Infectious agent
Lyme disease, also known as Lyme borreliosis, is caused by gram-negative, spirochete bacteria of the genus *Borrelia*. The etiologic agent in North America is *Borrelia burgdorferi*, whereas disease in Europe or Asia may be caused by *B. burgdorferi*, *B. garinii*, *B. afzelii*, or *B. japonica* (Fritz and Kjemtrup, 2003; Rabinowitz and Conti, 2009).

Lyme disease is the most commonly reported arthropod-borne bacterial infection in the United States (Bacon et al., 2008). It produces an acute, flu-like illness in the early stage of disease, and more serious chronic manifestations can develop weeks to years later.

Geographical occurrence
Lyme disease occurs throughout much of the United States and Canada, Europe, Russia, China, and Japan (Heymann, 2008). In the United States, the vast majority of cases occur in the Northeast and upper Midwest. Over 90% of cases are reported from just 10 states: Connecticut, Delaware, Massachusetts, Maryland, Minnesota, New Jersey, New York, Pennsylvania, Rhode Island, and Wisconsin (Bacon et al., 2008).

Reservoirs
In the northeastern and upper midwestern United States, the white-footed mouse is the primary reservoir of *B. burgdorferi* (Fritz and Kjemtrup, 2003). Other small rodents can also serve as important hosts, particularly in the western part of the country. Deer are a key maintenance host for the adult ticks that transmit Lyme disease, but they are not a competent reservoir for *B. burgdorferi* (Fritz and Kjemtrup, 2003). The main vectors of Lyme disease are *Ixodes scapularis* (deer tick) in the eastern United States and *I. pacificus* (Western black-legged tick) in the western U.S. (Little et al., 2010). The larval and nymph stages of these ticks acquire *B. burgdorferi* by taking a blood meal from infected white-footed mice or other small rodents. *B. burgdorferi* can also be transmitted trans-stadially from larva to nymph, as well as from nymph to adult (Fritz and Kjemtrup, 2003). *Ixodes* spp. nymphs are the most important stage for transmission of Lyme disease to people. Adult ticks generally feed on deer and are the most common source of Lyme disease transmission to dogs (Little et al., 2010).

Mode of transmission
Transmission of *B. burgdorferi* is via a bite from an infected *Ixodes* spp. tick. The 3-stage life cycle of these ticks dictates the seasonality of human cases. Eggs are laid by adults in the spring, and the larvae hatch in the summer. Maturation into the nymph stage requires a blood meal, and infection with *B. burgdorferi* occurs if larvae feed on infected white-footed mice or other small rodents. These larvae mature into nymphs by the following spring, at which point they begin seeking a blood meal that will permit development into the adult stage (Rabinowitz and Conti, 2009). Thus, most human cases occur in the spring and summer as a consequence of exposure to infected nymphs (Rabinowitz and Conti, 2009). Eggs are laid the following spring to complete the life cycle. It is thought that the tick must feed for about 24 hours in order for transmission of to occur, although transmission becomes more efficient after about 48 hours (Schwan and Piesman, 2000; Pal et al., 2004). A primary risk factor for Lyme disease is residing in a region of dense, undisturbed vegetation within an endemic area. Other risk factors include hiking, camping, or engaging in any outdoor activity in an endemic area (Ley et al., 1995; Orloski et al., 1998; Smith et al., 2001; Fritz and Kjemtrup, 2003).

Clinical signs
Approximately 95% of dogs infected with *B. burgdorferi* are asymptomatic (Little et al., 2010). Among dogs that do develop clinical disease, the incubation period is typically between 2-5 months (Fritz and Kjemtrup, 2003). Signs include
fever, lameness (may be a shifting leg lameness), swollen and painful joints (especially the carpus and tarsus), lymphadenopathy, anorexia, and lethargy (Fritz and Kjemtrup, 2003; Greene, 2006; Rabinowitz and Conti, 2009). Dogs with chronic infections may develop glomerulonephritis, which frequently progresses to renal failure and death (Little et al., 2010). The characteristic rash that often develops at the site of the tick bite in people is not known to occur in dogs (Little et al., 2010). Feline Lyme disease is poorly described; infected cats are typically asymptomatic, although fever, lameness, and arthritis may occur in rare cases (Fritz and Kjemtrup, 2003). Infected horses also remain clinically normal in most cases, but fever and lameness may be seen (Smith, 2008). The association between infection and clinical disease is tenuous in cattle, but signs may include fever, lameness, and abortion (Divers and Peek, 2008).

Diagnosis
Diagnosis is made via serologic testing in conjunction with compatible history and clinical signs. The C6 antibody assay detects antibodies against a synthetic C6 peptide derived from B. burgdorferi antigen (Littman et al., 2006). The presence of antibodies against this particular antigen confirms natural exposure to the organism; thus, Lyme vaccination will not cause a false-positive result. However, a positive C6 antibody result demonstrates B. burgdorferi exposure only and is not sufficient to prove clinical Lyme disease (Littman et al., 2006). Diagnosis therefore requires other supportive findings, including clinical signs of borreliosis, confirmed or suspected exposure to Ixodes spp. ticks in an endemic area, and favorable response to appropriate antimicrobial therapy (Littman et al., 2006; Little et al., 2010). It is also important to bear in mind that dogs with positive serologic results are often co-infected with other pathogens, including Anaplasma phagocytophilum, Babesia spp., Ehrlichia spp., and Rickettsia rickettsii (Littman et al., 2006).

Treatment
Dogs with Lyme disease are treated with an antibiotic, with doxycycline being the most common choice and amoxicillin as a viable alternative (Littman et al., 2006; Little et al., 2010). Evidence of Lyme nephropathy dictates more aggressive therapy, including intravenous fluids and other treatments directed at glomerulonephritis. There is no clear consensus on the management of asymptomatic dogs with positive serologic test results, but antimicrobial therapy is typically not indicated because so few of these patients are likely to develop clinical Lyme disease (Littman et al., 2006).

Disease in humans
Unlike dogs, the majority of people infected with B. burgdorferi will develop clinical disease. There are approximately 20,000 human cases of Lyme disease reported annually in the United States (Bacon et al., 2008). Most of these occur in the spring and summer because of the life cycle of the tick vector. The initial symptom in about 70-80% of cases is a skin rash known as erythema migrans (EM), located at the site of the tick bite (Little et al., 2010). This is a red rash that expands in an annular fashion over the course of several days, often with central clearing to create the classic bull's-eye appearance. The incubation period for EM is typically between 7-10 days but can range from 3-32 days (Heymann, 2008). Vague, flu-like symptoms generally accompany EM and include fever, headache, fatigue, myalgia, arthralgia, and lymphadenopathy (Rabinowitz and Conti, 2009). In untreated patients, dissemination of the bacteria can lead to a wide array of potential complications over the following weeks to months. These include neurologic disease (particularly meningitis and facial nerve paralysis) (Bingham et al., 1995; Halperin, 1995), cardiac disease (myocarditis with atrioventricular block) (Lelovas et al., 2008; Costello et al., 2009), and arthritis of large joints such as the knees (Steere, 1995; Puius and Kalish, 2008). It is important to note that a similar infection termed southern tick-associated rash illness (STARI) is seen among human patients in the southern U.S. The etiologic agent of this disease may be Borrelia lonestari but is currently unconfirmed; it is transmitted by the Lone Star tick (Clinton et al., 2010). Patients present with erythema migrans and flu-like symptoms, but serologic evidence of B. burgdorferi infection is absent.
Preventive veterinary measures

- Educate clients to keep themselves and their pets out of tick-infested areas whenever possible.

- Advise clients to be diligent regarding the use of tick control for their pets. This also promotes human health by limiting the number of reproductively active adult ticks in the environment around the home.

- Counsel clients to perform frequent tick checks on themselves and their pets and to promptly remove any attached ticks using forceps or a specific tick-removal instrument. Remember that wearing light-colored clothing while outside will facilitate the detection of ticks.

- Consider the use of a *B. burgdorferi* vaccine for dogs living in endemic areas.

- Educate the public to use protective clothing and repellents in order to avoid bites by tick vectors.

- Advise the public to manage the habitat surrounding the home in such a way to reduce tick populations; this includes keeping shrubs and grass closely trimmed, removing brush and leaf litter, and using mulch as a barrier between wooded areas and lawns (Fritz and Kjemtrup, 2003; Rabinowitz and Conti, 2009; Little et al., 2010).
References


