W hen I was selected as a member of the Tick-Borne Disease Working Group Subcommittee on Disease Vectors, Surveillance, and Prevention, I felt part of my responsibility was to

represent my home state of California. The CDC maps with their myriad little black dots make it look like Lyme and other tick-borne diseases (TBDs) barely exist in California and on the West Coast. We who live here know they do—at least 10 tick-borne diseases occur in California, with Lyme disease being the most prevalent. In this paper, I will discuss some of the scientific evidence and unique features that make California high risk for acquiring Lyme disease and other TBDs.

Early Years

After growing up in Connecticut and living in Lyme-endemic areas much of my youth (south of England, southern Germany), I finally contracted Lyme disease in Mendocino County, which is in the coastal range of northern California. No one knew it then, but the incidence of Lyme disease in my rural community would turn out to rival that of highly endemic areas that had been studied in the Northeast. But it was 1977, and no one even knew what Lyme disease was in those days. I got the flu-like illness and swollen knee, and then, months later, severe arthritis of the spine and other symptoms. I was told I had an autoimmune disease, a diagnosis I lived with for 10 years. Ten long years when I felt like death warmed over, struggling to get through each day, with pain, extreme fatigue, and no hope for a cure.

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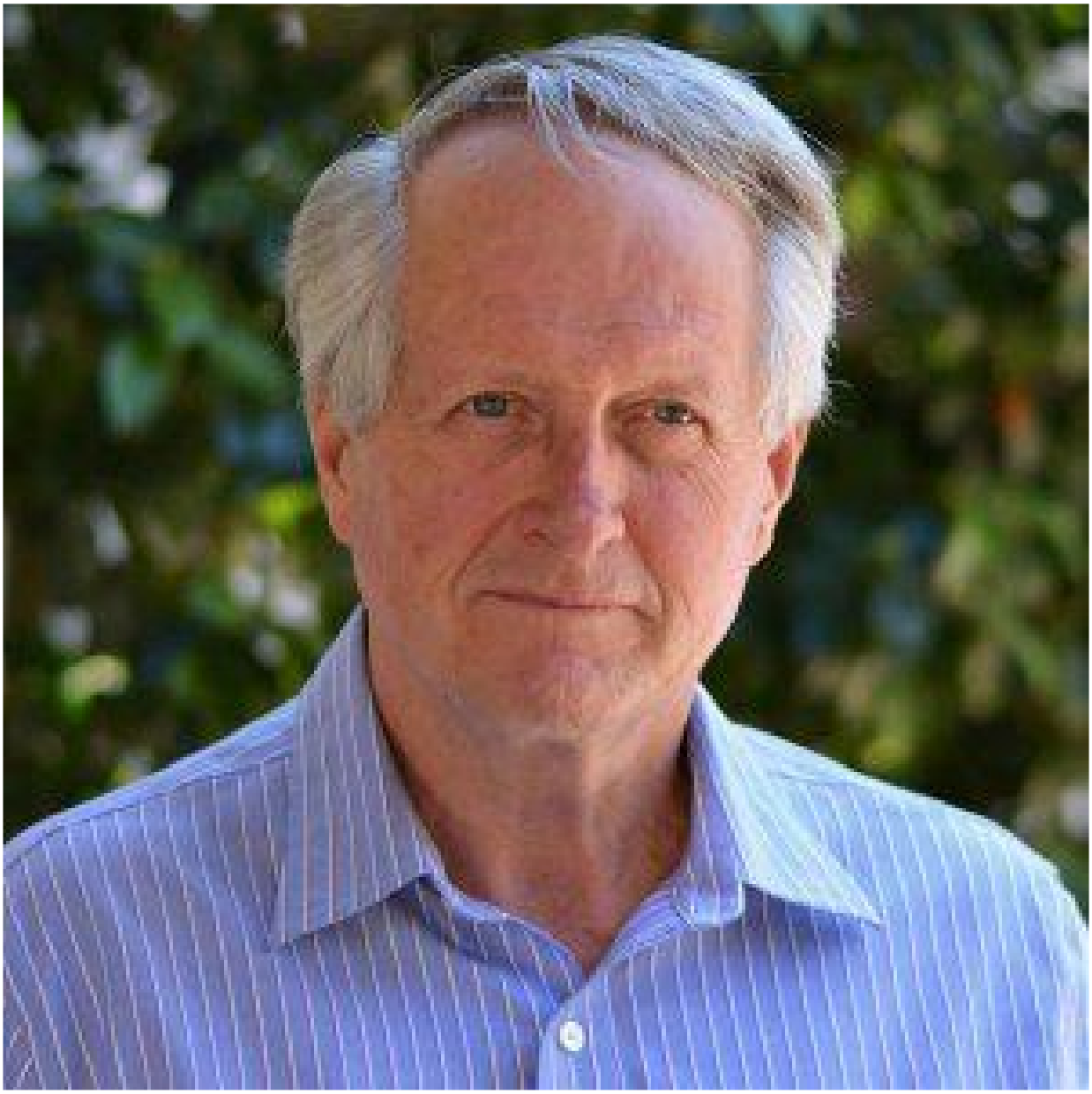
Diagnosed With Lyme Disease

It wasn't until 1987 that I was finally properly diagnosed and treated for Lyme disease. After three years of oral antibiotics, I could plan my life more than one day at a time. It was a good thing, because by then I had started trying to educate my community about it. My efforts led to a newsletter—*The Lyme Times*—which rapidly grew into a nationally distributed lay journal. Then I started a nonprofit to provide education and support to people with Lyme disease. This eventually became LymeDisease.org. If raising five kids and running a homestead wasn't enough to keep me busy, my new work was. The interest was huge and the need was great.

I have to thank my mentors, Paul Lavoie, MD, and Robert Lane. I had the good fortune to meet Dr. Lavoie, an early Lyme expert, at a critical time in my life. He treated me for chronic Lyme disease and encouraged my first steps in what became my vocation.



And then there was UC Berkeley entomologist Robert Lane, with whom (along with many post-docs and other students) I collaborated on his studies of my property and around the county for many years. I learned so much from both of them and we in California feel so blessed to have been on the receiving end of their intellectual curiosity and painstaking work.

Sadly, Paul Lavoie died when he was only 60, so we can't know what amazing things he would have done had he had more time. But Bob Lane had a full and illustrious career, publishing scores of peer-reviewed papers and mentoring many young scientists who follow

in his footsteps today.

Before I knew him, in the 1980s, Lane worked with Willy Burgdorfer and others to establish that adult western black-legged ticks could be vectors of Lyme disease in northern California. The fact that one third of the ticks had generalized infections was thought to have implications as to the speed with which transmission is likely to occur.[1] We now know that those ticks harboring generalized spirochetal infections probably were infected with the relapsing fever group spirochete *Borrelia miyamotoi*, which wasn't described until 1995.

Using blood samples obtained in 1987–89 from residents of a northern California community at high risk (CHR), Lane et al. examined intraspecies differences between *B. burgdorferi* isolates B31 (a New York strain) and CA5 (a California strain). They discovered that 5 of 24 (21%) blood samples differed significantly in their production of antibodies against B31 vs.

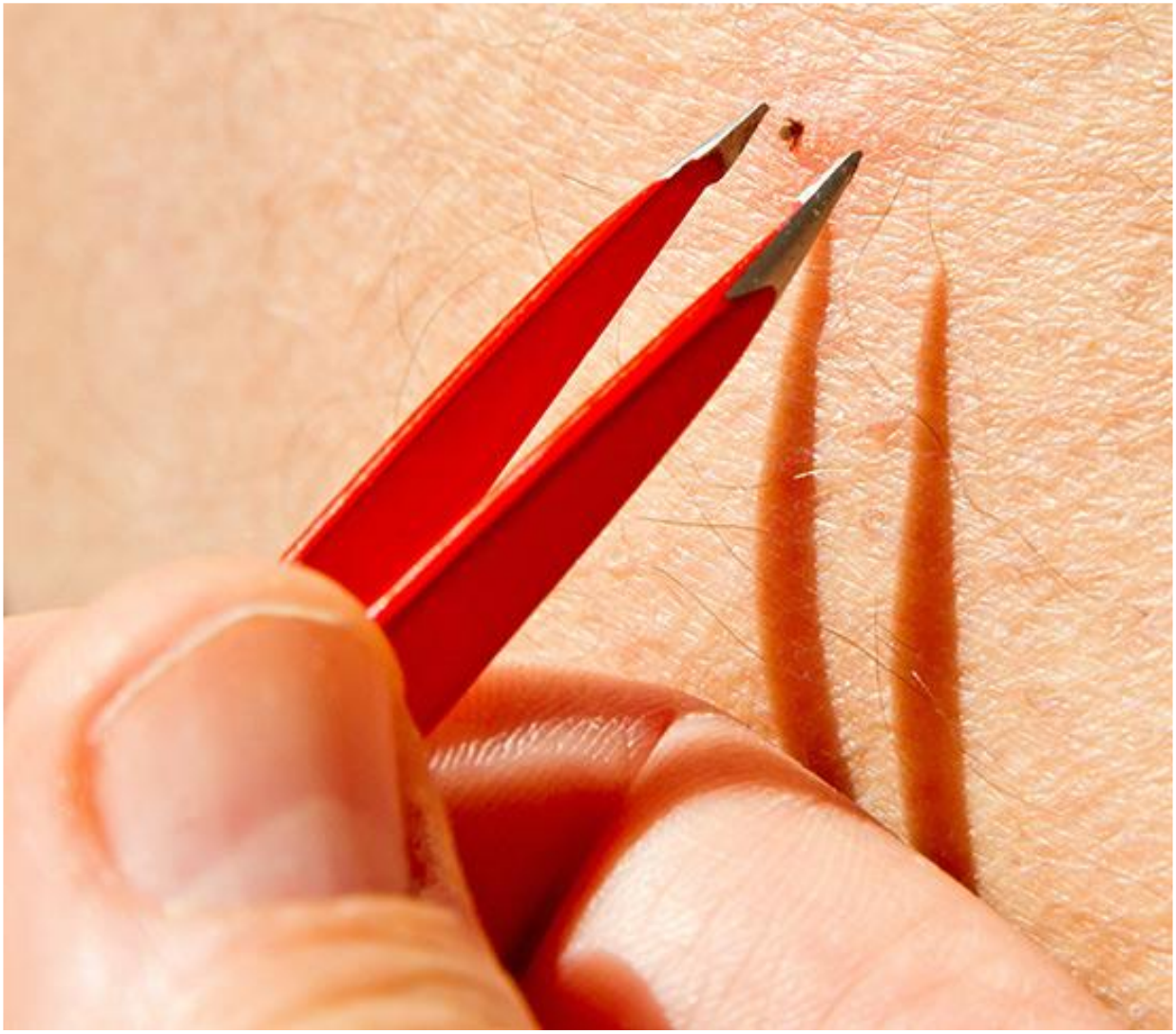
CA5. This discrepancy may cause false-negative test results when using FDA-approved commercial ELISA tests—all of which use B31 as the antigen—in people infected with CA5-like isolates.[2] People infected in California—or any other area with diverse Borrelia species—may be at a special disadvantage with the CDC testing protocol.

Lyme Disease Transmission More Complex On The West Coast

Brown and Lane found that West Coast transmission cycles were more complex than those on the East Coast and involved woodrats as reservoirs and a tick that did not bite humans.[3] Meanwhile, Boyce et al. were exploring the diversity of borreliae in California, including southern California.[4] Later papers expanded on this diversity, and eventually California emerged as the state with the most diverse group of borreliae in the U.S. Globally, around 20 different genospecies of Lyme disease group spirochetes have been described so far, 6 of which occur in California. In 2017, Margos et al. noted the "particularly high" diversity of borreliae species discovered in California and proposed the name *Borrelia lanei sp. nov.* for a recently identified genospecies in honor of Robert Lane.[5]

In a paper published in 1992, Lane et al. showed that the seroprevalence rate for the CHR residents was as high as or higher than that determined for most other high-risk communities or occupational groups (e.g., outdoor employees) that have been studied in the northeastern U.S. The cumulative frequency of seropositivity for Lyme disease in the study population was a whopping 24%. The physician associated with the study—my doctor, Paul Lavoie—clinically diagnosed 37% of the participants with definite or probable Lyme disease.[6]

Medical Community Skeptical Of Results



The medical community was skeptical of the results—how could so many people have Lyme disease when the infection rate of ticks in California was known to be in the low single digits? Clover and Lane then discovered that nymphal ticks were responsible for most cases of human infection. Not only did nymphs have a higher infection rate than adults, but attachments by nymphs coincided with the seasonal occurrence of most cases of Lyme disease.[7]

Lyme Disease Common In Certain Rural

Communities

Their higher infection rate helped to explain why Lyme disease was so common in certain rural communities despite a low infection prevalence in adult ticks, but it raised further questions. Why was the nymphal tick infection rate higher? It seemed counterintuitive. The discrepancy led researchers to investigate the role of the western fence lizard — a favored host of nymphal ticks—and other lizards in the transmission cycle of borrelia spirochetes. They discovered that complement in lizard blood kills borrelia spirochetes in attached nymphs and significantly reduces infection rates in, and disease risk to, adult ticks.8 Swei et al. later discovered that western fence lizards play a dual role in the ecology of Lyme disease. Specifically, they also may increase disease risk by maintaining higher densities of sub-adult ticks and, therefore, higher densities of infected nymphs.9

I followed up with the same individuals from CHR 10 years later, which I summarized at the International Conference on Lyme Borreliosis in Munich, with a poster that looked at long-term clinical outcomes. Using a standardized symptom assessment tool, I interviewed 70 people, 50 of whom had sought medical advice for continuing health problems that may have been Lyme-related. All but two respondents said they had been bitten by ticks multiple times.

Health Complaints Significantly Higher In The Lyme Group Than In The Non-Lyme Group

The total number of complaints for all systems was significantly higher in the Lyme group than in the non-Lyme group. There was a significantly higher prevalence of neurologic complaints in the Lyme group than in the non-Lyme group. Seven individuals (17%) in the non-Lyme group had very high composite symptom scores (avg. 20.0, range 15–24). These individuals had a high number of neurologic and musculoskeletal complaints—comparable to the Lyme group. They also had higher (i.e., worse) scores in all other categories. I thought they might have undiagnosed Lyme disease. Local doctors, however, were offering people antidepressants, sedatives, anti-inflammatory drugs, and physical therapy, and not antibiotic treatment. Only two doctors suggested Lyme as a possible diagnosis.10

Working in a semi-rural community an hour from CHR, Fritz et al. discovered that ticks in northern California carry Ehrlichia and Babesia in addition to borrelia. He emphasized that the risk of infection with these emerging tick-borne diseases, particularly in children, may be greater than previously recognized.11

Lyme Disease – Highly Endemic In Rural Areas Of Northwestern California

After more than 10 years of dragging flannels through leaf litter and manually removing ticks from mouse ears, Eisen and Lane felt compelled to state in one paper, “The high densities of infected nymphs recorded at the CHR suggest that, despite the low statewide incidence of Lyme disease, the medical community should be alerted that Lyme disease can be highly endemic in rural areas of northwestern California.”12 In another paper, after

finding that 79% of the CHR study subjects were positive for anti-arthropod saliva antibodies to I. pacificus, Lane et al. suggested that testing for anti-arthropod saliva antibodies might be a useful epidemiologic tool for studying emerging tick-borne infections.13 But academic research doesn't always trickle down to medical practice, or if it does, it may do so very slowly. Their words fell on deaf ears. I can count the Lyme-literate doctors in the county on one hand—in northern California, on two. But that's also because of the politics of Lyme. It will take a generation to change.

I must give a call out to Lars and Becky Eisen, now at the CDC in Fort Collins, CO, for their excellent work. Lars and colleagues found that there were extraordinary variations in density rates of infected nymphal ticks (11-fold to 97-fold at one site) from year to year that were only partly explained by environmental factors.14 He and his colleagues established that the western gray squirrel and certain bird species were important hosts of borrelia. Birds utilizing tick-questing substrates, such as leaf litter in dense woodlands, had 20-fold higher nymphal loads relative to woodrats and mice. Lizards carry a disproportionate share of larvae and nymphs compared to those rodents.15

Lane et al. established that only the western gray squirrel, Sciurus griseus, fulfilled the major criteria for a reservoir host of B. burgdorferi s.s.; i.e., 47% of I. pacificus larvae (n = 64) and 31% of nymphs (n = 49) removed from squirrels contained B. burgdorferi s.l.16 Salkeld and Lane confirmed the role of the western gray squirrel, the only source of infected nymphs, as a primary reservoir for Borrelia burgdorferi in northern California.17

Eisen et al. created a model of high-acarologic (tick-related) risk sites in California based on a number of variables collected from known high-risk areas. “Lyme disease incidence in zip code areas containing habitat with high projected acarologic risk was 10-fold higher than in zip code areas lacking such habitat and 27 times higher than for zip code areas without this habitat type within 50 km.” They found that “southern zip-codes from which Lyme disease cases had been reported were commonly located in close proximity to areas with high projected acarologic risk.”18

After recently finding evidence of B. miyamotoi infection in human blood samples collected at the CHR in northwestern California in 1988–1989, Peter Krause et al. called urgently for improved relapsing fever group spirochete antibody assays. Cross-reacting antibodies could not be ruled out.19

Patients Need Answers, And Their Numbers Are Multiplying.

Forty years into the epidemic, I no longer believe I will see the battle completely won for patients in my lifetime, but I know I've been fighting on the right side. I've seen and talked to a lot of Lyme patients over the years and don't always have good answers for them. A friend of mine probably has Lyme but is being treated for MS with immune suppressants. Another person told me she had had Lyme but was cured, and now she has fibromyalgia. Another friend died from ALS several years after a tick bite on his head. I know several local children with diseases like mild Asperger syndrome, autism, and atypical epilepsy and wonder if they could have acquired Lyme from their mothers in utero, and now it's in their brains. Maybe time will tell. We just have to reach more doctors with the science.

I hope the Tick-Borne Diseases Working Group will live up to its promise. Patients need answers, and their numbers are multiplying.

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Editor's note: Any medical information included is based on a personal experience. For questions or concerns regarding health, please consult a doctor or medical professional.