test result, one is now 99.99% sure the dog is not infected. Likewise, if a positive antigen test result is obtained, there is a low likelihood the dog is genuinely infected; multiple additional diagnostic tests are required to determine whether or not this is the

case. One alternative approach to annual testing, once baseline data have been obtained, is to carry out a risk-based assessment on all dogs every year, e.g. (i) has the dog traveled to a higher risk area since last year? (ii) was the dog on heartworm preventives last year? (iii) what was compliance with use of heartworm preventives like over the past year? If any of these issues are a concern, the dog should be tested. This risk-based approach focuses on dogs most likely to be infected with heartworm. For example, heartworm surveys in Canada have consistently shown that 85-90% of dogs diagnosed with heartworm were not on heartworm prevention in the year prior to testing; risk-based assessment would identify all these dogs. Testing less frequently than once a year is off-label testing and requires informed consent from owners.

MANAGEMENT: Dogs diagnosed with heartworm, whether clinical or subclinical, should be treated with melarsomine using the protocol described by the American Heartworm Society. This involves pre-treating with doxycycline for 28 days, then administering three doses of melarsomine. In dogs where immature parasites may be present, it is also recommended that animals should be pretreated for 60 days with a heartworm preventive before beginning melarsomine treatment. Pre-treatment with doxycycline, treatment with prednisone at the time of melarsomine treatment, and strict cage rest, all reduce the risk of post-adulticide complications. Sedation of dogs for the melarsomine injections reduces the risk of pain at the intramuscular injection sites.

The American Heartworm Society advises against the use of the slow-kill protocol (i.e. monthly treatment with a heartworm preventive) for treating heartworm infections in dogs. While infections have been eliminated in some dogs after 6 monthly treatments, in other dogs monthly treatment for 5 years has failed to eliminate the infection! In addition, such treatment likely selects for drug-resistant parasites. Furthermore, dogs should remain on strict cage rest throughout this treatment protocol.

DRUG(S)	PRODUCT	MANUFACTURER	ROUTE OF ADMINISTRATION	FREQUENCY OF ADMINISTRATION
Diethylcarbamazine	Decacide	P.V.L.	Oral	Daily
Ivermectin + Pyrantel Pamoate	Heartgard-30 Plus	Merial	Oral	Monthly
Milbemycin	Interceptor	Elanco (Novartis)	Oral	Monthly
Milbemycin + Lufenuron	Sentinel	Elanco (Novartis)	Oral	Monthly
Milbemycin + Spinosad	Trifexis	Elanco	Oral	Monthly
Moxidectin	ProHeart 6	Zoetis	Injection	6 months
Moxidectin + Imidacloprid	Advantage Multi	Bayer	Topical	Monthly
Selamectin	Revolution	Zoetis	Topical	Monthly
Afoxolaner + Milbemycin	Nexgard Spectra	Boehringer Ingelheim	Oral	Monthly
Milbemycin + Praziquantel	Interceptor plus	Elanco	Oral	Monthly

For heartworm prevention in dogs, the following products are currently available in Canada:

Heartworm preventives approved for monthly use have one month's reachback activity. Thus, treatment should begin within one month following the beginning of the heartworm transmission season (i.e. July 1) and finish a maximum of 1 month following the end of the transmission season (i.e. November 1); licensed use of Trifexis requires monthly treatment for 3 months following the end of the transmission season. Llicensed use of Nexgard Spectra and Interceptor Plus requires monthly treatment for 6 months following the end of the transmission season.

DRUG RESISTANCE: In the last few years, heartworm infections have been described in the Mississippi River Valley area of the USA that are resistant to macrocyclic lactones (i.e. ivermectin, milbemycin, moxidectin and selamectin). Such infections have been identified by observing (i) development of heartworm infections in dogs with compliant use of heartworm preventives by owners, or (ii) dogs diagnosed with heartworm where, following elimination of adult parasites using melarsomine, macrocyclic lactones failed to eliminate microfilariae. A few dogs in the latter category have been identified in southern Ontario (Bourguinat et al 2011); all were dogs that were imported in to Canada from the southeastern USA. Fortunately, to date, there is no evidence that such infections have established in Canada.

KEY REFERENCES:

American Heartworm Society: www.heartwormsociety.org

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Herrin, B.H., Peregrine, A.S., Goring, J., Beall, M.J., Little, S.E. (2017) Canine infection with *Borrelia burgdorferi*, *Dirofilaria immitis*, *Anaplasma* spp. and *Ehrlichia* spp. in Canada, 2013-2014. *Parasites and Vectors* 10:244. DOI 10.1186/s13071-017-2184-7

META-STRONGYLOID LUNGWORMS

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/ AELUROSTRONGYLUS ABSTRUSUS » CAT LUNGWORM

HOST RANGE: Cats and wild felids serve as definitive hosts. Numerous species of terrestrial gastropods (slugs, land snails) serve as intermediate hosts. Various amphibians, birds, reptiles and rodents serve as paratenic hosts.

GEOGRAPHIC RANGE: Worldwide – reported from every continent except Antarctica. In Canada it has been documented in Ontario but it is known to also occur in BC, NB, NL and NS.

LIFE CYCLE: Adult worms dwell in the terminal bronchioles and alveolar ducts of infected cats. Female worms lay undifferentiated eggs which develop and hatch releasing first-stage larvae (L1). The L1 are coughed up and swallowed to be passed in the feces. Terrestrial gastropods feeding on the feces ingest the L1, which undergo 2 moults to reach the infective third-stage (L3) in about 3-4 weeks. Cats become infected by ingesting L3 contained in the tissues of gastropods or paratenic hosts. The prepatent period is 5-6 weeks.

DIAGNOSIS: Detection of L1 in the feces, sputum, or transtracheal wash and bronchoalveolar lavage samples. Detection of larvae in feces is best achieved through use of the Baermann technique. Though much less sensitive, larvae may be detected in some cats by direct smear or centrifugal fecal flotation. L1 are identified based on size (360-400 microns in length) and morphology (cephalic button, kinked tail with a dorsal spine). In general, the fecal larval shedding pattern of metastrongyloids tends to be sporadic resulting in an increased likelihood of obtaining false negative fecal exam results. Examination of 3 fecal samples (collected on 3 consecutive days or within a 7-10 day period) will increase

detection sensitivity. Infected cats often show no signs, or they may present with dyspnea, coughing, and anorexia.

MANAGEMENT: Infected cats can be treated with emodepside, eprinomectin, fenbendazole, moxidectin, or selamectin. Preventing cats from hunting by denying outdoor access greatly reduces exposure.

/ ANGIOSTRONGYLUS VASORUM » FRENCH HEARTWORM

HOST RANGE: Dogs and various wild canids serve as definitive hosts. Red foxes are the natural definitive host. Numerous species of terrestrial gastropods (slugs and land snails) and frogs can serve as intermediate hosts. Frogs and chickens can serve as paratenic hosts.

GEOGRAPHIC RANGE: Endemic foci occur in Africa, Europe, North America and South America. In North America, infection occurs throughout Newfoundland. Recently, infection was reported in red fox in West Virginia in the USA. The danger of spread within Canada (particularly to the Maritimes) is a concern.

LIFE CYCLE: Adult worms reside in the pulmonary artery of dogs and foxes. Adult female worms lay undifferentiated eggs. The eggs develop and hatch in pulmonary capillaries, releasing L1 which break out into the alveolar air space. They are coughed up and swallowed to pass in the feces. Canids acquire infection by ingesting L3 contained in the tissues of gastropods, frogs or chickens (and presumably other birds). The prepatent period is 28-108 days (but usually occurs in 7-8 weeks).

DIAGNOSIS: As above for *A. abstrusus* in cats. The L1 are identified based on size (310-399 microns in length) and morphology (cephalic button, kinked tail with a dorsal spine). There are qualitative differences in the tail morphology sufficient to allow differentiation between the L1 of *A. vasorum* and those of *A. abstrusus*, which may be recovered from dog fecal samples due to coprophagy. Presently available only in Europe, commercial kits for use in the detection of circulating adult *A. vasorum* antigen can be used in the diagnosis of infection. Clinical signs are similar to those caused by *Dirofilaria immitis*, including coughing, dyspnea, and exercise intolerance; neurological signs and bleeding disorders may also occur.

MANAGEMENT: Fenbendazole, milbemycin oxime and moxidectin have been used to treat dogs infected with *A. vasorum*; efficacies of 85% were reported for all 3 anthelmintics. However, post-treatment complications (severe dyspnea, ascites) can occur. Milbemycin oxime and moxidectin, available for monthly prevention of *D. immitis* infection, also can be used as monthly preventive treatments for *A. vasorum*. When used as a preventive, an efficacy of 100% was reported for moxidectin. When used at dosages of 0.6 – 1.2 mg/kg, efficacies of 95-99% were reported for milbemycin oxime. Due to issues of efficacy, potential treatment complications and the possibility of permanent cardiopulmonary damage, prophylactic treatment is the preferred option. When feasible, preventing dogs from roaming or hunting will reduce the risk of exposure.

/ CRENOSOMA VULPIS » FOX LUNGWORM

HOST RANGE: Dogs, wild canids, bears, badgers and martens. Red fox is the natural definitive host. Numerous terrestrial gastropods (slugs, land snails) serve as intermediate hosts.

GEOGRAPHIC RANGE: Asia, Europe and North America. In North America, it is restricted to the northeastern quarter of the continent including the provinces of NB, NL, NS, PEI, QC and ON.

LIFE CYCLE: Adult worms reside in the bronchioles, bronchi and rarely the trachea of infected canids. Female worms lay larvated eggs which hatch shortly after deposit. The L1 are coughed up and swallowed to pass in the feces. Dogs acquire infection by ingestion of gastropods. The prepatent period is about 3 weeks.

DIAGNOSIS: As above for *A. abstrusus*, for the most part. The L1 are identified based on size (264-340 microns in length) and morphology (cephalic button, tail comes to a simple point lacking a kink or spine but there is a slight deflection). Many infected dogs appear to shed only a low level of larvae, increasing the risk of false negative results. Examination of 3 fecal samples greatly increases detection sensitivity. Additionally, due to the low shedding levels, detection of *C. vulpis* L1 by direct smear is very rare and even zinc sulfate centrifugal fecal flotation detects only about 10% of infections. The main clinical sign in dogs is a persistent cough.

MANAGEMENT: Febantel, fenbendazole, milbemycin oxime and moxidectin are available for treatment of dogs infected with *C. vulpis*. Complete clinical cure occurs in most dogs within 7-10 days of deworming. Since infections are nonfatal and easily treated, it is doubtful that a great deal of expenditure in time, effort and resources are appropriate for the prevention of infection by this parasite.

/ FILAROIDES HIRTHI

HOST RANGE: Infections have been reported in laboratory research colony beagles and rarely in client-owned pet dogs.

GEOGRAPHIC RANGE: Asia, Australia, Europe, North America (USA, Canada). In Canada, it has been reported in ON.

LIFE CYCLE: The life cycle is direct and the L1 is the infective stage. Adult worms occur in bronchioles and are embedded in lung parenchyma. Female worms lay larvated eggs. L1 larvae and unhatched eggs are coughed up and either pass out in saliva/sputum or are swallowed and pass out in the feces. Larvae passed in the feces lack vigour and are short-lived. Dogs acquire infection by ingestion of L1 in very fresh feces or in sputum, saliva or vomitus. The prepatent period is about 35 days.

DIAGNOSIS: Diagnosis is challenging. Baermann examination has low detection sensitivity due to the lack of vigour of the L1. L1 may be detected by zinc sulfate centrifugal flotation, however, false negatives are common. Fecal sedimentation may detect L1 but the technique is time consuming and the larvae quickly degenerate and become unrecognizable. L1 are best recovered from examination of saliva, sputum, or transtracheal wash or bronchoalveolar lavage samples. The larvae are 240-290 microns in length with a bluntly rounded head and a tail that has a kink but lacks a spine. The larvae are very similar to those of *Oslerus osleri. F. hirthi* infections are usually asymptomatic.

MANAGEMENT: Treatment involves ivermectin or prolonged (14-21 days) administration of fenbendazole. Most infections reported in research beagles have been subclinical. Infections reported in pet dogs have involved severe signs of respiratory disease and are usually associated with an

underlying immunosuppression (corticosteroid therapy, demodectic mange) or serious disease condition (distemper infection, neoplasia, and severe trauma).

/ OSLERUS OSLERI

HOST RANGE: Dogs and wild canids serve as definitive hosts.

GEOGRAPHIC RANGE: Worldwide – reported from all continents except Antarctica. In Canada, infection has been reported in AB, BC, MB, NS, ON, QC and SK. It is also known to occur in NB and PEI.

LIFE CYCLE: Adult worms occur in wart-like nodules attached to the epithelial surface of the lumen in the trachea and bronchi, clustered at the tracheal bifurcation. Larvated eggs are deposited into the lumen by female worms. Canids acquire infection by the ingestion of L1. Dogs acquire infection primarily as pups from exposure to L1 in saliva from dams during cleaning/grooming. Wild canids become exposed as pups from regurgitative feeding from dams. The prepatent period is 70-126 days.

DIAGNOSIS: As above for *F. hirthi.* The L1 recovered from mucus are 232-266 microns in length and those recovered from feces are 326-378 microns in length. The morphology is very similar to that of *F. hirthi.* The nodules are easily detected at the bifurcation of the trachea through bronchoscopy. Infected dogs present with a dry cough associated with exercise or cold air.

MANAGEMENT: Extra-label fenbendazole and ivermectin have been used to treat infected dogs.

Diagnosis of lungworm infection in dogs or cats in Canada On a worldwide basis, dogs are susceptible to infection with 7 helminth parasites (6 nematodes, 1 trematode) of the respiratory system. Canada is the only country in the world where endemic infection in dogs has been reported for all 7 of these lungworms. The nematodes include 2 capillarids (*Eucoleus aerophilus, Eucoleus boehmi*) and 4 metastrongyloids (*Angiostrongylus vasorum, Crenosoma vulpis, Filaroides hirthi, Oslerus olseri*). The trematode is *Paragonimus kellicotti*. Of these "lungworms", the most that might be endemic (at the present time) in any one region in Canada is 6 (ie all but *P. kellicotti* in Atlantic Canada; all but *A. vasorum* in Ontario). A thorough diagnostic evaluation in a case where "lungworm" infection was suspected in a dog would be to perform a direct smear (may detect all of the above but has overall poor detection sensitivity), zinc sulfate centrifugal flotation (eggs of E. aerophilus, E. boehmi; larvae of F. hirthi, O. osleri but has poor detection sensitivity for nematode larvae), Baermann examination (larvae of A. vasorum, C. vulpis) and fecal sedimentation (operculate eggs of P. kellicotti). Additionally, examination of sputum or a transtracheal wash sample may be useful to detect larvae of F. hirthi or O. osleri. Due to the sporadic fecal larval shedding patterns typical of metastrongyloid infection, multiple fecal examinations (3 examinations conducted on 3-consecutive-day samples or 3 samples collected over a 7-10 day period) greatly increases detection sensitivity of the Baermann examination.

In Canada, cats are susceptible to infection with 1 capillarid (*E. aerophilus*), 1 metastrongyloid (*Aelurostrongylus abstrusus*) and the lungfluke (*P. kellicotti*). In cases of suspected "lungworm" infection, the direct smear, Baermann examination, zinc sulfate centrifugal flotation and fecal sedimentation should be performed.

CESTODES AND TREMATODES

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/ CESTODES

Taenia, Echinococcus, Dipylidium, Diphyllobothrium

/ TAENIA SPP.

Species of veterinary importance include *Taenia pisiformis*, *T. krabbei*, *T. hydatigena*, and *T. taeniaeformis*; these species are not zoonotic.

HOST RANGE: Dogs and cats serve as definitive hosts, with a wide range of wildlife intermediate hosts.

GEOGRAPHIC RANGE: Widespread, wherever dogs and cats have access to wildlife.

LIFE CYCLE: Dogs and cats harbour adult cestodes in their small intestine and pass segments and eggs in feces. Wildlife intermediate hosts are infected by ingestion of eggs in environment. Dogs and cats are infected by consumption of larval stage (metacestode, usually a cysticercus) in the tissues of intermediate hosts.

DIAGNOSIS: Segments can be observed in feces by owners. Taeniid-type eggs (indistinguishable from *Echinococcus* spp.) can be detected on microscopy following fecal flotation or sedimentation, but these techniques have low sensitivity. Infected dogs and cats generally show no clinical signs.

MANAGEMENT: Prevent access of pets to wildlife intermediate hosts and don't feed raw offal/meat. Routine deworming with praziquantel or epsiprantel is recommended for high-risk animals. Reactive deworming is indicated if taeniid-type eggs are detected in feces, especially since these are indistinguishable from *Echinococcus* spp. Note that only some praziquantel products are specifically labeled for treatment of *Echinococcus* spp.

/ ECHINOCOCCUS SPP.

Species of importance in Canada include *E. canadensis* (*E. granulosus* G8 and G10) and *E. multilocularis*. Both are zoonotic.

HOST RANGE: Dogs (and cats for *E. multilocularis*) serve as definitive hosts. Wildlife intermediate hosts for *E. canadensis* are cervids (moose, elk, caribou, deer). Wildlife intermediate hosts for *E. multilocularis* are rodents (lemmings, voles, deer mice), and dogs can serve as aberrant intermediate hosts. People can serve as aberrant intermediate hosts for both species.

GEOGRAPHIC RANGE: *E. canadensis* is present throughout Canada where suitable wildlife hosts (wolves, coyotes, cervids) exist; it is not thought to be present in the Atlantic provinces and Island of Newfoundland. *E. multilocularis* is present in northwestern Canada, especially the prairie provinces, and appears to be expanding its range into Ontario.

LIFE CYCLE: Dogs (and, rarely, cats for *E. multilocularis*) harbour adult cestodes in their small intestine and pass eggs in feces. Wildlife intermediate hosts are infected by ingestion of eggs in environment. Dogs and cats are infected by consumption of larval stage (metacestode, a cystic hydatid for *E. canadensis* and alveolar hydatid for *E. multilocularis*) in the tissues of intermediate hosts. Rarely, dogs may also develop alveolar hydatid cysts (alveolar echinococcosis).

DIAGNOSIS: Segments are very small and will not be observed in feces by owners. Taeniid-type eggs (indistinguishable from *Taenia* spp.) can be detected on microscopy following fecal flotation or sedimentation, but these techniques have low sensitivity. Infected dogs and cats generally show no clinical signs as definitive hosts. Dogs with alveolar echinococcosis may have severe clinical disease and lesions can be detected on medical imaging.

MANAGEMENT: Prevent access of pets to wildlife intermediate hosts and don't feed raw offal. Routine deworming with praziquantel is recommended for high-risk animals in endemic regions (note: only some praziquantel products are specifically labeled for treatment of *Echinococcus* spp.). Reactive deworming is indicated if taeniid-type eggs are detected in feces. Alveolar echinococcosis in dogs is best managed with complete surgical resection, if possible, and/or life-long albendazole treatment.

/ DIPYLIDIUM CANINUM

There is only one species, and it is considered zoonotic, but not directly from dogs or cats.

HOST RANGE: Dogs and cats serve as definitive hosts, with fleas (*Ctenocephalides* spp.) and, less commonly, dog chewing lice (*Trichodectes canis*), serving as intermediate hosts.

GEOGRAPHIC RANGE: Wherever dogs and cats have fleas (southern BC and MB, ON, QC, and the Atlantic provinces).

LIFE CYCLE: Dogs and cats harbour adult cestodes in their small intestine and pass segments and egg packages in feces. Flea larvae are infected by ingestion of eggs in environment. Dogs, cats, and people (usually children) are infected by consumption of adult fleas (or chewing lice) containing the larval cestode (a cysticercoid).

DIAGNOSIS: Segments can be observed in feces by owners. Characteristic egg packages can be detected on microscopy following fecal flotation or sedimentation, but these techniques have low sensitivity. Infected dogs and cats generally show no clinical signs.

MANAGEMENT: Flea control is key to prevention and management of *Dipylidium caninum*. Routine deworming with praziquantel or epsiprantel is recommended for high-risk animals (where access to fleas cannot be controlled).

/ DIPHYLLOBOTHRIUM SPP.

There are multiple species, the most common in Canada in dogs being *D. latum*, *D. dendriticum*, and *D. ursi*. *Spirometra* is a related species that may rarely infect dogs and cats. These are considered zoonotic, but not directly from dogs.

HOST RANGE: Dogs and other fish-eating vertebrates serve as definitive hosts, with aquatic wildlife serving as intermediate and paratenic hosts.

GEOGRAPHIC RANGE IN CANADA: Wherever dogs and cats have access to locally harvested fresh fish (whitefish, salmon,

trout, char, grayling, burbot, perch, walleye, pike, sticklebacks, etc).

LIFE CYCLE: Dogs and cats harbour adult cestodes in their small intestine and pass segments and eggs in feces. Aquatic crustaceans (first intermediate hosts) are infected by ingestion of hatched eggs in environment. Dogs, cats, and people are infected by consumption of the larval stage (plerocercoid) in the tissues of fish serving as second intermediate or paratenic hosts.

DIAGNOSIS: Segments and long ribbons can be observed in feces by owners. Characteristic operculate eggs can be detected on microscopy following fecal flotation or sedimentation, but these techniques have low sensitivity. Infected dogs and cats generally show no clinical signs.

MANAGEMENT: Treatment involves high-dose, off-label praziquantel. Prevention involves eliminating access to raw fish (owners should feed only cooked or previously solidly frozen fish) and preventing dogs from fecally contaminating water.

/ TREMATODES: ALARIA, METORCHIS, NANOPHYETUS

Species of veterinary importance include *Alaria* spp., *Metorchis conjunctus*, and *Nanophyetus salmincola*. These species are considered zoonotic, but not directly from dogs.

HOST RANGE: Dogs and cats serve as definitive hosts, with aquatic wildlife serving as intermediate and paratenic hosts.

GEOGRAPHIC RANGE: Wherever dogs and cats have access to aquatic wildlife.

LIFE CYCLE: Dogs and cats harbour adult flukes in their small intestine (*Alaria, Nanophyetus*) or gall bladder (*Metorchis*, dogs only) and pass eggs in feces. Aquatic snails serve as first intermediate hosts for all trematodes. Second intermediate host species are frogs for *Alaria*, salmonid fish for *Nanophyetus*, and sucker fish for *Metorchis*. Dogs, cats, and people are infected by consumption of larval stages (metacercariae) in the tissues of second intermediate hosts, or a small mammal paratenic host (for *Alaria*). Transmammary transmission may occur in cats with *Alaria*. **DIAGNOSIS:** Characteristic, operculate trematode eggs can be detected on microscopy following fecal flotation or, preferably, sedimentation, but these techniques have low sensitivity. Eggs of *Alaria* float more readily than those of other flukes and are large and yellow. Eggs of *Metorchis* have a prominent lip on the operculum. Infected dogs and cats generally show no clinical signs, although liver abscesses have been reported for *Metorchis*. A rare but potentially fatal rickettsial disease called salmon poisoning is associated with *Nanophyetus* in coastal British Columbia

MANAGEMENT: Treatment involves off-label praziquantel. Prevention involves eliminating access to raw frogs or fish (owners should feed only cooked or previously solidly frozen fish) and preventing dogs from fecally contaminating water. Treatment for salmon poisoning requires antirickettsial drugs such as doxycycline.

SUPPLEMENTAL INFORMATION: **PART B**

04

MANAGING IXODES SCAPULARIS AND LYME DISEASE IN A RISK AREA

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Tick encounters have become increasingly common in eastern Canada due to the northerly expansion of Ixodes scapularis (also known as the blacklegged tick, or deer tick). A publication modeling range expansion for *I. scapularis* predicted a 46 km/year expansion between 2010-2020 (Leighton et al, 2012) and a recent study (Clow et al, 2017) finds that this projection is consistent with tick sampling in the field. *Ixodes scapularis* is now the most common tick submitted through passive surveillance in Ontario (Nelder et al, 2012) and is the vector for Borrelia burgdorferi, the causative agent of Lyme disease. Veterinarians should feel comfortable identifying and distinguishing between the main species of ticks found on companion animals in Canada (Ixodes scapularis, Dermacentor variabilis, Ixodes cookei, Amblyomma americanum, Rhipicephalus sanguineus). It is recommended that veterinary teams ensure clients are comfortable knowing the basics about ticks (relative size, appearance in the engorged and unengorged states, seasonality, habitat, etc).

Ixodes scapularis is a three-host tick, feeding once at each life stage (larva, nymph, adult), and lives for 2-4 years in order to complete this cycle. These ticks prefer a highmoisture environment such as leaf litter, preferably under hardwood forest canopy. Adult female ticks drop off their host after a blood meal and lay eggs in the late spring of the year. These eggs hatch in mid- to late-summer (July or August) as larval ticks. Larval ticks are not transovarially infected (i.e. they do not carry *Borrelia burgdorferi*) and instead may pick up *B. burgdorferi* during a blood meal. After feeding successfully, the larval tick falls off the host and molts into a nymph, transstadially carrying *B. burgdorferi*. This tick will feed in late spring or early summer (May-July) the following year. Nymphs prefer to feed on small mammal hosts or birds, but will bite humans and sometimes dogs. After feeding as a nymph, the tick will fall off the host and molt into an adult, which will feed between the late fall (typically September-November) and early spring (typically March-May). Because the adults have fed twice (once as a larva, once as a nymph), they generally have twice as great a chance of carrying *B. burgdorferi*. For example, in one study in 2009-2011 in the Thousand Islands, 16% of the nymphs and 31% of the adults carried *B. burgdorferi* (Werden et al, 2014).

It is important to note that adult *I. scapularis* will be active during the winter months on any day the temperature is >4°C. Since 2010 in Ontario, only February 2015 failed to see ambient temperatures reach 4°C and in Quebec, only January and February 2015 failed to reach this threshold. In Nova Scotia, all months since 2010 have seen at least 1 day >4°C. Therefore, risk of exposure to *I. scapularis* is possible in all 12 months of the year in areas with established populations.

Serological screening tests are available to detect exposure to *Borrelia burgdorferi*. Patients living in, or traveling to areas endemic for *B. burgdorferi*, or those with history of tick exposure should be screened for exposure following the recommendations in the ACVIM Consensus Update on Canine and Feline Lyme Borreliosis (Littman et al, 2006, 2018). Antibodies to *B. burgdorferi* typically take weeks to generate and testing is recommended 4-6 weeks after tick exposure. Treatment of positive dogs should be handled in accordance with the ACVIM Consensus Statement (Littman et al, 2006, 2018).

Lyme disease is preventable and focus in the veterinary practice should be on prevention rather than treatment of exposed patients. CPEP recommends the following three-pronged approach to prevention: 1. Client education and regular tick checks, 2. Using a preventive with label claim against *l. scapularis* (potentially year-round if temperatures >4°C) and 3. Vaccination. These steps should be instituted in order, based on escalating risk to the patient. The primary goal is to reduce (to as close to zero as possible) the number of ticks the animal is exposed to by performing tick checks

and using a preventive. In areas where tick burdens are high, vaccination should be considered to protect against those ticks that evade tick checks and preventives. Dogs living in, or regularly traveling to, endemic areas should have tick checks performed daily, receive a preventive and receive a Lyme vaccine.

There is little evidence to suggest that Lyme disease affects cats clinically. Cats will, however, seroconvert and can test positive on serological tests after exposure to *Borrelia burgdorferi*. There are laboratory studies that have demonstrated lameness and possible neurological signs in cats after exposure to *B. burgdorferi*, but naturally occurring clinical cases have not been reliably reported.

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EMERGING ISSUES WITH ECHINOCOCCUS SPP. CESTODES IN CANADA

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www.cliniciansbrief.com/article/echinococcus-spptapeworms-dogs-cats

Zoonotic *Echinococcus* spp. tapeworms are emerging as a cause of canine and human disease in Canada. Echinococcus canadensis is present across almost all of Canada, except the High Arctic and in the Atlantic provinces, where wolves, a key definitive host for the parasite, have historically been eradicated. However, E. canadensis has recently been detected in coyotes in southern QC and Maine, suggesting that the Eastern coyote may now be enabling the local life cycle of *E. canadensis*. Hunting dogs and free roaming dogs in remote and rural areas are considered high risk for this parasite, which they contract by consuming hydatid cysts in the lungs or liver of cervids. People can become infected with this parasite by inadvertently consuming food or water contaminated with eggs of this parasite shed in dog, wolf, or coyote feces. Human cases of cystic echinococcosis, or CE, are reported regularly across most of Canada, and there are hot spots of transmission in the northern territories and some regions of SK and MB.

A close relative, *Echinococcus multilocularis*, once thought to be restricted to Arctic and prairie regions of Canada, now appears to be established throughout most of western Canada, including boreal regions of BC and the NT, and southern Ontario. Increasingly, cases of alveolar echinococcosis (AE) caused by *E. multilocularis* are being detected in dogs in BC, AB, SK, MB, and ON. As well, human cases of AE that may be locally acquired are being detected in AB and SK; previously, only one locally acquired human case of AE had been reported in Canada, although foreign acquired cases are detected occasionally. At moment, it seems that recently introduced European-type strains of *E. multilocularis* (rather than native strains long established in prairie Canada) are involved in both canine and human AE cases in Canada. These strains may have been introduced through importation of dogs, which highlights the need to test and treat dogs being imported into Canada for a wide range of infectious diseases and parasites, in addition to current regulatory requirements for rabies vaccination.

It is unusual for dogs to develop AE (although this condition has been recognized in dogs in Europe since the 1990s). Dogs traditionally play the role of definitive host, where adult cestodes inhabit the intestine and cause few, if any, problems for the dog (but do pose a risk for human health). AE requires aggressive surgical and medical management in dogs and should be a differential diagnoses for liver masses, especially in younger dogs, in endemic regions. Confirmed intestinal infections of E. multilocularis and E. canadensis in dogs should be aggressively treated with an adult cestocide such as praziguantel. In endemic regions, dogs at high risk of consuming the larval stages of these parasites in wild rodents and cervids should be dewormed every 4-6 weeks. As no particular season of transmission is known, high risk dogs should be treated monthly with praziquantel year round. We acknowledge that this is a costly drug and this will pose problems for shelters and low income owners. Until better diagnostic tests are available, prophylactic treatment and modifying behavioural and dietary risk factors are the best line of defense.

ANTHELMINTIC RESISTANCE IN COMPANION ANIMAL PARASITES

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The regular use of anthelmintics has led to widespread drug resistance in many gastro-intestinal nematode species of grazing livestock and horses (Kaplan and Vidyashankar, 2012). Anthelmintic resistance has been shown to occur against multiple anthelmintic classes in multiple phylogenetic groups of nematodes including trichostrongyle species of ruminants, small strongyles of horses and ascarids of horses and poultry (Kaplan and Vidyashankar, 2012)

To date, anthelmintic resistance has been less of a problem in parasites of dogs and cats and there has been considerable debate as to the risk of its emergence. However, in the last few years macrocyclic lactone resistance has been confirmed in the canine heartworm Dirofilaria immitis (Wolstenholme et al., 2015) and, very recently, resistance to multiple anthelmintic classes in the canine hookworm Ancylostoma caninum in the USA (Dr Ray Kaplan, University of Georgia, personal communication). These are discussed in more detail below but it is important to emphasize that the tests available to detect anthelmintic resistance in companion animal parasites are not well established or widely applied. Consequently, our ability to detect resistance, particularly in its early stages, is very limited and its true prevalence is unknown. It is also noteworthy that the pattern of resistance emergence in livestock parasites has generally been of a relatively rapid increase in prevalence following the initial confirmed cases. Consequently, the recent reports of anthelmintic resistance in canine heartworm and hookworm are a cause for concern.

Prevention of canine heartworm is dependent on the routine use of macrocyclic lactone drugs. Concerns about potential resistance to this drug class were first raised in the USA by the observation of an increase in "lack of efficacy" reports to the FDA for heartworm control products between 1998 and 2003 (Hampshire, 2005). This led to a protracted debate as to whether this increase was due to the emergence of macrocyclic lactone resistance or just due to increased reporting of control failures due to owner non-compliance. The first peer-review report providing direct evidence of macrocyclic lactone resistance in a D. immitis isolate was a case in Canada of a dog that had been relocated from Louisiana following hurricane Katrina (Bourguinat et al., 2011). Following adulticide treatment, this dog remained microfilaremic for 18 months in spite of being adult antigen negative and having received repeated high dose milbemycin oxime treatments. Subsequently, two additional independent D. immitis isolates from Louisiana, derived from dogs with persistent circulating microfilaria following repeated macrocyclic lactone treatments, have been characterised in detail (Geary et al., 2011; Pulaski et al., 2014). Both of these have been established as experimental infections and shown to be phenotypically resistant to ivermectin by demonstrating the establishment of patent infections in dogs following challenge with mosquito derived L3s in the face of carefully controlled monthly interval treatments with sub-cutaneous ivermectin. This, and further characterisation of these isolates, has unequivocally confirmed the emergence of macrocyclic lactone resistant D. immitis in the Mississippi delta region of the USA (Wolstenholme et al., 2015). The relocation of large numbers of dogs from the region in the wake of hurricane Katrina has raised concerns about potential spread of resistant parasites beyond the region but the current extent and geographic range of the problem is unclear. However, there is currently a lack of sensitive diagnostic tools appropriate for large scale surveys for resistance.

Pyrantel resistance was confirmed in the dog hookworm *Ancylostoma* caninum in Australia as long ago as 2007 demonstrating the capacity of this nematode species to develop resistance (Kopp et al., 2007). Pools of L3 larvae derived from 8 shelter dogs were used in a placebocontrolled trial that determined pyrantel efficacy to be just 25.7%. There has been no new confirmed reports of anthelmintic resistance in *A. caninum* in the peer review literature since that time. However, a lack of anthelmintic treatment effectiveness against *A. caninum*, particularly in greyhounds, is not uncommon but this has generally been assumed to be due to "larval leak" in which somatic larvae reactivate and develop to adult worms in the small intestine following anthelmintic treatment. However, three independent cases of multiple anthelmintic resistance in *A. caninum* from the southern US have been confirmed in 2017 by both in vivo and in vitro testing following their establishment as experimental strains (Dr. Ray Kaplan, University of Georgia, personal communication). These cases suggest that resistance to pyrantel, macrocyclic lactones and benzimidazoles is an emerging problem in the southern US.

In summary, cases of anthelmintic resistance in two highly pathogenic canine nematode parasites have been confirmed in the USA in the last few years. As yet, there are no confirmed reports of anthelmintic resistance in *Toxocara* species, or in other dog or cat internal parasite species. However, this should be interpreted in the context of a general lack of appropriate diagnostic tools, a lack of routine testing and the tendency of resistance to emerge rapidly following the first cases detected. Consequently, there is a need for much greater vigilance in the assessment of anthelmintic efficacy in companion animal parasites and greater consideration given to the risk of the emergence of resistance when planning preventive anthelmintic treatment protocols.

HOOKWORM INFECTIONS IN DOGS THAT ARE NON RESPONSIVE TO TREATMENT (DR. ANDREW PEREGRINE)

In recent years, there have been increasing reports of dogs in Canada with hookworm infections that are not eliminated by standard treatment protocols (e.g. two treatments, 10-14 days apart). These dogs have usually originated from the southern USA and the infection is typically *Ancylostoma caninum*. Historically, these cases were thought to be due to the "larval leak phenomenon Unlike most dog dewormers, Advantage Multi (moxidectin + imidacloprid) is approved with activity against immature stages of *A. caninum*. Thus, if the problem is detected at a time of the year when heartworm risk is a concern in Canada, it makes most sense to use Advantage Multi on a monthly basis as a heartworm preventive until November. A fecal sample should then be collected 4-8 weeks after the last treatment to see if there is repopulation of the gut after the product has been discontinued. If the problem is detected when heartworm infection is not a risk, dogs should be treated twice with Advantage Multi, one month apart. A fecal sample should then be examined 4-8 weeks after the second dose to evaluate efficacy.

If the fecal sample is still positive for hookworm eggs, particularly in dogs originating from the southern USA, it should be recognized that this could be due to both drug resistance and the larval leak phenomenon. Thus, treatment with multiple drug classes at monthly intervals may be required to eliminate an infection. Since Lopatol (nitroscanate) is not available in the USA, but is available in Canada, it makes sense to use this dewormer if resistance to the other three drug classes is suspected.

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NORTHERN, RURAL AND REMOTE DOGS

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Dog and cat populations in rural, remote, and Indigenous communities have special issues regarding parasite fauna and management of parasites. While there are pets that live in the home and receive commercial pet food, others are free-roaming and may be exposed to a wide range of parasites transmitted through consumption of wildlife, fish, and scavenging human food waste. Helminth eggs rarely reported in urban dogs and cats are not uncommon in fecal flotations from dogs and cats in rural and remote regions, including taeniid-type eggs (Taenia or Echinococcus) spp. (from consumption of larval tapeworms in meat or organs of prey species such as cervids, rodents, and rabbits), Diphyllobothrium spp. (from consuming larval tapeworms in fish) and trematodes transmitted via consumption of aquatic vertebrates, such as Alaria spp. (frogs and other small paratenic hosts) and Metorchis conjunctus (suckerfish). There may also be dietary artifacts from consuming parasites shed in the feces of wildlife hosts. For example, dogs (and, rarely, cats) can shed eggs of *Baylisascaris* spp., for which they may serve as true definitive hosts (with adult nematodes in the intestine) or mechanical transport hosts (from consuming raccoon, bear, skunk or wolverine feces). For protozoans, it is not uncommon to find sporocysts of Sarcocystis spp. (from consumption of sarcocysts in bird and mammal intermediate hosts), Cryptosporidium spp. oocysts, and Giardia spp. cysts in feces of dogs in rural and remote regions. High prevalence of zoonotic genotypes (A and B) of Giardia have been reported in free-ranging dogs in northwestern Canada, in contrast with pet and kennel dog populations elsewhere (dominated by dog specific genotypes C and D). As well, dogs and cats in rural and remote regions may frequently harbor wildlife ectoparasites, such as fleas (Pulex simulans), or ticks such as Ixodes cookei, I. kingi, and Haemaphysalis leporispalustris. These should not be

confused with significant veterinary and human ectoparasites such as *Ctenocephalides* spp., *Pulex irritans*, or *Ixodes scapularis*. However, rural and remote dogs are often excellent sentinels of vector borne diseases (such as Lyme disease, tularemia, or plague) because they are often outdoors, share their environments with wildlife, and may not be examined or treated as frequently as urban pets.

Because many rural and remote communities and owners are unable to access or afford veterinary services on a regular basis, many pets are not routinely tested or dewormed and there may be high prevalence and intensity of "normal" nematode fauna such as Toxocara spp., Toxascaris leonina, and Uncinaria stenocephala, especially in young animals. However, surveillance in dogs and wild canids suggests that Toxocara canis is rare at latitudes north of 60°N, which may reflect freeze susceptibility of the eggs; further work is needed to better define the geographic distribution and bioclimatic limits of this important zoonosis, especially in light of rapidly warming climate in northwestern Canada. It is important to note that dogs and cats can be sources of human exposure to zoonotic parasites such as Echinococcus, Baylisascaris, Toxocara, Toxoplasma, Giardia, and Cryptosporidium. However, pets themselves are not usually the direct source of infection for people, who are infected through shared contaminated environments, or, for Giardia and Cryptosporidium, from other infected people. As well, pets may serve as sentinels of circulating zoonoses such as Diphyllobothrium, Alaria, and Metorchis, infected by the same foodborne routes as people, but not a direct source of human infection. It is important to note that country foods (hunted game or fish) are healthy, nutritious and economical, and with appropriate preparation - e.g., cooking or freezing need not increase exposure to parasites.

Special considerations for management of parasites in dogs and cats in remote, rural, and Indigenous communities include recognition of the need for better delivery of veterinary services to such regions, building local capacity to manage free-ranging pet populations (which may include surgical or other methods of sterilization, bylaws, etc), and supporting culturally sensitive wellness and education initiatives to improve animal and human health. There is an urgent need to coordinate, document, and critically evaluate the commendable efforts of a wide range of Non-Governmental Organizations, veterinary colleges, veterinary practices, and community groups involved in such work across Canada, as well as regulatory efforts to allow veterinary "Telehealth" and paraprofessionals to offer local wellness services in rural and remote regions. Also critically needed are programs to engage community members in the planning/execution/implementation of interventions, to build long term sustainable solutions. Until then, many of these animals will end up entering shelters or rescue organizations. Animals from a rescue or shelter in northern and western Canada should be screened and treated for the wider range of parasites that they may harbor, such as *Echinococcus canadensis*, which has been reported in shelter dogs in Canada.

IMPORTED PETS

Protozoal parasites

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Many parasites that occur abroad are not seen, or very rarely, in Canada and several of them are major diseases transmitted by arthropods. Companion animals living in Canada will not have met any of these parasites before travelling abroad and are likely to be susceptible. Veterinarians should consider these important diseases when animals travel to tropical and Mediterranean areas. In addition, and not to be neglected, several of these exotic maladies do not have licensed /veterinary medicines available in Canada, which can lead to long delays before obtaining the correct drug by the veterinarian. It is vital to inform pet owners before and after they have been abroad with their animals, especially when they become ill soon after their return to Canada. Travelling animals should adhere to preventive programs against ticks, sandflies, heartworm and tapeworms. These treatments should be always planned according to current knowledge of pathogens' prevalence in targeted destinations.

Most frequent diseases include: babesiosis, ehrlichiosis, hepatozoonosis, leishmaniasis, Chagas disease, heartworm and tapeworms. Babesiosis, ehrlichiosis and hepatozoonosis are spread by ticks. Whereas babesiosis and ehrlichiosis are transmitted when the tick feeds, hepatozoonosis occurs when dogs (rarely cats) groom off and swallow infected ticks. Symptoms may include: anemia, fever, weakness and red-to-dark-brown urine in the case of babesiosis and fever, bleeding and depression in the case of ehrlichiosis. Usually, animals infected by hepatozoonosis do not display clinical signs unless they are affected by a concomitant immunosuppressive disease. These three diseases can be easily confirmed by blood sample testing but treatment is difficult and require specific drugs. Tick control plans are necessary to minimize the risk of infection.

Leishmaniasis and Chagas disease are transmitted by sandflies and kissing-bugs, respectively. Canine leishmaniasis mainly occurs through the tropics, being highly prevalent in wooded areas of the Mediterranean basin. *Leishmania* parasites are transmitted by the vector during its blood feeding. Leishmaniasis is manifested by a broad spectrum of clinical signs and degrees of severity, which can start a few months or several years after the infection. Clinical signs may include cutaneous (different kinds of skin inflammation, dermatitis and onychogryphosis) and general manifestations: generalized lymphadenomegaly, lethargy, mucous membrane pallor, splenomegaly, polyuria/polydipsia and fever. Leishmaniasis can be confirmed by testing blood (e.g. detection of specific serum antibodies by immunofluorescence antibody test) or biopsy samples (PCR and parasite culture from tissues). Current treatments are highly aggressive, long and expensive. Moreover, clinical response to treatment can vary from very poor to good depending on the initial status of the animal.

Chagas disease is considered endemic in most of Mexico's territories, Central America, and South America. Dogs can become infected by Chagas disease by different routes, however, ingestion of infected kissing-bugs represents the most frequent one. Disease symptoms depend on the progression and duration of the infection. Acute phase is characterized by fever, lethargy, swollen lymph nodes, and an enlarged liver and/or spleen. Chronic infection can lead to dilated cardiomyopathy, a severe heart disease that may result in congestive heart failure. Chagas disease diagnostics is highly complex and includes blood testing, urinalysis, X-rays, electrocardiogram and heart ultrasound. Unfortunately, no drug is able to cure Chagas disease, which means that even early-treated dogs will progress to the chronic form of the disease.

Control for both *leishmaniasis* and Chagas disease should rely on prevention. Prevention measures include: avoiding 'high-risk' areas, keep animals inside at dawn and dusk and house dogs indoors at night to reduce exposure to sandflies and kissing-bugs, use repellents, prevent dogs from eating bugs and/or potentially infected animals (mice, rats, etc.). In addition to exotic protozoan parasites, animals travelling abroad may increase their risk of exposure to heartworm and tapeworm infections. Detailed information concerning these parasites can found in the corresponding sections in these guidelines.

REFERENCES

CONFLICT OF INTEREST STATEMENT

ACKNOWLEDGEMENTS



5 : ACKNOWLEDGMENTS, CONFLICT OF INTEREST STATEMENT, REFERENCES

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CONFLICT OF INTEREST STATEMENT

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