Lyme Disease: Epidemiology, Current and Developing Treatment Options

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Abstract

The most frequently reported arthropod-borne sickness is Lyme disease, mostly reported in the United States, Europe, and Asia and is brought on by the spirochete *Borrelia burgdorferi*. Lyme disease is a multisystemic infection that affects multiple organs and is spread by tick bites. It is most common in the spring and summer season. According to recent data, the number of annual cases has increased, with over 476,000 cases documented since 2010. The illness exhibits a bimodal age distribution, with children aged 5 to 9 and adults aged 55 to 59 having the highest prevalence. Although it has historically been concentrated in New England and the surrounding areas, its geographic reach is noteworthy. Early localised symptoms include erythema migrans; second-stage heart and neurological problems; and third-stage chronic arthritis are the clinical presentations. Due to the available tests' limited sensitivity and specificity, diagnosis is still difficult. Antibiotics are usually an effective treatment in the early stages, but more intense management may be needed for late-stage symptoms. Avoiding tick exposure is the mainstay of preventative measures, and despite past failures, attempts are still being made to create viable vaccines. In order to improve public awareness and prevention efforts and lessen the growing threat of Lyme disease, comprehensive initiatives are necessary.

Keywords: Tick bites, Erythema migrans, Lyme disease, *Borrelia burgdorferi*, Antibiotics and vaccines.

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Introduction

Lyme disease, also known as Lyme borreliosis, was identified as a significant new pathogen in the late 20th century. In the United States, Europe, and Asia, it is currently the most often reported arthropod-borne disease (Pal et al., 2023). It is a multisystemic illness that affects numerous organs, including the heart, joints, skin, and neurological system (Mahajan, 2023). It happens more often in the spring and summer season (Goren, 2024). Adults and children can contract Lyme disease from genospecies of the *B. burgdorferi* sensu lato complex (Radolf et al., 2021), through the bite of an infected tick (Kamp et al., 2020). It was 26 years ago that the pathogen responsible, *B. burgdorferi,* was identified (Pustijanac et al., 2024). The Lyme disease-causing bacteria was identified from the liver of the passerine bird *Catharus fuscescens* (veery) and from *Ixodes dammini* (tick) larvae that were consuming *Geothlypis trichas* (common yellowthroat) and *Pheucticus ludovicianus* (rose-breasted grosbeak) (Skeen, 2022). Several genetic and behavioural traits that distinguish *B. burgdorferi* from other prokaryotes include the presence of one cell with a linear chromosome and several linear and circular plasmids (Kneubehl & Lopez, 2023). The bacterium *B. burgdorferi* has many endoflagella and a helically formed body. The cells are 0.2 to 0.5µm wide and 10 to 30µm long, with three to ten loose coils (Tindell, 2021). *B. burgdorferi* sensu lato is a spiral-shaped, gram-negative bacterium with seven to eleven periplasmic flagella, just like other *Borrelia* species. It ranges in width from 0.2 to 0.5µm and in length from 10 to 30µm. The type strain *B. burgdorferi* sensu stricto B31's genome comprises 21 plasmids, 12 of which are linear and 9 of which are circular totalling more than 613,000 bp in size, as well as a linear chromosome of 910,725 bp with an average G+C content in of 28.6%. Individual plasmids have a G+C composition ranging from 23.1 to 32.3% (Hunfeld, 2023).

In Europe, the most prevalent infectious disease spread by ticks is Lyme disease (Pustijanac et al., 2024). According to a recent study, there have been over 476,000 new cases each year since 2010, although a prior review of the same period from 2005 to 2010 suggested that there were only 329,000 LD cases annually (Adkison & Embers, 2023). The National Notifiable Diseases Surveillance System (NNDSS) received reports of 642,602 vector-borne disease cases between 2004 and 2016, according to the Centres for Disease Control and Prevention (CDC). Of these, 77% (491,671 cases) were recorded as tick-borne illnesses (TBDs), with the overall number of cases tripling over a 13-year period (Bobe et al., 2021). The Lyme Disease Enhanced Surveillance System reported instances of Lyme disease in seven Canadian provinces between 2009 and 2019. The cases are broken down by demographics, region, time of year, and season. There were more men than women in the population.

The incidence of all clinical indications, with the exception of cardiac symptoms, which were more uniformly distributed across age groups, showed bimodal maxima in children and older persons (≥60 years of age). Provinces reported varying percentages of disease stages: Ontario reported equal percentages of early and late-stage Lyme disease, whereas Atlantic Provinces reported primarily early-stage Lyme illness. In contrast to late Lyme disease, which was recorded in December through April, early Lyme disease cases were primarily reported in May through November (Murison et al 2023). The distribution of Lyme disease is bimodal in relation to age. Adults aged 55 to 59 (7.8 cases per 100,000 population) and children aged 5 to 9 (8.6 cases per 100,000 population) have highest rates of cases. Young individuals aged 20 to 24 have the lowest rate (3.0 cases per 100,000 population). 53% of reported cases involve male patients (Smith, 2022). Despite still being mostly found in New England, the Middle Atlantic States, Wisconsin, and nearby states, Lyme disease has expanded its geographic range, with indications of its spread to new regions, usually those that are close to known endemic areas (Bisanzio et al., 2020).

The genome of the pathogenic spirochete of Lyme disease has been sequenced, effective diagnostic and treatment methods have been developed, vaccines have been produced, and the ecological dynamics of its maintenance in nature have been recorded (Moustafa et al., 2024). In temperate parts of the northern hemisphere, Lyme borreliosis (LB) remains the most prevalent arthropod-borne disease despite advancements in prevention, diagnosis, and treatment. The risk of infection is linked to certain outdoor recreational activities like mushroom collecting and occupations like forestry work (Nepveu-Traversy et al., 2024). Therefore, considering the rapid growth of Lyme disease, a multidimensional effort is required to improve preventative methods, diagnosis, and therapies, as well as advance basic understanding about ticks, tick-borne infections, and the pathophysiology of LD, given the prevalence of LD and the danger of serious long-term health implications for individuals afflicted (Adkison & Embers, 2023).

Pathogenesis

The pathogen responsible for Lyme disease, *B. burgdorferi*, spreads illness by adhering to host cells, migrating across tissues, and avoiding immune clearance (Steere, 2004). The interplay between the various tick developmental stages and their blood meals from various animal reservoirs and human's results in the production of harmful Borreliae (Sala & De Faveri, 2016). The bacteria experience substantial alterations in gene expression during transmission from the infected tick, which leads to adaptation to the mammalian environment. In humans, the organisms cause inflammatory reactions that lead to clinical signs and symptoms as they proliferate and disseminate locally. Borrelia virulence includes a variety of ways to spread, colonise different tissues, and avoid the host's immune system. Despite the low bacterial counts in impacted locations, the majority of tissue damage observed in non-reservoir hosts seems to be caused by host inflammatory responses. The host's reaction to Lyme disease In the disseminated and persistent stages of infection, Borrelia can produce symptoms related to the nervous system, heart, joints, and skin shown in Figure1 (Coburn et al., 2021).

There are three kinds of tick-borne spirochetes in the *B. burgdorferi* sensu lato genogroup that cause Lyme disease (LD), a multisystem and multistage infection. *Borrelia Afzelii* (Western Europe, Central Europe, and Russia), *Borrelia garinii* (Europe, Russia, and northern Asia), and *B. burgdorferi* sensu stricto (North America and Western Europe) are some of them (Reed, 2002). The only pathogen that causes Lyme disease in the United States is the spirochete *B. burgdorferi* sensu stricto, sometimes known as *B. burgdorferi*. But in addition to *B. burgdorferi*, other similar species, such as *B. afzelii* and *B. garinii*, also cause Lyme disease in Europe and Asia. Hard-bodied ticks such as *Ixodes scapularis*, also known as the black-legged tick or deer tick, in the East and Midwest and *Ixodes pacificus*, also known as the western black-legged tick, on the Pacific Coast are responsible for spreading these bacteria in the United States. In Asia and Europe, the vectors are *Ixodes persulcatus*, also known as the taiga tick, and *Ixodes ricinus*, often known as the sheep tick (Shapiro, 2014).

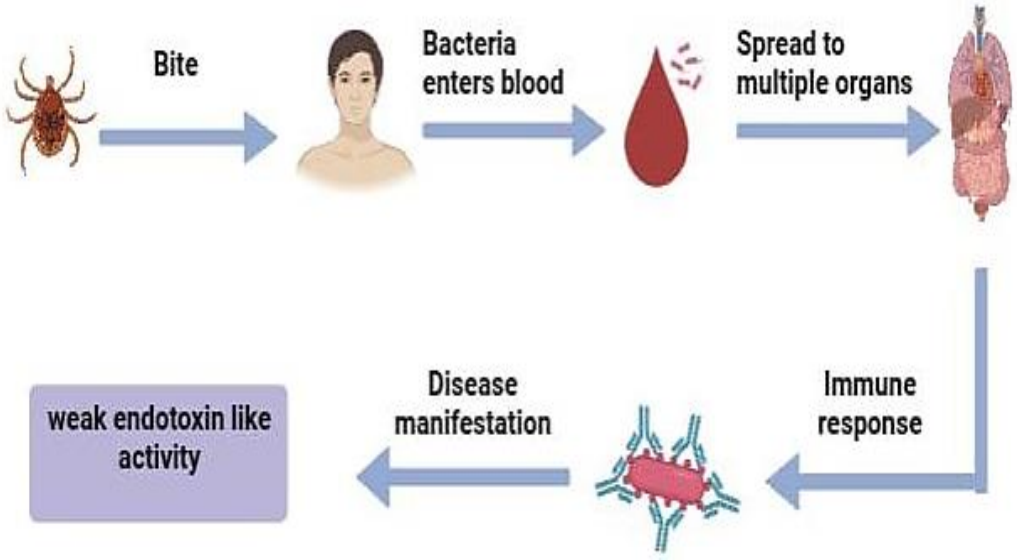

Fig. 1: Transmission of Lyme disease (Retrieved from Biorender)

Symptoms

Clinical signs of Lyme disease usually appear seven to ten days following a tick bite, though they can appear anywhere from one to thirty-six days later. Erythema migrans and influenza-like symptoms are hallmarks of the early, localised form of Lyme disease, which affects 60 to 80%of individuals (Depietropaolo et al., 2005). In line with erythema migrans (EM) or erythema chronicum migrans, which was initially

identified in Europe in 1909, Lyme disease frequently starts with an erythematous rash. While some individuals (20%) may not show any more symptoms, the other patients may develop cardiac (4–8%), neurological (11%), or infrequently, ocular issues, and 45–60% may finally develop arthritis (Borchers et al., 2015). The development of a little annular papule is a characteristic of erythema chronicum migrans (ECM). The rash must start at the location of the tick bite and grow to a minimum of 2.5 inches in diameter in order to be classified as Lyme disease and differentiated from a tick bite reaction. If neglected, the initial rash could grow to be more than 10 inches, and several more lesions could appear (Krause & Bockenstedt, 2013).

Lyme disease was first found in the United States in the late 1970s, prior to the identification of the pathogenic bacteria. Subsequently, it was noted that patients with untreated Lyme arthritis often also had concurrent symptoms like headache, fatigue, myalgia, and hyperaesthesia. Some of the first patient case series first mentioned the potential for these symptoms to persist after getting antibiotic treatment. Years after stopping treatment, up to 50% of patients treated in the early to mid-1980s (primarily with penicillin and/or tetracycline) developed symptoms like headaches, musculoskeletal pain, fatigue, and memory loss. Major population-based research on Nantucket Island found that after receiving treatment for Lyme disease in the late 1980s, 36% of patients still experienced symptoms six years later. Additionally, they reported headaches, exhaustion, sleep difficulties, cognitive symptoms, and musculoskeletal discomfort, numbness, and/or weakness far more frequently than those without a history of Lyme disease (Rebman & Aucott, 2020).

Stages of Lyme Disease

Lyme disease typically progresses through three stages as shown in Figure 2, each of which is marked by remissions and various clinical symptoms. In stage 1, erythema chronicum migrans and nonspecific constitutional symptoms such as fever, malaise, headache, and exhaustion appear days to weeks after tick exposure. Stage 2 involves the development of cardiac and neurologic problems and can place weeks to months following stage 1. After stage 2, there follows stage 3, which is characterized by arthritis. (Bush & Vazquez-Pertejo, 2018).

Stage 1

Erythema chronicum migrans (ECM), a distinct skin lesion, is usually the first sign of Lyme disease which occurs at stage1. In addition, patients may experience migratory musculoskeletal pain, hepatitis, sore throat, non-productive cough, conjunctivitis, periorbital oedema, testicular swelling, headache, meningeal irritation, mild encephalopathy, multiple annular secondary lesions, malar or urticarial rash, generalised lymphadenopathy, and splenomegaly (Tekin et al., 2020).

Stage 2

A median of 21 days after the commencement of erythema migrans, cardiac manifestations take place during the early stages of the illness. Myopericarditis, atrioventricular block, bundle branch block, intraventricular conduction abnormalities, and congestive heart failure are all signs of Lyme carditis (Radesich et al., 2022). Major cardiac issues, including mortality, can result from Lyme carditis, a very uncommon sign of Lyme borreliosis (Lubaszka et al., 2023).

Stage II Lyme disease will exhibit neurological manifestations (Aucott & Rebman, 2023). Peripheral neuropathies, radiculopathies, myelopathies, encephalitides, meningitides, and pain syndromes can all result from individual or combined neurologic disorders (Mnatsakanova & Abrams, 2020). In rare cases, the brain or spinal cord becomes inflamed (Abercrombie, 2024). Radiculoneuritis, meningitis, and cranial neuritis (often unilateral or bilateral facial nerve palsy) are the most frequent neurologic side effects of Lyme disease. These might happen separately or together. One of Lyme disease's most prevalent neurologic symptoms is unilateral or bilateral cranial nerve palsy. Lower motor neurone facial weakness develops in patients. The most typical sign of Lyme meningitis is a headache. While meningismus and fever may be minimal or nonexistent, patients may exhibit photo- and phonosensitivity. A normal glucose content, a slightly elevated protein concentration, and lymphocytic pleocytosis are all seen in the CSF analysis. In rare cases, adults may get papilledema brought on by cerebral hypertension, which has been documented in children with Lyme meningitis. Pain and weakness in one or more limbs are possible symptoms of radiculoneuritis. However, electrophysiologic studies and the experimentally infected rhesus macaque monkey have shown that this is a mononeuropathy multiplex, despite the early attribution of radiculitis or plexitis (Roos, 2021).

Stage 3

Four days to two years (mean, six months) after the EM skin lesion, arthritis started to develop. Throughout a number of years, patients experienced sporadic or ongoing flare-ups of joint pain and swelling, mostly in one or a small number of major joints, particularly the knee. However, additional major or small joints, the temporomandibular joint, or periarticular areas (bursa, tendons) were occasionally impacted, especially in earlier episodes. In most cases, fewer than five joints were impacted simultaneously. In addition to ruptured Baker's cysts, knee joints were frequently extremely swollen but not painful (Arvikar & Steere, 2022).

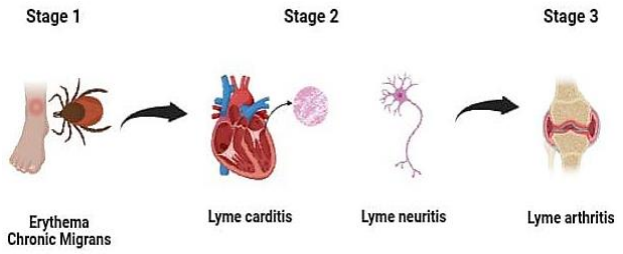

Fig. 2: Stages of Lyme disease (Retrieved from BioRender)

Diagnosis

It is challenging to diagnose Lyme disease since there are insufficient or delayed diagnostics that show active disease or have adequate sensitivity and specificity. Assay variations, gene targets, and a lack of clinical validation make molecular techniques contentious (Dumler, 2001). For the laboratory diagnosis of Lyme disease, a two-tiered serologic test consisting of an immunofluorescence assay (IFA) or enzyme-linked immunoassay (ELISA or EIA) and a reflex Western immunoblot is advised. For the diagnosis of disseminated Lyme disease, 2-tiered serologic testing is

a useful and extremely specific clinical technique when performed in compliance with current testing criteria (Moore et al., 2016). The German Society of Hygiene and Microbiology's standards state that a two-step process should be followed when making a serological diagnosis. It is advised to start with a sensitive ELISA that distinguishes between IgM and IgG. The second stage, immunoblots (IgM and IgG), is performed if the ELISA is reactive. The use of recombinant antigens makes it simple to identify the reactive diagnostic bands. Using recombinant antigens rather than entire cell lysates has significantly improved immunoblot sensitivity and standardisation. Sensitivity was enhanced by combining homologous proteins from many borrelia strains (e.g., DbpA) and using recombinant proteins that are mostly generated in vivo (e.g., VlsE). Additionally, it appears potential to use recombinant proteins (DbpA, VlsE, and others) or synthetic peptides (the conserved C6 peptide derived from VlsE) as ELISA antigens (Wilske, 2003).

Serum antibody detection rates are currently 20–50% for localised disease, 70–90% for diffused early disease, and over 100% for late disease. Only certain indications should be used for PCR or culture-based borreliae detection. Skin biopsies (50–70% with culture or PCR) and synovial tissue or fluid (50–70% with PCR) yield the best results. Only 10–30% of cerebrospinal fluid is positive. Antigen tests in bodily fluids, PCR of urine, and lymphocyte transformation assays are among the techniques that are not advised for diagnostic reasons (Willke, 2007).

Current and Developing Treatment Options

The existence of common antibodies isolated from individuals with active arthritis or an active EM lesion was reported by Steere and Malawista in 1977, indicating a shared cause for these two clinical manifestations. The Yale researchers had mounting evidence suggesting a bacterial infection plays a part in Lyme disease, even though it would take years to isolate the infectious agent that causes the illness. Antibiotic therapy "shortens the duration of ECM and may prevent or attenuate subsequent arthritis. According to (Sigal, 2024) 113 patients who presented with an EM lesion were included in the study. Antibiotics were administered to half of the group, while the other half did not receive any medication. In individuals without antibiotics, the EM lesion and related symptoms resolved within ten days on average following the first visit. With a median duration of 4 days, EM resolved considerably quicker in patients receiving antibiotic treatment. Additionally, compared to patients in the control group, a considerably lower number of patients in the antibiotic group developed arthritis. Antibiotic therapy is still the principal line of treatment for Lyme disease (Elbaum-Garfinkle, 2011).

A single course of oral antibiotic therapy can cure the majority of people with early Lyme disease as described in Table 1, but certain patients with Lyme arthritis, a late-stage symptom, are more resistant to antibiotics and need alternative therapeutic approaches (Schoen, 2020). First-line treatments include oral amoxicillin and doxycycline; second-line treatments include cefuroxime axetil, azithromycin, and phenoxymethylpenicillin. Antibiotics are not usually successful in treating secondary and tertiary Lyme borreliosis, and treatment information is less clear. This is because late Lyme borreliosis has a distinct pathophysiology that includes both an immune response and bacterial infection (Hansmann, 2009).

To treat Lyme disease, the Infectious Diseases Society of America recommends using antibiotics that are generally effective in the early stages of the illness, such as amoxicillin for patients under the age of nine (50 mg/kg per day orally) or doxycycline for nonpregnant patients aged nine and older (100 mg orally, twice daily). For adults, amoxicillin (500 mg taken orally three times a day) is the second-choice treatment. 500 mg taken orally twice a day, or 30 mg/kg daily, of cefuroxime axetil (Bratton et al., 2008).

Table 1: Prescribed treatment for Lyme disease

Group of patients	Suggested antibiotic	Required dosage	References
Patients under the age of nine	Amoxicillin	50mg/kg per day orally	(Fuchs, 2023)
Non- pregnant patients aged nine and older	Doxycycline	100mg orally, twice daily	(Brown et al., 2023)
Adults	Amoxicillin	500mg taken orally three times a day	(Miller, 2024)
Adults	Cefuroxime axetil	500mg taken orally twice a day, or 30mg/kg daily	(Omole et al., 2024)
Children (ages 2–4)	Amoxicillin	Oral 50mg daily	(Ficon, 2022)
Women who are pregnant	Amoxicillin	Oral 500mg three times daily	(Horowitz & Freeman, 2020)
Patients suffering from severe Lyme illness	Ceftriaxone	200g VI per day	(Horowitz et al., 2023)
Patients who are allergic to doxycycline	Cefuroxime axetil	30mg/kg daily or 500 mg taken orally three times a day	(Zafar et al., 2024)
An elderly patient	Amoxicillin or Doxycycline	100mg orally twice daily (doxycycline) or 500mg orally three times daily (amoxicillin)	(Das et al., 2024)
Patients with neurological complications	Ceftriaxone or Doxycycline	Ceftriaxone 2g IV daily or 100mg oral twice daily (doxycycline)	(Kortela et al., 2021)

For individuals who have taken the prescribed course of antibiotics for Lyme disease but nevertheless suffer from enduring symptoms, there are currently no widely recognised or FDA-approved treatments. Until the pathophysiology of these chronic symptoms is identified and/or a biomarker is developed, treatment recommendations are probably going to stay ad hoc. A small number of double-blind, placebo-controlled clinical trials have examined the efficacy of alternative antibiotics; however, the enrolment criteria, intervention, and outcome measures varied somewhat. A recent study also looked at the greater benefit of longer-term antibiotic re-treatment in PTLD compared to shorter-term antibiotic re-treatment (Fymat, 2023). In conclusion, despite disagreements over the study design and the clinical significance of the results, the Infectious Diseases Society of America (IDSA) has not found sufficient proof of a substantial, long-lasting therapeutic effect to support the inclusion of

more antibiotics in their guidelines (Rebman & Aucott, 2020). Although the medical community generally agrees on how to treat acute Lyme disease, treating patients who fit the case definition for Post-treatment Lyme Disease Syndrome (PTLDS) is still difficult because of the lack of knowledge about the condition and associated uncertainties. Furthermore, PTLDS is completely eliminated from the recently revised IDSA guidelines for the management of LD (Bobe et al., 2021).

Additionally, anecdotal accounts of side effects or even fatalities, as well as the possibility of population-level antibiotic resistance due to prolonged, untargeted antibiotic usage, are frequently mentioned as serious concerns. However, the International Lyme and Associated Diseases Society (ILADS) has issued highly conflicting clinical guidelines that focus on the potential for many tick-borne co-infecting agents and the often-unrestricted use of antibiotics for chronic infection. A comprehensive review of the literature supports these recommendations, pointing to microbial persistence as a cause for both treated and untreated Lyme disease's persistent symptoms. One of the main causes of the ongoing dispute around Lyme disease is the disagreement over suitable and successful treatment plans for individuals who experience chronic symptoms (Rebman & Aucott, 2020).

Antibiotic medication is not the only treatment option being investigated due to the uncertainty surrounding the proper diagnosis and management of chronic LD. A medication called disulfiram, which is usually used to treat alcoholism, has been suggested as a treatment for late-stage Lyme disease. 16 individuals who received disulfiram treatment for late LD, either with or without antibiotic adjunct therapy, participated in a recent questionnaire-based study carried out in France. The most often reported symptoms included severe weariness, joint pain, and cognitive problems. Overall, 43.75% experienced reductions in pain and exhaustion, especially after stopping disulfiram, while 81.25% reported harmful effects from the drug. This study doesn't clearly show if disulfiram actually helped these patients or if it was a contributing factor (Alvarez-Manzo et al., 2020). According to an in-vitro investigation, disulfiram alone proved ineffective at eliminating B. burgdorferi, but it worked well when combined with cefuroxime and nitroxoline to reduce bacterial viability to 12.5%. However, given the substantial adverse effects of Disulfiram, it was determined that the best course of action going forward would be to investigate cefuroxime and nitroxoline as possible treatments for stationary phase B. burgdorferi. In one case study, a 30-year-old Florida woman's PTLDS pain symptoms were assessed in relation to the efficacy of intravenous ketamine. The patient received 200 mg of ketamine infusions at the beginning of the 10-day treatment, with the dose being increased by 200 mg each day until 800 mg was reached. The patient had a ketamine booster infusion after the discomfort subsided initially but then progressively reappeared. Overall, the patient reported significantly less discomfort, no longer experiencing sadness or suicidal thoughts, and satisfaction with the treatment and booster infusions. But it's important to remember that this patient's pain symptoms were not relieved by painkillers or other medications, such as opioids, so ketamine might not be a suitable initial treatment. Before being used to the entire patient population, more research is necessary to ascertain how well it treats pain related to PTLDS (Maksimyan et al., 2021).

Vaccination against Lyme Borreliosis

Lyme disease can be avoided safely and effectively with the help of the vaccine as shown in Figure 3 (Poland & Jacobson, 2001). The first vaccination against Lyme disease was approved for human use in the 1990s as a result of the growing push to create a vaccine. It was only on the market for four years, and a number of circumstances contributed to its failure. The excitement surrounding a follow-up product may have its roots in basic research rather than the pharmaceutical sector. Nonetheless, prominent experts have urged fresh interest in a vaccine to prevent Lyme disease (Embers & Narasimhan, 2013). After several years, a Lyme disease vaccine using recombinant outer surface protein A was licensed by the U.S. Food and Drug Administration in December 1998 (LYMErix, SmithKline Beecham, Philadelphia, Pennsylvania). The lipidated outer surface protein of the pathogenic spirochete Borrelia burgdorferi is the source of the vaccine, which is significant since it may reduce the morbidity and financial expenses related to Lyme disease. Its method is distinct in that it prevents human infection by operating inside the tick vector itself (Thanassi & Schoen, 2000).

Because the disease was treated, prevented by other means, and limited in geographic scope, LD vaccines faced market and regulatory obstacles even if they were shown to be safe and efficacious. Nevertheless, pharmaceutical corporations aimed to capitalise on consumers' general fear of the disease as well as their desire for control and protection. After initially endorsing the immunisations, the LD advocacy community quickly turned against them. Their core belief that LD was chronic, erratic, and challenging to cure was seen to be threatened by the vaccines' efficacy. The social and psychological effectiveness of the immunisations was reversed by the activists' rejection. Beliefs that the immunisations created an LD-like state undercut demand rather than restoring control and lowering fear (Aronowitz, 2012). The producer voluntarily removed its product from the market three years later due to dwindling sales, media attention, and concerns about vaccination side effects (Nigrovic & Thompson, 2007).

More advanced OspA-based vaccinations are in the process of being created and should be accessible in the upcoming years. In an effort to stop tick-borne illnesses from spreading to humans and wildlife reservoirs, there has been a recent push to create vaccinations that target the tick vector rather than the infection (Johnson et al., 2024).

Preventive Measures

The best defence against *Borrelia burgdorferi* infection at the moment is avoiding contact with vector ticks. Before *B. burgdorferi* can spread, it is advised to use protective clothing and tick repellents, check the entire body for ticks every day, and remove any attached ticks as soon as possible if exposure to *Ixodes scapularis* or *Ixodes pacificus* ticks cannot be avoided (Wormser et al., 2000). Despite having sufficient knowledge about Lyme disease's symptoms and how it spreads, many people do not take precautions to lower their risk of infection, according to research conducted in endemic areas (Böhm et al., 2025). Increasing people's confidence in their ability to engage in preventive behaviours, increasing understanding of the desired results, and helping individuals realise that the tools and abilities needed to take preventative action are available, are all goals of new prevention techniques (Corapi et al., 2007).

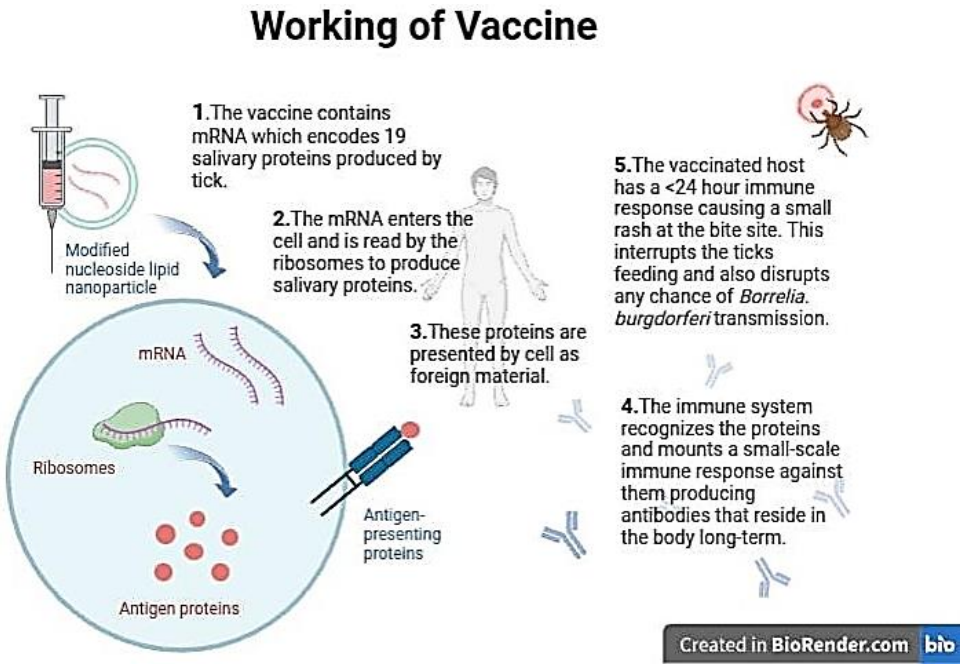

Fig. 3: Working of vaccine (Retrieved from Biorender)

Conclusion

The bacterium *Borrelia burgdorferi* is the cause of Lyme disease, which is the most common arthropod-borne sickness in both Europe and the United States. Late in the 20th century, Lyme disease was recognised as a serious infection that can impact the heart, joints, skin, and nervous system. Since 2010, the incidence has increased significantly, with approximately 476,000 new cases recorded annually. Two age groups are most affected: adults 55 to 59 years old and youngsters 5 to 9 years old. Beginning with flu-like symptoms and erythema migrans, the illness proceeds through three phases, leading to possible neurological and heart problems and, ultimately, arthritis. Because current approaches are insufficiently sensitive and specific, diagnosis is still complicated and depends on serological testing and clinical examination. Antibiotics are usually used in the treatment of Lyme arthritis, while some cases may be more resistant. Avoiding tick exposure, wearing protective clothes, and employing repellents are the mainstays of prevention. A vaccine to prevent Lyme disease was developed in the 1990s, but it was withdrawn due to business difficulties and public scepticism. In order to lessen the effects of Lyme disease, ongoing research attempts to increase public awareness and develop better vaccine options. For management and prevention to be successful, comprehensive approaches are necessary.

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