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Lyme Disease: A Grand Challenge

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Abstract

Lyme disease (Lyme borreliosis), first discovered in 1908, is the most common vector-borne disease in the United States, with around 476,000 new cases per year. As a global disease, the impact of Lyme disease is such that it should be thought of as one of the Grand Challenges in Global Health. Despite its pervasiveness, there are very few approved tests that are accurate in detecting it. Similarly, there are even fewer treatments for Lyme disease after it passes its initial stages. It is vital for the medical community and the general public to further educate themselves on the early symptoms of Lyme disease and the overall prevalence of vector-borne illnesses so that they can be treated before they suffer immense repercussions. Moreover, further research needs to be done into treatments, testing, and the impact of climate change on disease risk.

Keywords: Identity, Gender, Socioeconomic class, Education, Politics

1. Introduction

1.1 Objectives

Aims of this review article:

a) To raise awareness about the prevalence and impact of Lyme disease as a Grand Challenge in Global Health.
b) To highlight the need for accurate diagnostic tests for Lyme disease.
c) To emphasize the importance of early detection and treatment of Lyme disease.
d) To identify the gaps in research related to treatments, testing, and the impact of climate change on disease risk.

1.2 Hypotheses/Implications

The prevalence of Lyme disease is significantly underestimated, and there is an increased need for education and awareness related to the early symptoms and ubiquity of it. Current diagnostic tests for Lyme disease, such as the two-tier serological test, have limitations and may lead to false results, indicating a need for the development of more specific and sensitive tests. The early detection and prompt treatment of this disease can markedly reduce the risks of long-term complications and patient outcomes. Further research on treatments, testing methods, and the impact of climate change on disease risk contribute to the development of more effective strategies for Lyme disease prevention and treatment.

This review provides a broad synopsis of Lyme disease and highlights important areas for further examination. The details discussed, and information provided support the provided objectives.

1.3 Background

The discovery of diseases is not usually accredited to dermatologists; however, this has been known to occur in specific instances. Dermatologists, as its prefix "derma" would imply, specialize in skin-based conditions, putting

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them at the forefront of uncovering diseases or markings indicative of a particular disease. One of these distinctive lesions is the erythema migrans (EM), a tell-tale sign of Lyme Disease (LD) (Radolf, et al., 2020; Bockenstedt and Wormser, 2014; Bratton, et al., 2008), which a Swedish dermatologist named Arvid Afzelius first observed in 1908 (Burgdorfer, et al., 1983; Afzelius, 1921) and was soon associated as a symptom of a tick bite (Bratton, et al., 2008). Despite being observed in Europe during the early 1900s, erythema migrans would not be reported in the United States until 1970 by a Wisconsin dermatologist named Rudolph Scrimenti (Radolf, et al., 2020). Shortly after this, physicians in New England identified groups of children in areas near Lyme, CT, who shared a strange rash that resembled EM and had other symptoms that had previously been associated with it. Due to the close geographical proximity of the children and the symptoms that they had in common, the belief was that the children all had a similar illness, likely transmitted by a tick. In 1977, more than half a decade after EM was first observed, the condition the children suffered from was named Lyme Disease (Bratton, et al., 2008).

Following the discovery of LD in the United States, scientists began researching potential causes of the condition. Soon, in 1981, Willy Burgdorfer and colleagues uncovered a previously unknown spirochete known today as *Borrelia burgdorferi* (Steere, et al., 2004; Radolf, et al., 2020). Later, *Borrelia burgdorferi* spirochetes were found in the intestinal tracts of *Ixodes dammini* ticks, known today as *Ixodes scapularis*. Subsequently, in 1982, The Centers for Disease Control and Prevention (CDC) began surveillance for Lyme disease; by 1991, Lyme disease was classified as a nationally reportable disease. After starting surveillance, researchers noticed a gradual uptick in cases each year. By 1992, there had been 9677 confirmed cases of Lyme Disease across 47 states, a slight increase from the year prior (Lyme Disease 4, n.d., 1993). Most cases were reported from the Northeast, Mid-Atlantic, and Pacific Coastal regions (Lyme Disease 3, n.d., 1994). This steady increase in cases would continue into the new millennium, with cases going from around 11,000 in 1995 to approximately 18,000 in 2000 (Lyme Disease 1, n.d., 1997; Lyme Disease 2, n.d., 2002). Figure 1 demonstrates the yearly increase in Lyme disease cases in the United States.

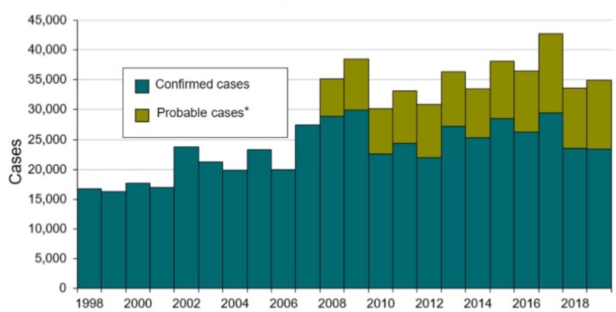

Figure 1. Reported cases of Lyme disease in the United States by year; 1998-2019. (Surveillance Data, 2022)

Today, Lyme disease is the most reported vector-borne illness in the United States, having been reported in all 50 states (NCEZID: Vector-Borne Diseases, 2019). Although state and local health departments estimate that there are around 35,000 new cases of Lyme disease each year, the CDC estimates that about 476,000 Americans are diagnosed with Lyme and receive treatment for it each year. Despite the high number of new cases reported to the CDC each year, the National Institutes of Health (NIH) investment in research into Lyme disease remains relatively small compared to other infectious diseases (Bobe, et al., 2021). In addition to the increase in cases each year since its discovery, Lyme disease case numbers in each state have also been increasing accordingly. Much like that of the United States, the incidence of Lyme Disease continues to grow in both Canada and Europe, with Western Europe having greater than 200,000 cases per year (Marques, et al., 2021), and Canada has its highest number of cases to date in 2021, with nearly 3,000 cases (Lyme disease: Monitoring*,* 2022). The incidence of LD in Europe is highest in Northern Europe, most notably in Scandinavian states. Additionally, LD is prevalent in Central Europe. In particular, Czechia, Germany, Austria, and nations in the Balkan Peninsula. Interestingly, *B. burgdorferi* is not found in *I. ricinus and I. persulcatus;* instead, LD is caused by *B. garinii and B. afzelii,* with most cases of LD in Europe being caused by *B. afzelii. To date,* neither of these *Borrelia* strands is found in the United States (Marques, et al., 2021; Vanderkerckhove, et al., 2019). Much like their Western counterparts, China also suffers from endemic Lyme disease, with confirmed cases in 29 out of 31 provinces. (Wu, et al., 2013) In the four northernmost provinces, approximately 3 million are bitten by ticks, with around 30,000 people infected with Lyme borreliosis (Wu, et al., 2013). Inexplicably, LD in China is more complex than LD in other regions. There is a noticeable difference in the species of tick and Borrelia between Northern and Southern China. Northern China is the

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less complex region, with I. persulcatus acting as the primary vector, transmitting both B. afzelii and B. garinii. However, in Southern China, it has yet to be entirely known what the most prominent vector is; however, it is likely one of I. granulatus or H. bispinosa. Despite this, the peak of incidence is the same in both regions between June and August (Wu et al., 2013; Hao et al., 2011). With the global reach of Lyme disease and the classification of vector-borne illnesses as Grand Challenges in Global Health, Lyme disease should be thought of as one of these Grand Challenges that the world must invest funding into in attempts to find a means of prevention and a potential cure.

Table 1: Disease expenditures and number of reported cases.

Disease	NIH Funding FY 2021 (in millions)	Most recent number of reported cases in the USA	Funding reported per case	Deaths per year in the United States
HIV/AIDS	$3,082	34,800[b]	$88,563	~13,000
Malaria	$229	~2,000[c]	~$114,500	~5
Tuberculosis	$594	7,174[d]	~$82,800	526
Hepatitis-B	$149	~3,000[e]	$49,666	~3,000
Lyme disease	$39	~ 34,945[f] (~476,000 estimated cases)[g]	$1,116 ($81.93 per estimated case)	N/A

a. https://report.nih.gov/funding/categorical-spending#/
b. https://www.hiv.gov/hiv-basics/overview/data-and-trends/statistics
c https://www.cdc.gov/parasites/malaria/index.html
d https://www.cdc.gov/tb/statistics/tbcases.htm
e https://www.cdc.gov/hepatitis/statistics/2018surveillance/HepB.htm
f. https://wonder.cdc.gov/nndss/static/2019/annual/2019-table2j.html
g. https://www.cdc.gov/lyme/stats/humancases.html

2. Clinical Manifestations

In most cases, patients experience the onset of LD in stages in reaction to the immune response of the *Borrelia burgdorferi* spirochete. The first stage, known as early localized LD, is estimated to occur 3-30 days after being bitten and presents in most cases as an erythematous, annular-shaped lesion that often contains a defined center and expands outwards. This lesion, colloquially known as a "bullseye rash" due to its likening to a bullseye, is the EM lesion that Afzelius discovered in 1908 (shown in figure 2). Despite a widespread belief that one must display EM to have Lyme disease, EM is not present in around 15-30% of patients (CDC, 2022; Aucott, et al., 2009; Bratton, et al., 2008). In addition to EM, most patients experience "flu-like symptoms," including but not limited to fever, chills, fatigue, joint pain, headache, and myalgia. In some cases where there is a lack of EM, patients can experience swelling of the lymph nodes. Occasionally, there can be a tingling or burning sensation associated with EM. Intriguingly, many cases of LD in Europe display clinical manifestations that have not been observed in other regions: Acrodermatitis chronica atrophicans (ACA) and Borrelial lymphocytoma. ACA is a cutaneous manifestation of LD primarily found on the hands and feet. It begins with a reddish-blue discoloration as well as swelling of the skin. This swelling continues to enlarge and can be followed by atrophic changes several months to years later. Borrelial

Figure 2. A, B, and C. Erythema migrans presenting as a single lesion (A, B) and as multiple lesions (C). (Lyme Disease Rashes and Look-Alikes, 2022)

lymphocytoma first appears as a small area of skin induration which slowly grows into a solitary nodule. It is primarily found on the breast in adults and on the earlobes of children. Due to the lack of a presence of these manifestations in the United States, they are likely caused by the *B. afezlii* infection (Marques, et al., 2021).

Following the conclusion of the early localized infection, the disease progresses to the early disseminated stage, occurring days to weeks after infection. As spirochetes spread from the site of infection, additional EMs can appear (Bobe, et al., 2021). Furthermore, patients can develop various musculoskeletal symptoms such as migratory muscle or joint pain, swelling of the joints, and the development of arthritis. Neurological issues can also appear weeks or months after infection, most often as potentially bilateral seventh cranial nerve palsy. Meningitis, radicular neuropathies, and neuroborreliosis can occur with or without nerve palsy. If left untreated after this stage, LD progresses to its final stage, late disseminated infection. Symptoms of this stage can include intermittent pain and swelling of one or more joints, typically the knees and hips. Like in the early disseminated stage, neurological manifestations such as polyneuropathy and encephalomyelitis can develop (Radolf, et al., 2020; Bockenstedt and Wormer, 2014). Encephalomyelitis specifically can cause somewhat debilitating effects, including insomnia, changes in personality, and impaired mental ability, leading to memory issues and brain fog.

Arguably the most severe symptom of LD is Lyme carditis. Despite being present in only 1% of cases reported to the CDC (Bockenstedt and Wormer, 2014), Lyme carditis is unlike other LD symptoms because it can be deadly. Patients might experience heart palpitations, shortness of breath, and lightheadedness, common symptoms of an atrioventricular nodal block. If left untreated, Lyme carditis can progress to a complete heart block, which could cause a higher probability of sudden death. This symptom can manifest in any of the stages discussed above. It is believed to occur because of *Borrelia* spp. coming in contact with heart tissue. This action causes an exaggerated macrophagic and lymphocytic response within cardiac tissues (Lyme carditis: A can't miss diagnosis., 2020). Despite the relatively small number of spirochetes found within the heart tissue of this Lyme carditis, there tends to be an excessive inflammatory response. Despite the severity of the symptom, it can be fully treated with the appropriate antibiotics and therapy (Lyme carditis: A can't miss diagnosis., 2020).

3. Diagnosis & Testing

In most cases, LD is diagnosed based on the presence of clinical manifestations such as an EM lesion. Keeping in track with other tick-borne illnesses, anywhere from 30-50% of patients do not recall a tick bite, usually because deer tick nymphs are small and can go unnoticed. Typically, standard laboratory tests are not well equipped to diagnose LD as they cannot distinguish it from other entities (Bockenstedt and Wormser., 2014; Bratton et al., 2008). White blood cell counts have the potential to be elevated or standard, and the results of hemoglobin, hematocrit, creatinine, and urinalysis testing all tend to be within expected limits. Furthermore, PCR testing of blood, serum, or plasma is unreliable for diagnosing LD because spirochetes are transient and have a low copy number (Bobe, et al., 2021). However, in the early stages of infection, liver function tests may reveal mild elevations (Bockenstedt and Worsmer., 2014). A biopsy of the EM lesion is a more helpful tool for diagnosis, but this step is unnecessary, as those with an EM lesion should begin antibiotic treatment as soon as diagnosed.

The mainstay of laboratory diagnosis for LD is a two-tier serological test consisting of first an enzyme-linked immunoblot assay (ELISA) followed by a separate Western immunoblot test if the ELISA result is positive or equivocal (Bobe, et al., 2021; Sanchez et al., 2016; Bockenstedt and Wormser, 2014; Stricker and Johnson., 2011; Bratton, et al., 2008). The reasoning for the two-tiered structure of testing is that the ELISA test detects antibodies but does not test specifically for *B. burgdorferi*. In many cases, this can provide false positives, but if it is negative, it is unlikely that the patient has LD. A concern arises with false negatives, as in early cases of LD, it is improbable that *B. burgdorferi* antibodies will be present. If the test is positive or inconclusive, it is then recommended for the patient to undergo a Western blot test. If this result is positive, the patient has likely contracted LD. If the result is negative, it suggests that the patient does not have LD and the ELISA test was a false positive (Lyme Disease Diagnostics Research, 2022). In addition, serological tests are incapable of distinguishing prior exposure to *B. burgdorferi* from an active infection (Bobe, et al., 2021). However, this test is not necessarily essential to diagnosing LD and primarily acts as a tool to further confirm diagnosis after the presence of an EM lesion.

To date, there are very few FDA-approved tests for diagnosing LD. The two-tiered serological testing remains the most common form of LD test and is primarily recommended by the CDC. However, this test is not without its faults, and those who seek it should be wary of false results. Naturally, this should be of concern since not all LD patients develop an EM lesion. There is a need for a highly sensitive and specific test that can reliably detect infection of multiple strains of *Borrelia* at all stages of infection.

4. Coinfections

Despite the prevalence of LD in the US, it is not widely known to physicians that several coinfections can be found along with it that can cause a variety of symptoms and make treatment for LD more complicated. Of these coinfections, Babesiosis, Human Granulocytic Anaplasmosis (HGA), and Bartonella are the most commonly found in LD patients.

4.1 Babesiosis

Babesiosis, a worldwide tick-borne infection caused by hemoprotozoan parasites of the genus Babesia, has a similar geographic expansion to that of LD, albeit more restricted. This infection is spread via the bites of Ixodes ticks, a commonality between LD and its coinfections. The bacteria that cause this condition is *Babesia microti*, and the prevalence of *B. microti* infection in nymphal *I. scapularis* ticks can range from 1% in areas where it has recently become endemic to around 20% in well-established areas (Vannier, et al., 2015). Babesiosis has a lower incidence than LD, despite an exponential increase in the past five decades, a more significant proportion of asymptomatic infection, and a more remarkable lack of physician awareness.

Diagnosis of active babesiosis is usually made via visualization of Babesia parasites on Giemsa- or Wright-stained thin blood smears (Sanchez, et al., 2016). Due to the small size of the Babesia parasites, thick blood smears are not recommended. Symptoms can include chills, sweats, headaches, body aches, nausea, fatigue, and loss of appetite. Since *Babesia* parasites infect red blood cells, babesiosis can lead to hemolytic anemia, a disorder in which red blood cells are destroyed faster than they can be produced (CDC, 2022; Hemolytic Anemia, 2022). A one-week course of antibiotics should be considered for those with an asymptomatic Babesia infection. For those suffering from mild to moderate babesiosis, a 7–10-day course of antibiotics such as atovaquone and azithromycin or clindamycin and quinine is recommended for severe babesiosis, which typically develops in patients who suffer from external risk factors, intravenous treatments in hospitals are recommended.

4.2 HGA

Human Granulocytic Anaplasmosis (HGA) is a deer tick-transmitted rickettsial infection commonly found in the Northeast and Upper Midwest and a common cause of fever. Although the disease usually resolves in most cases, as many as 3% of patients may develop life-threatening complications, and almost 1% succumb to these complications (Bakken and Dumler., 2015). The incidence of HGA increased 12-fold between 2001 and 2011 (Bakken and Dumler., 2015). HGA is carried by *Ixodes scapularis* ticks in the Northeast and Midwestern United States and by the *Ixodes pacificus* throughout the West Coast (Transmission, 2022). The usual symptoms of HGA include fever, chills, severe headache, nausea, vomiting, diarrhea, and muscle aches. However, if left untreated, HGA can cause severe illness, including bleeding problems, respiratory failure, organ failure, and death. (CDC, 2022). Much like LD, HGA is commonly treated with antibiotics, most commonly doxycycline. Doxycycline treatment is highly efficacious, and there tends to be a marked improvement in symptoms within 24-72 hours (CDC, 2022)

4.3 Bartonella

Bartonellosis, also known as cat scratch disease, is a condition carried by vectors, primarily fleas and animal bites. It is caused by the *Bartonella henselae* bacterium, an intracellular parasite that prefers red blood cells and endothelial cells (Bartonellosis, 2022). It has previously been thought that *B. henselae* is not transmittable via tick bite. However, studies have shown that *Ixodes* ticks can potentially be vectors for *B. henselae* (Cotté, et al., 2008). Bartonellosis first appears as a papule which eventually develops into a pustule. In patients with competent immune systems, symptoms are typically limited to region adenopathy and occasional fevers. However, in immunocompromised patients, more severe symptoms such as bacillary angiomatosis, a condition in which tumor-like masses form due to the proliferation of blood vessels, and endocarditis (Bartonellosis, 2022). Other manifestations of Bartonellosis can include but are not limited to depression, reduced impulse control, sleep disorders, Guillain-Barré syndrome, and osteomyelitis (Berghoff., 2012). Antibiotic treatment is not usually recommended for those with competent immune systems, as the infection should resolve independently. However, antibiotic treatment, such as doxycycline and erythromycin, is recommended for those with more severe symptoms or a more complicated condition.

5. Treatments and preventions

If caught in its early stages, Lyme disease can be effectively treated with oral antibiotics such as doxycycline or amoxicillin for 14-21 days (Bobe, et al., 2021). However, a shorter treatment is less effective as the disease progresses, and a longer treatment time is likely recommended. In cases of neurologic-Lyme disease, such as meningitis or Lyme arthritis, oral antibiotics are less effective, and intravenous antibiotics are preferable (Johns Lyme Disease Treatment, 2022). Several studies have found that complementary natural and herbal products can help treat LD (Bobe, et al., 2021). These treatments have been shown to have activity against *Bb and Babesia*, but further trials are needed to evaluate their effectiveness. Approximately 7-30% of LD patients develop Jarisch-Herxheimer reaction (JHR) (Nykytyuk, et al., 2020; Bratton, et al., 2008) within 24 hours of starting therapy. This reaction appears as a worsening of LD symptoms such as fever, sweating, general malaise, and headache. The JHR is believed to be caused by the release of harmful toxins by dying microorganisms during antibiotic treatment, but the cause is not definitively known. The clinical manifestations of JHR can vary in expression, time of onset, and duration. As a result, physicians tend not to be aware of the presence of JHR and mistake it for an allergic reaction to antibiotic treatment (Nykytyuk, et al., 2020).

The concept of a vaccine for LD is one of much discussion. While a vaccine was developed and approved for use in the late 1990s, it was quickly made unavailable to the public. Limited efficacy, low demand, high price, and a potential association with the development of autoimmune-related arthritis led to the downfall of the original LD vaccine. In 2017, the French biotech company Valneva began developing an LD vaccine with the help of Pfizer. This vaccine, dubbed VLA15, has proved promising in early animal-based trials as it has shown efficacy against spirochetes that express the outer surface protein A (OspA), an abundant immunogenic lipoprotein of *Borrelia burgdorferi* (Comstedt, et al., 2017). Preclinical studies have shown that immunization with VLA15 has demonstrated protection from five types of OspA, and in addition to this, antibodies that contain VLA15 provide further protection upon passive immunization (Comstedt, et al., 2017)

Personal protection measures should be taken in areas where LD is expected to prevent infection. Such protection methods include but are not limited to protective clothing and insect repellants. Many health organizations recommend that those in areas where ticks are commonly found wear long-sleeved, light-colored clothing so that ticks are more visible if attached (Ticks and Lyme Disease, 2022). It is also recommended to avoid walking through tall bushes and other vegetation and instead walk in the center of trails. Moreover, it is recommended to tuck pant legs into socks or shoes and tuck shirts into the waistband of pants to prevent ticks from crawling through the space between articles of clothing to get to the skin. The Environmental Protection Agency (EPA) recommends using registered insect repellents that contain 20% or higher concentration of DEET for skin and products that contain 0.5% permethrin for clothing to prevent LD. (Prevent Lyme Disease, 2022; Symptoms and causes, 2022)

5.1 Ten suggestions that can help prevent the contraction of Lyme disease

- Know where to expect ticks.
- Seek to avoid brushy, woody, and grassy areas. Especially during regional periods of high tick activity

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- Wear long pants and long-sleeved shirts, as well as closed-toed shoes.
- Wear light-colored clothing for easier visibility of ticks present on clothing.
- Wear a hat
- Tuck pant legs into socks or shoes, and tuck shirts into pants
- Apply an insect repellant that contains DEET on clothing and uncovered skin
- Walk in the center of trails
- Carefully check for ticks after outdoor activities
- Look into potentially purchasing repellent-treated clothing.

6. Post-Lyme Disease Syndrome

Post-Lyme Disease Syndrome (PTLDS), also called chronic Lyme disease, is a term typically applied to people with otherwise-unexplained symptoms of LD lasting more than six months after completion of antibiotic treatment. PTLDS occurs in below 10% of patients diagnosed and treated for LD (Bockenstedt and Wormser., 2014.) Despite this, PTLDS can be debilitating with persistent and recurring symptoms of PTLDS, including severe fatigue, myalgias, cognitive disruptions, and arthralgias (without the presence of arthritis) (Bobe, et al., 2021; Rebman and Aucott, 2020; Bratton, et al., 2008). More symptoms are displayed in Figure 3, as shown below.

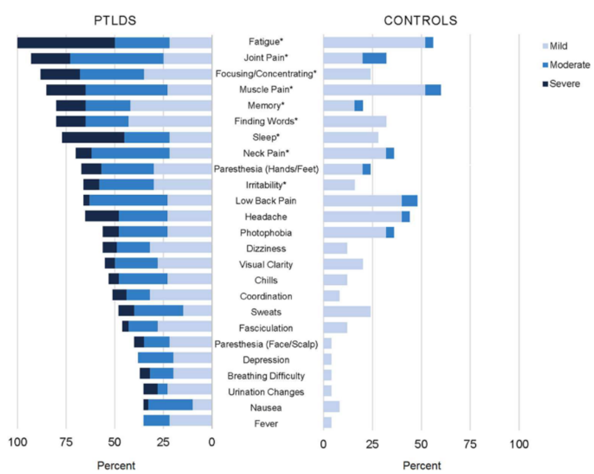

Figure 4. Participants with PTLDS and controls were asked about the presence and severity of 36 signs/symptoms over the past two weeks. The 25 signs/symptoms display a statistically significant difference in severity by group. (Teixeira, et al., 2017)

The reasons for the continuation of symptoms in some patients following treatment for LD are unknown. Residual tissue damage, slowly resolving inflammation, and a cytokine-induced illness because of raised levels of circulating cytokines before and during treatment of LD (Bockenstedt and Wormser, 2014; Bratton et al., 2008). These symptoms can last for months or years following treatment of LD, and there are no FDA-approved or commonly agreed-upon treatments for patients suffering from PTLDS (Bobe, et al., 2021; Rebman and Aucott, 2020).

Furthermore, no current test can objectively prove the presence of PTLDS, and there seems to be no commonality in antibody levels found in those who suffer from PTLDS (Bobe, et al, 2021; Bockenstedt and Wormser, 2014). According to the CDC, patients with PTLDS typically get better as time goes on; however, it can take many months or years to feel completely well.

7. Remaining Problems

To date, LD case numbers continue to increase at an increasing rate and do not show any signs of stopping. The issue of climate change should concern all sectors of the world, especially the medical and vector-borne illness community. According to the American Public Health Association (APHA), the development of ticks, and LD via proxy, is heavily influenced by climatic factors. More specifically, temperature, precipitation, and humidity. With the looming threat of global warming, areas with a high incidence of LD will likely experience milder winters and, as a result, an increase in both tick population and risk of contracting LD (APHA, 2022.) The life cycle and abundance of *Ixodes* ticks, particularly *scapularis*, are strongly influenced by temperature (Dumic and Severnini, 2018), with *I. scapularis* being most active in areas with temperatures above 45˚F and prospering in areas with at least 85% humidity

(EPA, 2022). It is clear to see the link between rising temperatures and humidity and increased tick population. It has been falsely believed in the past that reforestation aided the expansion of the tick life cycle in the northeastern United States during the initial emergence of LD; new studies have shown that despite deforestation, *I. scapularis* population continues to increase and expand into new areas. It can be assumed that a considerable increase in the incidence of LD cases in endemic regions is at hand. This logic should alert public health agencies and officials, physicians, and everyday people to the imminent vector-borne illness crisis we will soon face. In times such as this, it is crucial for physicians and the general populace to educate themselves to be aware of the early symptoms of prevalent vector-borne illnesses, which can effectively be treated before debilitating consequences ensue. Moreover, vector-borne illnesses should be treated as a serious issue by public health authorities and thought of like other Grand Challenges in Global Health. As a result, there should be a vast increase in funding not only for Lyme disease but also for vector-borne illnesses as a whole.

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