Dog-borne Zoonotic Diseases

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Javier Ventura-Cordero[1*], Francisco Alejandro Méndez-Ortíz[1], Juan José Vargas-Magaña[1], Liliana Aguilar-Marcelino[2] and Gloria Sarahi Castañeda-Ramírez[3*]

ABSTRACT

The increasing significance of the human-animal bond in contemporary society, especially in the context of pets serving various roles such as entertainment, companionship, and support, underscores the need to address potential health threats. This chapter explores the intricate relationship between dogs and their owners, emphasizing the heightened risk of zoonotic diseases transmission. Zoonoses, particularly those transmitted by dogs, pose a global threat to public health, with both developed and developing nations grappling with diseases like Leishmaniasis and Chagas disease. The epidemiology of these zoonotic diseases is multifaceted, involving environmental, socioeconomic, religious, and cultural factors, incurring substantial costs. Dogs serve as reservoirs for diverse pathogens, including bacteria, protozoa, and arthropods. Bacterial infections, such as canine brucellosis and leptospirosis, highlight the potential severity of zoonotic diseases. Protozoal infections like babesiosis, leishmaniasis, trypanosomiasis, and giardiasis demonstrate the broad spectrum of diseases associated with dogs. Moreover, mycoses, particularly dermatophytosis, showcase the prevalence of fungal infections. Arthropods, such as fleas, ticks, scabies mites, and demodex, play a pivotal role in disease transmission. This chapter outlines the infections caused by these pathogens and discusses preventive strategies, emphasizing the importance of maintaining the health of both dogs and their owners. Additionally, the impact of dog-borne zoonotic diseases on global health is addressed, emphasizing the need for coordinated efforts between government authorities and society to curb the spread of these diseases. Strategies for prevention, encompassing vaccination, hygiene practices, and veterinary care, are crucial in mitigating the risks associated with zoonotic diseases.

Keywords: Zoonotic diseases, Dogs, Bacterial infections, Protozoal infections, Arthropods

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[1]Facultad de Ciencias Agropecuarias, Universidad Autónoma de Campeche, Calle 53 S/N entre calle 18 y 20, Col. Unidad, Esfuerzo y Trabajo #2, Escárcega, Campeche, México, CP 24350.
[2]Centro Nacional de Investigación Disciplinaria en Salud Animal e Inocuidad, INIFAP, Km 11 Carretera Federal Cuernavaca-Cuautla, No. 8534, Col. Progreso, Jiutepec, Morelos, México, CP 62550.
[3]Centro de Investigación en Biotecnología (CEIB), Universidad Autónoma del Estado de Morelos (UAEM), Cuernavaca, Morelos, México. C.P, 62209.
***Corresponding author:** sarahi.castaneda@uaem.mx; jventura@uacam.mx

1. INTRODUCTION

In today's society, the human-animal relationship is becoming essential, particularly in pets participating in entertainment, companionship, farming, military purposes, for people with disabilities, and emotional support for their owners. However, such a bond between dogs and owners potentially increases the possibility of acquiring zoonotic diseases (Alho et al. 2018).

The threat to public health due to zoonotic diseases transmitted by pets is reported in both developed and developing countries i.e., diseases such as Leishmaniasis and Chagas disease become a serious problem in tropical and subtropical regions (Dantas-Torres and Otranto 2016). The epidemiology of zoonotic diseases involves several components, i.e., environmental, socioeconomic, religious, and cultural factors, causing significant costs (Kardjadj and Ben-Mahdi 2019).

Dogs could serve as reservoirs of several pathogens, including viruses, bacteria, helminths, protozoa, and vector-borne diseases such as fleas, ticks, mosquitoes, sand flies, and several other flies (Irwin 2014). This chapter highlights the infections caused by bacteria, protozoa and finally, arthropods from dogs (Fig. 1). In addition, it discusses strategies to prevent transmission from those pathogens and maintain the dog owners protected. Ultimately, different effects of dog-borne zoonotic diseases are addressed in human health and its cots from government programs.

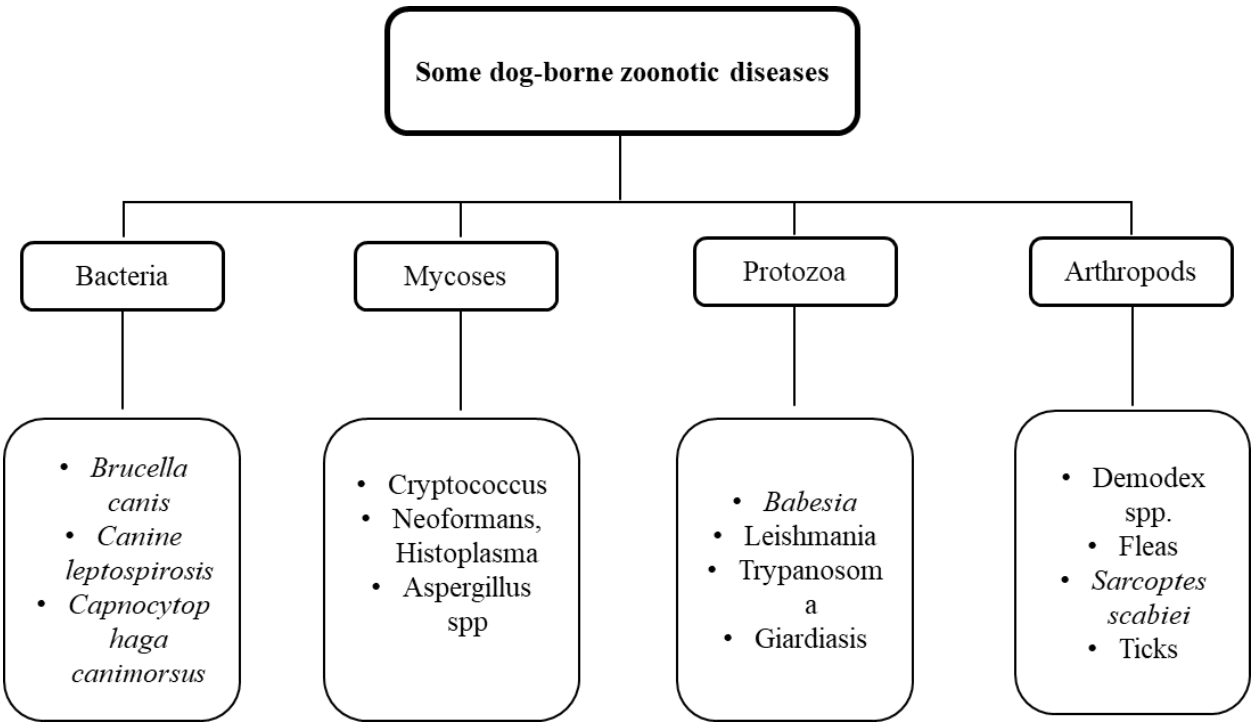

Fig. 1: Schematic outline of dog-borne zoonotic diseases.

2. BACTERIAL INFECTIONS

2.1. *BRUCELLA CANIS*

Canine brucellosis is a zoonotic disease that can cause reproductive problems, infertility, and abortion (Wanke 2004). More cases have been reported in humans when in contact with secretions of animals

infected with *Brucella (B.) canis*. On the other hand, the genus Brucella has more than eight species reported with zoonotic potential (Sánchez-Jiménez et al. 2013). *B. canis* is a large negative coccobacillus, an immotile bacterium lacking a capsule, spore and flagella. It was first isolated in 1966 by Carmichael (Nárez et al. 1999).

However, the serological tests necessary for diagnosis still need to be improved, and molecular tools are currently being sought for diagnosis. The disease can be asymptomatic or can show symptoms. *B. canis* infection penetrates the dog, starts as a bacterial infection, and then spreads in the organism. Initially, it can lodge in the lymph nodes, spleen, liver, uterus, prostate glands, vesicles, and bone marrow (Carmichael and Kenney 1970). In addition, it is important to mention that significant seropositivity frequencies have been reported, between 8.5 and 17% in various breeds (Bulldog, Poodle, Pug, Beagle, Schnauzer, Shih Tzu, Labrador retriever and Maltese) (Giraldo Echeverri et al. 2009).

In the case of human infection, it may or may not show symptoms, and many years can pass without showing signs (Corbel 1997). Nevertheless, documented cases in humans present symptoms such as fever, sore throat, chills, asthenia, muscle pain, joint pain, arthritis, weakness, anorexia, diarrhoea, weight loss, pneumonia and endocarditis (Paixão et al. 2009; Manias et al. 2013). Sanchéz-Jiménez et al. (2013) proposed a model of infection by the oral route, the bacterium passes until it reaches the stomach and activates the "ure" operon, then comes the adherence and cell invasion, ending with the establishment of the infection.

2.2. CANINE LEPTOSPIROSIS

It is a disease associated with a pathogenic bacterium, which can be transmitted by ingestion, or exposure of mucous membranes to canine urine residues or infected people. This bacterium can also live in contaminated water. The worldwide incidence of human Leptospirosis was estimated at one million people and almost 59,000 deaths yearly (World Health Organization 2011). In addition, the Event Management System considers Leptospirosis among the top ten public health risks or threats.

Canines can acquire the disease from infected wild animals such as rats, raccoons, and rodents. An infected dog may not show symptoms or present severe liver and kidney infections, sometimes even risking the canine's life. Antibiotic treatments are commonly used for humans and animals, including ampicillin, amoxicillin, doxycycline, penicillin, ceftriaxone, cefotaxime or, in more severe cases, blood transfusions (Harrison 2006). There are some vaccines to prevent Leptospirosis in dogs. A total of 26 biological products produced by 15 different commercial laboratories have been reported to protect against Leptospirosis (Luna et al. 2008).

When a human is infected, leptospires are distributed throughout the bloodstream to the organs and initiate with the symptoms i.e., headache, fever (39°C), malaise, muscle and joint pain, renal failure and abdominal or thoracic pain, cutaneous or mucosal haemorrhages, jaundice, haemoptysis and ultimately liver failure. The disease is diagnosed by various serological tests (World Health Organization 2008).

2.3. *CAPNOCYTOPHAGA CANIMORSUS*

This is one of the main bacteria associated with dog bites. These bacteria are the part of the flora of dogs and require 5 to 10% CO2 for their growth (Chanqueo et al. 2019). *Capnocytophaga (C.) canimorsus* is a gram-negative bacterium. For the diagnosis of this bacterium, biochemical tests, the catalase test, oxidase, and 16S rRNA sequence are used. These tests are used because sometimes it

is complicated to grow the bacterium due to its nutritional requirements and the speed of its growth (Fernández-Vecilla et al. 2022).
The transmission of *C. canimorsus* bacteria was sometimes observed after the canine bite. Most of the cases reported after five days without treatment and 28% could have a fatal evolution. They were showing a great variety of symptoms, mild or lethal. In patients with a history of splenectomy or with functional hyposplenism (chronic alcoholics or cirrhotic), fulminant sepsis with shock, disseminated intravascular coagulation, renal failure and pulmonary infiltrates or meningitis may occur (Le Moal et al. 2003). On the other hand, the bite area may also present gangrene (Henry 2018).
For its treatment, amoxicillin-clavulanic acid or 3rd generation cephalosporins are recommended. Other antibiotics, such as imipenem, clindamycin, and doxycycline, have also shown clinical efficacy (Dorronsoro 2001).

3. PROTOZOAL INFECTIONS

3.1. BABESIOSIS

Babesiosis has a considerable economic and public health impact and is one of the most common tick-borne diseases transmitted to dogs around the world and can infect various vertebrates, including humans (Petra et al. 2018). It is also known as piroplasmosis, which is a multisystem disease caused by the protozoa belonging to the genus *Babesia* (Hildebrandt et al. 2021).
The main route of infection is through the tick bite. However, vertical transmission, transmission by blood transfusion or organ transplantation, in addition to possessing reservoirs in wildlife, has been reported (Tołkacz et al. 2017). Symptoms in humans can vary from mild to fatal disease with multisystem failure (Bajer et al. 2022), in addition to synergising with other tick-borne diseases, which can change it to a more severe form of the disease (Kumar et al. 2021). Infections occur throughout the year but more frequently in temperate zones in early summer to late autumn (Vannier and Krause 2012).
Control in endemic areas is carried out to prevent vector infestation. A vaccine against *Boophilus microplus*, the primary transmitter of Babesia to cattle, is now available and reducing transmission. Self-immunisation is used in newly admitted animals in endemic areas with blood from healthy carriers infected with *Babesia*, resulting in a mild infection that can be treated with palliatives (Petra et al. 2018).

3.2. LEISHMANIASIS

This genus constitutes one of the most widespread parasitic species and produces a disease called leishmaniasis. In humans, it has three forms i.e., cutaneous, mucosal and visceral. One of the main species transmitted by dogs to humans is *Leishmania (L.) infantum*, which occurs as a multisystem disease that affects dogs which constitute as its main reservoir (Alvar et al. 2004). Its life cycle includes a mammalian host and the sand fly (Phlebotomidae), which acts as a vector and needs vertebrate blood to mature its eggs (Morales-Yuste et al. 2022). It is challenging to cure leishmaniasis in dogs, however, it seeks to control the sinology and reduce the disease to asymptomatic levels. Therapy depends on the level of the disease and is classified into four stages: Stage I: no signs or are very mild and may not be treated or treated with allopurinol only; Stage II and III: have moderate (II) to severe signs and may be associated with chronic kidney disease (III), these animals are treated with mixtures of allopurinol and antimonials/miltefosine; stage IV: animals with very severe disease having nephrotic syndrome and treated with allopurinol to prevent damage to the kidneys, in addition to including management for chronic kidney disease (Solano-Gallego et al. 2011).

3.3. TRYPANOSOMIASIS

This parasite has a high prevalence in dogs and cats, which are the main reservoir of this disease for humans. The Triatomidae family are the main vectors of this disease, which are infected by feeding on the blood of infected mammals, from where they obtain the trypomastigotes which reproduce in the insect and, finally, after 15 to 30 days, they appear as metacyclic trypanosomes in the faeces of these insects (Acha and Szyfres 2001).

Dogs chronically infected with trypanosomiasis show atrial and ventricular arrhythmias, as well as the dilation of the cardiac chambers and in the acute phase, presents fever, eyelid oedema, hepatomegaly and alterations of the nervous system. The acute phase of the disease lasts for 10 to 30 days after which the disease enters an indeterminate chronic stage (Freitas et al. 2022).

Because the drugs used for the treatment of the acute phase of Chagas disease are toxic, it is decided not to treat the animals and measures are established to prevent the transmission of the disease. In areas where the vector is present, measures are taken to eliminate cracks and crevices where the vectors breed, as well as the use of residual insecticides such as pyrethroids in places with high infestations. Blood transmission is prevented by using donor blood tests, treating donors with gentian violet at 250 mg/mL 24 hours before donation, and using ascorbic acid and exposing the blood to light (Timm et al. 2023).

3.4. GIARDIASIS

This disease is considered endemic worldwide and can be prevalent in developing countries, with more than 15% of infections in children. Although most infections are asymptomatic, if there is any damage to the immune system in puppies, diarrhoea, stomach inflammation, and abdominal pain, sometimes accompanied by vomiting, occur. In humans, the disease can be prolonged, and episodes of diarrhoea, flatulence, urticaria and intolerance to certain foods occur that are discontinued after treatment (Acha and Szyfres 2001). The main reservoir of Giardia towards animals is man, and the source of contamination is faeces contaminated with oocysts that reach water sources from where dogs consume them. Animals with chronic diseases ensure the agent's persistence (Scorza and Lappin 2021).

The control of this disease consists of protecting water sources from faecal contamination. Measures such as boiling water, filtering it or sedimentation flocculation and filtration methods are also helpful for disease control (Acha and Szyfres 2003). The drugs of choice for the treatment of Giardia are fenbendazole and metronidazole, which can be used alone or in combination for a period of three days (ESCCAP 2013). A recent study reports 100% effectiveness of the drug secnidazole, which was supported by a homoeopathic remedy to reduce diarrhoea in puppies (Glombowskv et al. 2020).

4. MYCOSES

Mycosis is the proliferation of fungi on the skin of animals. Depending on the location of this infection, it is divided into 1) superficial and 2) deep. The superficial one is characterized by an infection that develops in the stratum corneum, and the deep one in the animals' fermis and internal organs (Bourdeau 2018).

The pathogens that fungi produce is grouped into three large groups: 1) primary, 2) opportunistic and 3) pathogens. Table 1 and Fig. 2 shows the brief classification of fungi based on their pathogenicity.

Table 1: The classification of fungi.

Group	Examples	Reference
Primaries	Blastomyces, Coccidioidomycoses, *Cryptococcus neoformans*, Histoplasma	(Brömel and Sykes 2005; Lin et al. 2011)
Opportunist	Moulds and yeasts (*Aspergillus* spp.)	(Bennett et al. 2018; Elad 2019)
Pathogens	Dermatophytes (Dermatophytosis), Microsporum y Trichophyton	(Segundo et al. 2004)

4.1. DERMATOPHYTOSIS

Dermatophytosis is a disease that affects dogs and is one of the most frequent infections as it represents 50-60%. The species of fungi that cause this disease are *Trichophyton mentagrophytes, Microsporum gypseum* and *Microsporum persicolor*. The clinical signs are hard hair, fistulas and nodules, and it is contagious which vary according to different characteristics such as race and season of the year (temperature and relative humidity). This disease is controlled through chemical products i.e., griseofulvin, ketoconazole and itraconazole that have been reported as effective to control this mycosis (Segundo 2004; Gupta et al. 2005).

5. ARTHROPODS

5.1. DEMODEX SPP

Demodex is a parasite found on the skin of dogs and cats as part of their physiological fauna and is generally not associated with any disease. However, sometimes alopecia or mild to moderate dermatitis is usually found when the number of mites increases excessively (Foley et al. 2021).
Demodex (D.) canis is the most common mite in dogs, although *D. injai* or other species are usually found (Xhaxhiu et al. 2009). The most reported species in humans are *D. folliculorum* and *D. brevis* (Czepita et al. 2007). Demodicosis is not transmissible by contact between animals or other species. Demodex mites adapt to a definitive host, and there is no evidence of cross-infectivity. There is one report of *D. folliculorum* infection of a child and his dog, the only case reported so far of the same species of Demodex (Morsy et al. 1995). Due to the characteristics of Demodex mites, it should not be considered as a zoonotic risk (Gazi et al. 2019).

5.2. FLEAS

Fleas are 2 to 4 cm long and have no wings. Approximately 2200 species and subspecies of fleas exist; however, very few infect dogs (Blagburn and Dryden 2009). Dogs are usually infected by *Ctenocephalides felis* (cat flea) (Rinaldi et al. 2007). *Pulex irritans* (human flea) and *Echidnophaga gallinacea* (sticky poultry flea) can occasionally infect dogs. The most common species in humans is *Pulex irritans*. However, it is not exclusive to the humans as it is found in other species, including cats, dogs, wild canids and pigs (Weese and Peregrine 2011).
Fleas use visual and thermal signals to locate their host. The flea's life cycle lasts in about 3 to 8 weeks (Blagburn and Dryden 2009). Once fed, the female flea will produce eggs within 20 to 24 hours of feeding (Young et al. 2020).
Infestation rates of 6.8 to 17% have been found in dogs and 2.5 to 23% in cats (Farkas et al. 2009). The means of infestation is the environment. Transmission is usually direct between pets in the same household or by transient contact with other pets in parks, kennels or veterinary clinics. It can also occur by contact with wildlife (Blagburn and Dryden 2009). Humans are usually infected by meeting animals that have fleas (Weese and Peregrine 2011).

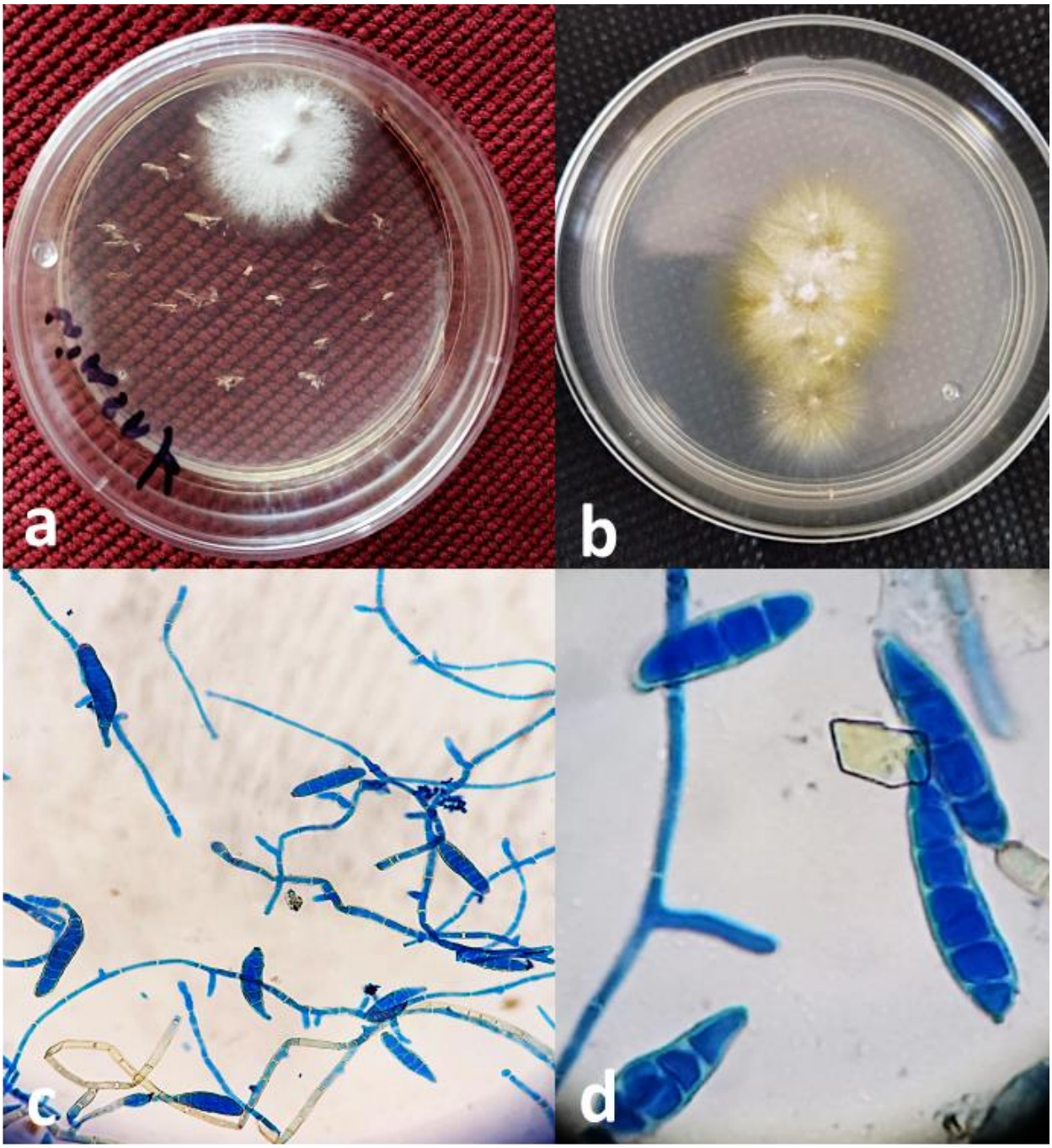

Fig. 2: a) Culture of *Nannizzia gypsea* in Petri dishes. b) Macroconidia of *Nannizzia gypsea*. c) *Microsporidium canis* in Petri dishes. d) *Microsporidium canis* in optical microscopy (Photograph by Dr Isabel Garcia-Abundis)

Exposure to fleas in humans usually causes transient or recurrent itching, a universal response caused as an antigenic response to flea saliva, which occurs mainly in allergic individuals (Scott and Horn Jr 1987). Another severe problem that fleas can cause is the transmission of pathogens. The most common pathogens are Bartonella spp., *Rickettsia felis*, *Rickettsia typhi*, *Yersinia pestis* and *Dipylidium caninum* (Beugnet and Marié 2009).

Lesions from flea bites can be observed in groups of three and are known as breakfast, lunch and dinner of fleas (Scott and Horn Jr 1987). Children are the mainly affected by fleas. The distal extremities, mainly the legs, are the most affected regions in children where urticaria papules can be observed (Naimer et al. 2002).

Human diagnosis of a flea infestation is rarely diagnosed by the presence of flea infestation or faeces. Clinical signs and a history of flea infestation in pets or other flea-infested animals or environments are indications to suspect the disease (Weese and Peregrine 2011).

5.3. *SARCOPTES SCABIEI*

Sarcoptes (S.) scabiei is a mite that digs into the skin and causes intense itching, culminates in skin problems, and mainly occurs in dogs, coyotes, foxes and humans. The varieties that *S. scabiei* cause infestations in humans and canines are different, but cross-infestation can occur (Mofiz et al. 2016).

There are only one species of *S. scabiei* that is called *S. scabiei* var. *canis* in dogs (Arther 2009), and *S. scabiei* var. *hominis* in humans. There is evidence of genetic variation among *S. scabiei* var. *canis* and *S. scabiei* var. *hominis* (Walton et al. 1999).

S. scabiei mites enter the epidermis, causing intense itching and a type I and IV hypersensitivity reaction to the host. The life cycle of this mite is completed in 30 days, and this begins when the strands lay eggs on the walls of the excavations. The larvae hatch and moult to become nymphs one and moult again to nymphs 2 that later become adults (Arther 2009). Adult males die after mating, and females migrate to dig their burrows (Sunderkötter et al. 2016).

Prevalence from 7 to 19% *has* been found in stray dogs. According to a study, dogs that interact with stray dogs are at higher risk of infection (Rodríguez-Vivas et al. 2003). Mild to moderate infestations usually occur when mites adapted to one species are transmitted to another species (Arther 2009).

S. scabiei var *hominis* can affect all socioeconomic levels; however, poor hygiene, poverty, malnutrition, and sexual promiscuity increases the risk of infection (Diaz 2005a). Close contact with infected persons can cause infestation, mainly in endemic areas (Rodríguez-Vivas et al. 2003). When a human infestation occurs by an infected animal, it is considered a zoonotic transmission of great relevance since they are scarce (Meijer and van Voorst Vader 1990). The scabies mite usually lives in humans for about six days, and usually, at 24 to 96 hours of the infestation, rashes arise on the skin (Moriello 2003).

S. scabiei cause intense itching with papular rash in adults and children. The most affected areas are the interdigital folds, elbows, armpits, navel and genitals. In younger children, vesicular lesions usually appear on the scalp, face and palms of the hands (American Academy of Pediatrics 2003). In immunocompromised patients, particularly with HIV/AIDS, generalised or localised or crusty hyperkeratotic plaques are often present (Zafar et al. 2002). Although zoonotic mange is difficult to differentiate from human mange, we can observe some differences, such as *S. scabiei* var. *canis* tends to cause milder, self-limiting disease, and burrows should not be present (Diaz 2005a).

5.4. TICKS

Ticks are the insects belonging to the class Arachnida. They are characterised by sucking the blood of their host. There are two types of ticks: Ixodidae (hard ticks) and Argasidae (soft ticks). The Ixodidae include three more genera: Ixodes, Rhipicephalus and Amblyomma, which are related to zoonotic diseases and involve pets and humans (Dantas-Torres 2010).

For most tick-borne diseases infection occurs during feeding (Greene 2006). This point is essential as timely identification and proper disposal reduce the risk of pathogen transmission. Finding ticks in pets is

important to human health, as it indicates that they are present in the area and there is human exposure to the agent. The tick could leave the animal and attach itself to the human. Human-to-human transmission is unknown (Weese and Peregrine 2011).

When there is a risk of being in an area potentially infested with ticks, animals and humans should be carefully inspected for ticks. Close examination is required, particularly for the poppy-sized nymph (Diaz 2005b). Humans should pay attention to the scalp, pubis, and armpits (Wagner and Stallmeister 2000).

In one locality in Italy, 240 individuals infected between 1995 and 1996 were found with an average of 1.3 ticks per individual. 89% individuals were infected with *Ixodes ricinus* at all stages. *R. sanguineous* was the second most prevalent species found with 10%, and Dermacentor was third with 1%. Cases occurred in 11% children, 26% students, 22% workers and 24% retirees (Manfredi et al. 1999).

A study conducted at a medical school in Georgia, U.S.A. and recorded 521 infestations in two and a half year with an average of 1.3 ticks per person (Felz and Durden 1999). Another study in Chile showed 2.2% tick bites in 1384 patients referred for spider bites (Acha and Szyfres 2001). Table 2 highlights the zoonotic pathogens found in ticks of companion animals.

6. STRATEGIES FOR PREVENTION AND CONTROL OF DOG-BORNE ZOONOTIC DISEASES

Different control strategies should be considered to prevent any bacterial agents, mycosis, protozoa, helminths, and arthropods. In constant contact with canines, it is necessary to have control of the pet and its history to maintain the health of dog and the human. Some diseases can be prevented by vaccination and thus prevent exposure to these diseases (Grassmann et al. 2017).

It is also vital to maintain hygiene and a constant check-up of canine with the veterinarian. In addition, it is better not to leave a person's wounds exposed, as it can generate complications due to poor care or exposure to other agents. Furthermore, take care of the canine's feeding and storing the canine's food in a different place than the food consumed by people (Li-Wui Y and Orozco-Cardenas A 2014).

Care should also be taken for the excretions and secretions of the canine and its correct handling for the surrounding people. Do not manipulate faeces or urine directly with unprotected hands and after this manipulation, washing hands with soap and water is necessary. In the case of dog bites, it is necessary to go immediately to the doctor for medical attention and not to let the event pass, which could later generate more complications. There are some zoonotic diseases eligible for vaccines which is a strategy adopted by some countries but not used worldwide. (Koizumi and Watanabe 2005; Grassmann et al. 2017). Prevention of zoonotic diseases needs the coordination of government authorities, society and awareness campaigns (Shiferaw et al. 2017).

7. GLOBAL IMPACTS OF DOG-BORNE ZOONOTIC DISEASES

About 14 to 62% of pet owners allow their pets into their rooms, which could increase the occurrence of zoonoses (Chomel and Sun 2011). Companion animals and pets have increased in recent decades but are also an integral source of disease-producing agents. The growing popularity of pets and companion animals has put human health at risk due to the possible spread of infections (Fig. 3). In many homes today, pets of exotic species are kept along with ordinary pets. Therefore, significant individuals are at risk of acquiring new zoonotic diseases from pets, companion animals, and exotic birds and animals (Chomel 2014).

Various infectious diseases (viral, bacterial, parasitic, and fungal) are associated with pets and companion animals (Halsby et al. 2014). Zoonotic diseases frequently associated with pets and companion animals include brucellosis, campylobacteriosis, chlamydiosis, cat scratch fever (*Bartonella henselae*), ehrlichiosis, giardiasis, hantavirus, hookworm, influenza, rabies, Lyme disease, Rocky Mountain spotted fever, plague,

Table 2: Zoonotic pathogens found in ticks of companion animals (Weese and Peregrine 2011).

Tick	Pathogen(s)
Rhipicephalus sanguineus	*Coxiella burnetii*
	Rickettsia rickettsii
	Rickettsia conorii
	Bartonella vinsonii subsp.--
	Berkhoffi
Ixodes scapularis	*Anaplasma phagocytophilum*
	Ehrlichia chaffeensis
	Ehrlichia ewingii
	Bartonella henselae (possibly)
	Borrelia burgdorferi
	R. rickettsii
	R. conorii
Ixodes pacifi cus	*B. burgdorferi*
Ixodes ricinus	*A. phagocytophilum*
	C. burnetii
	Borrelia spp.
Amblyomma americanum	*E. chaffeensis*
	E. ewingii
	B. burgdorferi
	Francisella tularensis
Dermacentor variabilis	*R. rickettsii*
	F. tularensis
Dermacentor andersoni	*R. rickettsii*
	F. tularensis

Leptospirosis, monkeypox, Pasteurella, Q fever, roundworms, salmonellosis, methicillin-resistant *Staphylococcus aureus* (MRSA), streptococcus and toxoplasmosis (Jacob and Lorber 2015; Day 2016). Many zoonoses, such as salmonellosis, diseases caused by staphylococcus, and rabies, are also found in many pets and companion animals (Halsby et al. 2014).

The transmission of pathogens from these animals occurs by direct or indirect contact. Transmission can occur at home, outside, pet stores, hospitals, or elsewhere. In many cases, transmission occurs when these animals and birds are taken to shows and competitions (Belchior et al. 2011). Typically, animal bites or scratches are routes through which humans contract infections, such as pasteurellosis and cat scratch disease (Chomel 2014).

It has been shown that 50% of European households allow dogs to lick their owners' faces or share ice cream (Overgaauw et al. 2009). However, more indications have been found that licking a dog can cause infections or severe health consequences (Van Knapen and Overgaauw 2015). A study conducted in the Netherlands showed that pet owners allow dogs to sleep in the bedroom (33-56%) or even sleep in the owner's bed (18-50%), undoubtedly contributing to the transmission of zoonoses, including parasites. Intensive contact with the skin and nose can lead to contamination with MRSA. It should be noted that the most common zoonotic disease associated with dogs is rabies, caused by the *Lyssavirus* (family: Rhabdoviridae), which kills tens of thousands of people every year. Similarly, pet-associated MRSA is a serious health problem for humans worldwide (Faires et al. 2009; Burgos-Cáceres 2011).

Zoonoses have countless impacts on human and animal health. However, the impact of zoonoses is challenging to quantify because many of these diseases are undiagnosed, not nationally notifiable and can be transmitted from sources other than companion animals. It can be assessed by disease prevalence, incidence, morbidity, mortality, and economic losses (Meslin 2006). Given these limitations, a review of

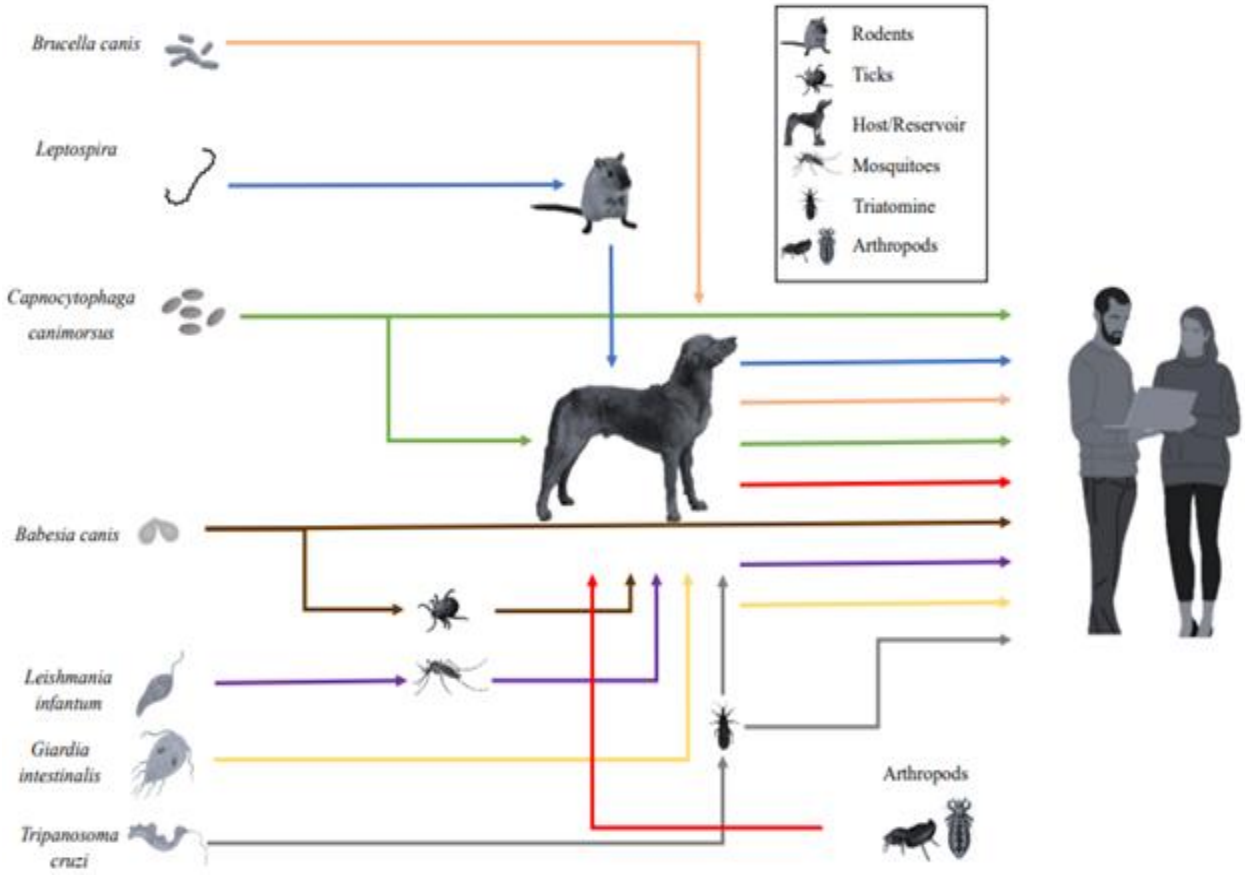

Fig. 3: Agents, hosts, reservoirs, and possible route of transmission of dog-borne zoonotic diseases.

national disease surveillance data and published literature suggests that more than four million people in the United States are infected annually with pet-borne zoonoses at a cost of more than $300 million. These costs include those of direct medical care during an acute illness (e.g., salmonellosis), chronic supportive care (e.g., congenital toxoplasmosis) and disease prevention (e.g., rabies), but not the loss of life - or quality of life - resulting from these diseases. Efforts should be made to prevent the transmission of zoonoses from pet animals to humans through appropriate pet health care to eliminate infectious agents and by educating the public, in particular pet owners, about the zoonotic potential of these diseases so that they can take precautions to minimise the risks of disease transmission (Pfukenyi et al. 2010).

8. CONCLUSION

Human-dog bonds nowadays could increase the risk of acquiring zoonotic diseases. However, it is undeniable that the role of dogs in the current lifestyle of their owners is due to different purposes, such as emotional support, work, and companionship. The epidemiological actions to protect pets and, most importantly, humans against dog-borne zoonotic diseases have been discussed briefly. To reach this point, we must develop social campaigns informing people about how to prevent diseases caused by bacteria, mycoses, ticks, and arthropods. The latter pathogens cause several signs and symptoms in animals and owners, respectively.

REFERENCES

Acha P and Szyfres B, 2001. Zoonoses and Communicable Diseases Common to Man and Animals: Volume 3: Parasitoses. Vol. 580 Pan American Health Org, Washington, USA

Alho AM et al., 2018. Awareness of zoonotic diseases and parasite control practices: A survey of dog and cat owners in Qatar. Parasites and Vectors 11: 1-7.

Alvar J et al., 2004. Canine leishmaniasis. Advances in Parasitology 57: 1–88.

American Academy of Pediatrics, 2003. Red Book: 2003 Report of the Committee on Infectious Disease. Elk Grove Village, Illinois, USA.

Arther R, 2009. Mites and lice: biology and control. Veterinary Clinics: Small Animal Practice 39: 1159–1171.

Bajer A et al., 2022. Babesiosis in Southeastern, Central and Northeastern Europe: An emerging and re-emerging tick-borne disease of humans and animals. Microorganisms 10: 945.

Belchior E et al., 2011. Psittacosis outbreak after participation in a bird fair, Western France, December 2008. Epidemiology & Infection 139: 1637-1641.

Bennet PF et al., 2018. Long term survival of a dog with disseminated *Aspergillus deflectus* infection without definitive treatment. Medical Mycology Case Reports 22: 1-3.

Beugnet F and Marié J, 2009. Emerging arthropod-borne diseases of companion animals in Europe. Veterinary Parasitology 163: 298–305.

Blagburn B and Dryden M, 2009. Biology, Treatment, and Control of Flea and Tick Infestations. Veterinary Clinics: Small Animal Practice 39: 1173–1200.

Bourdeau P, 2018. Dermatology/Preventology/Mycology Unit, Veterinary school of Nantes Oniris, France; NP3 Unit Oniris, LUNAM University, Nantes, France.

Brömel C and Sykes JE, 2005. Histoplasmosis in dogs and cats. Clinical techniques in small animal practice 20(4): 227-232.

Burgos-Cáceres B, 2011. Canine rabies: a looming threat to public health. Animals 1: 326–342.

Carmichael LE and Kenney RM, 1970. Canine brucellosis: the clinical disease, pathogenesis, and immune response. Journal of the American Veterinary Medical Association 156: 1726-1734.

Chanqueo L et al., 2019. *Capnocytophaga canimorsus*. Revista chilena de infectología 36: 219-220.

Chomel B, 2014. Emerging and re-emerging zoonoses of dogs and cats. Animals 4: 434-445.

Chomel B and Sun B, 2011. Zoonoses in the bedroom. Emerging Infectious Diseases 17: 167-172.

Corbel MJ, 1997. Brucellosis: an Overview. Emerging Infectious Diseases 3 (2): 213-221.

Czepita D et al., 2007. *Demodex folliculorum* and *Demodex brevis* as a cause of chronic marginal blepharitis. Annales Academiae Medicae Stetinensis 53: 63-67.

Dantas-Torres F, 2010. Biology and ecology of the brown dog tick, *Rhipicephalus s*anguineus. Parasites and Vectors 3: 1-11.

Dantas-Torres F and Otranto D, 2016. Best Practices for Preventing Vector-Borne Diseases in Dogs and Humans. Trends in Parasitology 32: 43-55.

Day MJ, 2016. Pet-Related Infections. American Family Physician 94: 794-802.

Diaz JH, 2005a. Scabies. In: Mandell GL, Bennett JE and Dolin R, editors. Principles and Practice of Infectious Diseases; pp: 3305-3307.

Diaz JH, 2005b. Ticks, Including tick paralysis. In: Bennet JE, Dolin R and Blaser MJ, editors. Principles and Practice of Infectious Diseases; pp: 3505-3526.

Dorronsoro I, 2001. Revisión: Género Capnocytophaga. Control de calidad de la SEIMC 2001. Control de Calidad de la SEIMC 2001: 1-9.

ESCCAP, 2013. GUÍA ESCCAP NO 6 Control de Protozoos Intestinales en Perros.

Elad D, 2019. Disseminated canine mold infections. The Veterinary Journal 243: 82-90.

Faires M et al., 2009. An investigation of methicillin-resistant *Staphylococcus aureus* colonisation in people and pets in the same household with an infected person or infected pet. Journal of the American Veterinary Medical Association 235: 540–543.

Farkas R et al., 2009. Prevalence of flea infestation in dogs and cats in Hungary combined with a survey of owner awareness. Medical and Veterinary Entomology 23: 187-194.

Felz M and Durden L, 1999. Attachment sites of four tick species (Acari: Ixodidae) parasitising humans in Georgia and South Carolina. Journal of Medical Entomology 36: 361-364.

Fernández-Vecilla D et al., 2022. Sepsis por *Capnocytophaga canimorsus* en un paciente inmunocompetente. Revista Española de Quimioterapia 35: 304-306.

Freitas NEM et al., 2022. Technological advances in the serological diagnosis of Chagas disease in dogs and cats: a systematic review. Parasites & Vectors 15(1): 343.

Foley R et al., 2021. Demodex: a skin resident in man and his best friend. Journal of the European Academy of Dermatology and Venereology 35(1): 62-72.

Gazi U et al., 2019. Immune mechanisms in human and canine demodicosis: A review. Parasite immunology 41: e12673.

Giraldo Echeverri CA et al., 2009. *Brucella canis* in Medellin (Colombia) a current problem. Revista U.D.C.A Actualidad & Divulgación Científica 12: 51-55.

Glombowskv P et al., 2020. Uso de secnidazol y homeopatía para el control de giardiasis en perros. Revista MVZ Córdoba 25: 170-176.

Grassmann A et al., 2017. A Universal Vaccine against Leptospirosis: Are We Going in the Right Direction? Frontiers in Immunology 8: 256.

Greene C, 2006. Environmental factors in infectious disease. In: Greene CE, editor. Infectious diseases of the dog and cat; pp: 991-1013.

Gupta A et al., 2005. Dermatophytosis: the management of fungal infections. Skinmed: Dermatology for the Clinician 4(5): 305-310.

Halsby KD et al., 2014. Healthy animals, healthy people: Zoonosis risk from animal contact in pet shops, a systematic review of the literature. PLoS ONE 9: e89309.

Harrison RJFP, 2006. Principios de Medicina Interna, 16th Ed., McGraw Hill Interamericana, Distrito Federal, Mexico

Henry R, 2018. Etymologia: *Capnocytophaga canimorsus* capsular serovar and disease severity, Helsinki Hospital District, Finland, 2000-2007. Emerging Infectious Diseases 24 (12): 2201.

Hildebrandt A et al., 2021. Human babesiosis in Europe. Pathogens 10: 1165.

Irwin PJ, 2014. It shouldn't happen to a dog . . . or a veterinarian: Clinical paradigms for canine vector-borne diseases. Trends in Parasitology 30: 104-112.

Jacob J and Lorber B, 2015. Diseases transmitted by man's best friend: the dog. In: Scholossberg D, editor. Infections of Leisure; pp: 111-131.

Kardjadj M and Ben-Mahdi MH, 2019. Epidemiology of dog-mediated zoonotic diseases in Algeria: a One Health control approach. New Microbes and New Infections 28: 17–20.

Kumar A et al., 2021. The global emergence of human babesiosis. Pathogens 10: 1447.

Le Moal G et al., 2003. Meningitis due to *Capnocytophaga canimorsus* after receipt of a dog bite: Case report and review of the literature. Clinical infectious diseases 36: e42–e46.

Lin JB and Arceneaux KR, 2011. Histoplasmosis. Compendium: Continuing Education for Veterinarians. 33(3): E1-E10; quiz E11.

Li-Wui Y and Orozco-Cardenas A, 2014. Tratamiento de las mordeduras de perros. Revista Médica de Costa Rica y Centroamérica 71(610): 289-292.

Luna AMA et al., 2008. La leptospirosis canina y su problemática en México. Revista de Salud Animal 30: 01-11.

Manfredi M et al., 1999. Tick species parasitising people in an area endemic for tick-borne diseases in north-western Italy. Parassitologia 41: 555-560.

Manias V et al., 2013. Endocarditis por *Brucella canis*: primer caso documentado en un paciente adulto en Argentina. Revista argentina de microbiología 45: 50-53.

Meijer P and van Voorst Vader P, 1990. Canine scabies in man. Nederlands Tijdschrift voor Geneeskunde 134: 2491-2493.

Meslin FX, 2006. Impact of zoonoses on human health. Veterinaria Italiana 42: 369-379.

Mofiz E et al., 2016. Mitochondrial Genome Sequence of the Scabies Mite Provides Insight into the Genetic Diversity of Individual Scabies Infections. PLoS Neglected Tropical Diseases 10(2): e0004384.

Overgaauw PAM et al., 2009. Zoönotic parasites in fecal samples and fur from dogs and cats in the Netherlands. Veterinary Parasitology 163: 115-122

Moraes-Souza H and Bordin JO, 1996. Strategies for prevention of transfusion-associated Chagas' disease. Transfusion Medicine Reviews 10: 161-170.

Morales-Yuste M et al., 2022. Canine leishmaniasis: Update on epidemiology, diagnosis, treatment, and prevention. Veterinary Sciences 9, 387.Moriello K 2007. Zoonotic skin diseases of dogs and cats. Animal Health Research Reviews 4: 157-168.

Moriello KA, 2003. Zoonotic skin diseases of dogs and cats. Animal health research reviews 4(2): 157-168.

Morsy T et al., 1995. Demodex (follicular mite) infesting a boy and his pet dog. Journal of the Egyptian Society of Parasitology 25: 509-512.

Naimer S et al., 2002. Household papular urticaria. The Israel Medical Association journal 4: 911-913.

Nárez G et al., 1999. Seguimiento de un brote de *Brucella canis* en un criadero de perros en la ciudad de Mexico. Revista Mexicana de Ciencias Pecuarias 37: 43-50.

Paixão TA et al., 2009. Establishment of systemic *Brucella melitensis* infection through the digestive tract requires urease, the type IV secretion system, and lipopolysaccharide O antigen. Infection and Immunity 77: 4197-4208.

Petra B et al., 2018. Canine babesiosis: Where do we stand? Acta Veterinaria 68: 127-160.

Pfukenyi DM et al., 2010. A survey of pet ownership, awareness and public knowledge of pet zoonoses with particular reference to roundworms and hookworms in Harare, Zimbabwe. Tropical Animal Health Production 42: 247–252

Rinaldi L et al., 2007. A survey of fleas on dogs in southern Italy. Veterinary Parasitology 14: 375-378.

Rodríguez-Vivas RI et al., 2003. Factors affecting the prevalence of mange-mite infestations in stray dogs of Yucatán, Mexico. Veterinary Parasitology 115: 61-65.

Sánchez-Jiménez M et al., 2013. Infección por *Brucella canis* en humanos: propuesta de un modelo teórico de infección a través de la ruta oral. Infectio 17: 193-200.

Scorza V and Lappin MR, 2021. Giardiasis. In: Saunders EB, editor. Greene's Infectious Diseases of the Dog and Cat; pp: 1263-1277.

Scott D and Horn Jr R, 1987. Zoonotic dermatoses of dogs and cats. Veterinary Clinics of North America: Small Animal Practice 17: 117-144.

Segundo C et al., 2004. Superficial infections caused by *Microsporum canis* in humans and animals. Revista Iberoamericana de Micologia 21(1): 39:41.

Shiferaw ML et al., 2017. Frameworks for preventing, detecting, and controlling zoonotic diseases. Emerging infectious diseases, 23(Suppl 1): S71.

Solano-Gallego L et al., 2011. LeishVet guidelines for the practical management of canine leishmaniosis. Parasites and Vectors 4: 1-16.

Sunderkötter C et al., 2016. S1 guidelines on the diagnosis and treatment of scabies–short version. JDDG: Journal der Deutschen Dermatologischen Gesellschaft 14(11): 1155-1167.

Timm BL et al., 2023. Arylimidamides Have Potential for Chemoprophylaxis against Blood-Transmitted Chagas Disease. Pathogens 12(5): 701.

Tołkacz K et al., 2017. Prevalence, genetic identity and vertical transmission of *Babesia microti* in three naturally infected species of vole, Microtus spp. (Cricetidae). Parasites and Vectors 10: 1-12.

Vannier E and Krause PJ, 2012. Human Babesiosis. New England Journal of Medicine 366: 2397-2407.

Van Knapen F and Overgaauw P, 2015. Dogs and transmission of infection to man, "respected member of the family?" In: Sing A, editor. Zoonoses-Infections Affecting Humans and Animals: Focus on Public Health Aspects; pp. 575–585.

Wagner R and Stallmeister N, 2000. *Cheyletiella dermatitis* in humans, dogs and cats. British Journal of Dermatology 143: 1110-1112.

Walton SF et al., 1999. Genetically distinct dog-derived and human-derived *Sarcoptes scabiei* in scabies-endemic communities in northern Australia. The American Journal of Tropical Medicine and Hygiene 61: 542-547

Wanke MM, 2004. Canine brucellosis. Animal Reproduction Science 82–83: 195-207.

Weese J and Peregrine A 2011. Parasitic diseases. In: Weese J and Fulford M, editors. Companion Animal Zoonoses; pp. 3-108.

World Health Organization, 2008. Leptospirosis humana: guía para el diagnóstico, vigilancia y control.

World Health Organization, 2011. Report of the second meeting of the leptospirosis burden epidemiology reference group.

Xhaxhiu L et al., 2009. Ectoparasites of dogs and cats in Albania. Parasitology Research 105: 1577-1587.

Young et al., 2020. Efficacy of lotilaner (Credelio™) against the adult cat flea, *Ctenocephalides felis* and flea eggs following oral administration to dogs. Parasites Vectors 13: 25.

Zafar A, Beidas S and Sylvester L 2002. Control of transmission of Norwegian scabies. Infection Control & Hospital Epidemiology 23: 278–279.