The Connecticut Agricultural Experiment Station

The History *of* Public Health Entomology *at* The Connecticut Agricultural Experiment Station 1904–2009

JOHN F. ANDERSON, Ph.D.
Distinguished Scientist Emeritus,
Department of Entomology

The Connecticut Agricultural Experiment Station

The History *of* Public Health Entomology *at* The Connecticut Agricultural Experiment Station 1904–2009

JOHN F. ANDERSON, Ph.D.
Distinguished Scientist Emeritus,
Department of Entomology

Funded, in part, by The Experiment Station Associates

Bulletin 1030

2010

Acknowledgments

This publication is in response to citizen requests that I write an Experiment Station publication of my talk entitled, "104 Years of Public Health Entomology at The Connecticut Agricultural Experiment Station." I gave this presentation in New Haven at an open house event in the spring of 2008.

I express my sincere appreciation to Bonnie Hamid, who formatted the complex figures and the entire text and provided assistance with library searches and the writing. Vickie Bomba-Lewandoski assisted with acquiring some of the historical publications and scanning some of the photographs. Dr. Toby Anita Appel, John R. Bumstead Librarian for Medical History, and Florence Gillich, Historical Medical Library Assistant at the Harvey Cushing/John Hay Whitney Medical Library, Yale University, assisted me with locating critical publications, as did Suzy Taraba, University Archivist and Head of Special Collections at Olin Library, Wesleyan University, and Professor Durland Fish, Yale University. James W. Campbell, Librarian and Curator of Manuscripts at the New Haven Museum sent me a copy of the New Haven Chronicle masthead (Figure 7). The extraordinary efforts of Mr. David Miles, photographer, Mr. Andrew Rogalski, Technical Services Librarian, and Terrie Wheeler, Chief Librarian, Gorgas Memorial Library, Walter Reed Army Institute of Research, in providing the superb image of Dean Cornwell's painting entitled "Conquerors of Yellow Fever" (Figure 12) are greatly appreciated.

Edward D. Baker, Executive Director of the New London County Historical Society provided helpful information on early shipping into and out of New London. The catalogue of historic pictures of Experiment Station mosquito control efforts arranged by Rose Bonito was extraordinarily useful. Paul Capotosto and Roger Wolfe of the Connecticut Department of Environmental Protection were generous with their time and provided historical documents and photographs on mosquito control in Connecticut.

I found the following two unpublished reports useful in compiling the history of events pertaining to mosquitoes and disease in Connecticut: Potter, L. 1980. Yellow fever in Middle Haddam, 1796. History 331, Wesleyan University, 30 pages; Wrenn, J. 2000. The history of Connecticut's state mosquito control program. Practicum Project, University of Connecticut, MPH program, 23 pages.

I owe a special thanks to Jane Bradley, Creative Advertising & Publishing Services, for her patience, yeoman effort, and artistic creativity in assembling this publication.

Drs. Louis A. Magnarelli, Theodore G. Andreadis, Kirby C. Stafford III, and Andy J. Main made constructive comments of an early draft of this manuscript. Michael J. Misencik and Angela B. Bransfield provided needed assistance in preparing the text.

Funding was provided in part by the United States Department of Agriculture Hatch Grant 344, the Experiment Station Associates, industry grant funds, and the William R. Lockwood Trust.

Contents

Introduction

The Connecticut Agricultural Experiment Station, hereafter referred to as the Experiment Station, was founded in 1875 for "the purpose of promoting agriculture by scientific investigation and experiment" as the Nation's first state agricultural experiment station (Horsfall 1992).

In that year, the Experiment Station's first Director, Wilbur O. Atwater, hired a chemist and two assistants and established a chemistry laboratory in Judd Hall (**Figure 1**) at Wesleyan University in Middletown, Connecticut. In October 1875, the Experiment Station began to analyze fertilizers to prevent fraud (Atwater 1904).

The focus on analyzing fertilizers continued after the Experiment Station relocated to Sheffield Hall (**Figure 2**) at Yale University in New Haven, Connecticut in 1877 under Director Samuel W. Johnson, "the Nestor of agricultural chemistry in the United States" (Atwater 1904). The Board of Control was established by General Statute at that time, and the Experiment Station has continued to be governed by this eight-member citizen board to this day. The Experiment Station moved in 1882 to its current location on six acres of land on Suburban Street, which was later renamed Huntington Street, in New Haven (**Figure 3**).

The Department of Biochemistry (now the Department of Biochemistry and Genetics) was established in 1886, and the Department of Mycology (now the Department of Plant Pathology and Ecology) was created in 1888. Wilton E. Britton was hired in 1894 as a horticulturist. In 1901, the Connecticut General Assembly established the Office of State Entomologist at the Experiment Station. The Station's Board of Control appointed Britton as State Entomologist, and he established the Department of Entomology in 1901 (Turner 1974). The Department of Entomology was initially located on the second floor in Thaxter Building (**Figure 4**) and moved into an addition to Johnson Building in 1910 (**Figure 5**). Upon completion of the Jenkins Building in 1932, the Department relocated to the second floor and basement of the new Jenkins Building, where it has been to the present day (**Figure 6**).

The Experiment Station's first document in public health entomology was published on mosquitoes

Figure 1. Judd Hall, Wesleyan University, was completed in 1871.

Figure 2. Sheffield Hall, Yale University, was demolished in 1931.

Figure 3. Chemistry Building (l), built in 1882, is the Experiment Station's Osborne library. Eli Whitney Jr. house (r) was built in 1859 and no longer exists.

Figure 4. Thaxter Building was built in 1889 and was demolished in 1959.

Figure 5. Johnson Building, completed in 1910.

Figure 6. Jenkins Building, constructed in 1932.

(Britton and Viereck 1904). During the past 105 years, the Experiment Station has published hundreds of scientific papers or State reports on mosquitoes and other arthropods of public health importance. The part played by the Experiment Station in keeping citizens informed of the importance of biting arthropods and their control is a continuous, unfolding story of responding to important entomological and ecological problems affecting the health of people living in or visiting Connecticut. Our scientific findings not only benefit local citizens, but also they are of interest and benefit to scientists and others throughout the United States and beyond.

Public health entomology at the Experiment Station began at a time when malaria was causing disease in Connecticut citizens and salt marsh mosquitoes were a scourge to residents and visitors of shore areas along Long Island Sound. It was also a time when epic medical discoveries had relatively recently documented the importance of mosquitoes in transmitting the human pathogens causing malaria, filariasis, and yellow fever. The importance of controlling mosquitoes in terminating the epidemic of yellow fever and reducing the numbers of cases of malaria in Havana, Cuba, had been heralded throughout the country (Anonymous 1902, Gorgas 1904). Also, the control of salt marsh mosquitoes by ditching had begun in New Jersey (Smith 1902) and Long Island, New York (Britton and Viereck 1904). In Connecticut, an extensive salt marsh in Stratford had been privately ditched for the control of mosquitoes as had salt marshes in the Indian Neck and Pine Orchard sections of Branford, Fairfield, and fresh water sites in Hartford (Britton and Viereck 1904).

I begin by describing the Connecticut experience with two mosquito-associated diseases, yellow fever and malaria, that impacted the state during its relatively early history. This is followed by a review of the important discoveries made elsewhere, linking mosquito bites to human disease, and I then provide a historical overview of the Experiment Station's scientific and practical work in public health entomology that began with surveying for mosquitoes and led to the seminal publication of Britton and Viereck (1904), more than 100 years ago.

Figure 7. New Haven Chronicle masthead, 1786, showing New Haven Harbor. The first cases of yellow fever occurred in June 1794 in people living or visiting in Long Wharf, a few rods from where a sloop had been hauled. This sloop had recently arrived from Martinico and had been used to transfer the sick in the West Indies. Of the 150 people who contracted yellow fever, 64 died.

The sections in this historical review are intended to present the work of scientists at the Experiment Station responding to the needs of Connecticut citizens, and do not cover the complete field of each scientific and medical subject. The emphasis throughout is on the accomplishments in public health entomology at the Experiment Station.

Yellow Fever and Malaria in Early Connecticut

Yellow fever

Yellow fever was initially recognized as a disease in America in the seventeenth century (Warren 1951). It was one of the major plagues of the world, causing devastating epidemics in tropical and subtropical regions, and in areas as far north as Boston, Massachusetts, in the United States and north to England and Spain in Europe. Widespread epidemics frequently swept over the West Indies, Central America, and the southern United States. Between 1702 to 1800, epidemics of yellow fever appeared in the United States on at least thirty-five occasions and between 1800 and 1879, this disease was recorded in every year but two of them (Hiscock 1942). About 13,000 deaths were recorded during the 1878 epidemic in the Mississippi Valley (Warren 1951). Eastern cities situated along the Atlantic Coast were often repeatedly infected with summer epidemics. For example, 20, 15, 8, and 7 epidemics were recorded for Philadelphia, Pennsylvania, New York, New York, Boston, Massachusetts, and Baltimore, Maryland, respectively. One tenth of the population was reported to have perished during the 1793 epidemic in Philadelphia, Pennsylvania (Hiscock 1942).

Yellow fever is an acute infectious disease of short duration and extremely variable severity, caused by a virus that is transmitted by mosquito bite and followed by life-long immunity in the survivors (Kerr 1951). Both the causative agent and method of infection were unknown when yellow fever struck fear into people in the late 1700s and 1800s. Seaports were susceptible to the introduction of yellow fever because the mosquito vector, *Aedes aegypti* (L.), breeds in artificial containers, including the water casks of sailing vessels. Sailors infected with yellow fever would serve to infect biting mosquitoes on board ship. Infected mosquitoes would transmit the virus to others. When the ship entered a port during summer, infected mosquitoes would feed on visitors to the ship or would leave the ship, feed on susceptible residents, and breed in artificial containers in the port so that transmission could continue during the warm months. This mosquito cannot survive the cold, and epidemics would cease in temperate North America with the advent of cold weather.

Seafaring towns in Connecticut were not immune and at times suffered just as greatly as did larger cities elsewhere (**Figure** 7). Yellow fever in Connecticut was asso-

Yellow Fever Epidemic in Norwich, Connecticut, 1753

Norwich is located at the convergence of the Thames, Shetucket, and Yantic rivers (red star). This map is part of a map of the Colony of Connecticut, drawn by Moses Park, November 24, 1766.

Benedict Arnold, who defected from the Continental Army to the British Army during the American Revolutionary War, was born in Norwich and was a student at a private academy in Canterbury, Connecticut, when the epidemic swept through Norwich (Brandt 1994). His attendance at this private academy saved him from possible exposure to the yellow fever virus.

His mother, Hannah Arnold, wrote in letters to the 12-year-old Benedict:

Benedict Arnold, Engraving by H. P. Hall

– August 13, 1753. *"Deths are multiplied all round us … and more daly expected …. Your uncel Zion Arnold is dead … Capt bill has lost all his sons John post has lost his wife John Lathrop and his son barnabus are boath dead…."* **(Arnold 1753)**

– September 10, 1753. *"My dear … I should send for you to ye funeral, but ye contagion is such I am afraid"* *(Brandt 1994). Benedict's eight-year-old sister, Mary, had died.*

Benedict's youngest sister, Elizabeth, also died of yellow fever before the epidemic subsided.

Figure 8.

ciated with the maritime trade with islands in the West Indies, which, at the time, were often ravaged with this disease. Epidemics were documented in Norwich (1753) (Brandt 1994) (**Figure 8**), New Haven (1794) (Hoadley 1900), Middle Haddam (1796) (Tully 1823b), New London (1798) (Caulkins 1895, Labensky 1942), and Middletown (1820) (Tully 1823a, 1823c). Cases were also reported in other years, for example, in Hartford in 1799 and in New Haven in 1743 and 1805 (Sternberg 1908). The manner in which yellow fever was introduced into seaports in Connecticut and the terror it sometimes caused are illustrated by the 1796 epidemic in Chatham (now part of Middle Haddam). The brig Polly arrived at Knowles Landing in Chatham, which was situated along the Connecticut River, from Cape St. Nicholas Môle, Haiti, in August 1796 (Tully 1823b). One crew member had died at sea from yellow fever. People from the community who went aboard the ship or who were close to the ship became infected, as did others who were associated with these individuals. In all, eleven residents from Chatham contracted the illness and nine died from a disease that had been introduced into the community by a single sailing vessel. All but five of the about 200 healthy town residents fled following the death of the third person, leaving the five remaining persons to take care of the sick and to bury the dead.

Figure 9. The New London Courthouse, as it appears today. Built in 1784, it was converted to a makeshift hospital during the yellow fever epidemic of 1798.

Tully (1823b) reported that there was scarcely a season for the past 25 years in which individual instances of yellow fever had not occurred on the Connecticut River. The Connecticut River at the time was a major artery of commerce.

The largest epidemic in Connecticut occurred in 1798 in New London, which is located along the Thames River and was a major port for the State (Avitable 2009). Eighty-one of 350 stricken people died within the compact portion of New London, with a population of about 2,800 (Caulkins 1895, Graves 1922, Labensky 1942), although total number of cases of 246 and more than 350 were listed by others (Graves 1920, 1922) (**Figure 9**). The disease was almost totally confined within an area of 30 rods to the north and 30 rods to the south and 30 rods in width of the residence with the first case (Graves 1922). In one small neighborhood, there were 15 houses with 92 persons of which 90 were stricken. As had happened in Chatham, Connecticut, two years earlier in 1796, panic set in and many left the infected district of New London. A few cases also appeared in 1795 and 1803 in New London (Sternberg 1908).

Another sizeable outbreak had occurred in New Haven in 1794 (**Figure 7**). The probable source of this epidemic was a sloop that arrived in New Haven in early June. The sloop earlier had been used to transfer patients, sick with yellow fever, from place to place in the West Indies (Hoadley 1900). The first person in New Haven became ill on June 10 and the last person died in November. In all, 64 of 150 persons diagnosed with yellow fever died in New Haven, which at the time had a population of 3,471.

A possible epidemic occurred in 1746 among the Mohegan Indians living in a village along the Thames River between Norwich and New London, Connecticut (Webster 1799). The disease began in August and ended with cold weather. The sick Indians were attended to by Dr. Elisha Tracy of Norwich, Connecticut, who acquired the disease but recovered. According to Dr. Philemon Tracy, Elisha Tracy's son, the disease "began with severe pain in the head and back followed by fever; in three or four days, the skin turned 'as yellow as gold', a vomiting of black matter took place, and generally a bleeding at the nose and mouth til the patient died." About 100 Indians perished. The disease was local and did not extend to other nearby villages.

The evidence supporting that this epidemic was caused by yellow fever was provided in part by the attending physician who included the time of year when it occurred and clinical symptoms matching those reported by Carter (1931) and Kerr (1951). American Indians were known to be susceptible to yellow fever, and this epidemic, local in nature, occurred along a river where ships from the Caribbean traveled and in an area where other yellow fever epidemics have been documented.

The last epidemic of yellow fever in the United States occurred in 1905 in New Orleans, Louisiana, and other southern port cities where 5,000 cases and 1,000 deaths were recorded (Warren 1951).

Malaria

Many diseases were classified under the general term malaria in colonial times (Barber 1929), but it is certain that malaria, even though its cause *(Plasmodium)* and method of transmission (bite from an *Anopheles* mosquito infected with *Plasmodium* sp.) were unknown, was causing human disease in North America in the 1600s (Boyd 1941). The hallmark of acute malaria is high fever, chills, and rigor (Wyler 1990). Malaria occurred in New England chiefly near marsh land and wet soil with decaying vegetation and where the water was stagnant (Chapin 1884).

Epidemics were recorded in Massachusetts from 1647 through 1668, and malaria had become endemically established along the eastern seaboard from Massachusetts to the Caribbean long before the end of the colonial period (Boyd 1941). In Connecticut, malaria was reported to be present in Pomfret during early settlement, and in 1671 malaria was reported in New Haven and other towns along the shore of Long Island Sound eastward to New London (Chamberlain 1881). Malaria was reported in Guilford in 1668 (Graves 1922). It was reported to be present in Enfield in 1780 and in New Milford from 1782–1799 (Chapin 1884). In 1904, Britton and Viereck reported that malaria almost certainly occurred in portions of Connecticut for nearly 250 years, but they were quick to write that "the term malaria, like charity, covers a multitude of sins and is doubtless applied to many troubles of a different nature."

In tracing the history of malaria in Connecticut, Chapin (1884) reported that it affected the early settlers along the shore of Long Island Sound in southwestern Connecticut. It reappeared from 1792–1800 along the Housatonic and Connecticut rivers. Malaria became "very prevalent" along Long Island Sound from 1828-1836 and spread up the Housatonic and Connecticut rivers. The largest epidemic began about

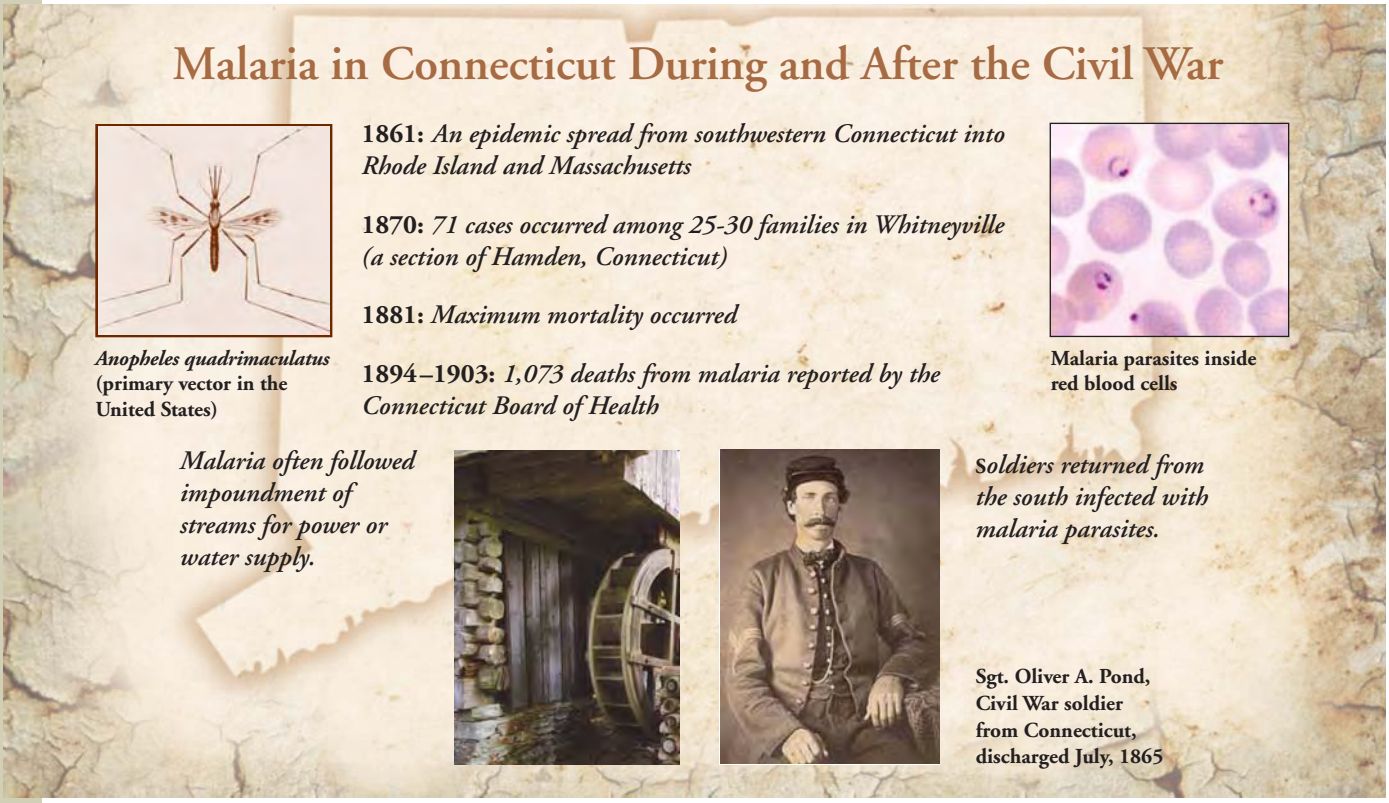


Figure 10.

1860 in southwestern Connecticut and gradually spread throughout the state (Britton and Viereck 1904, Chapin 1884) and into adjacent Rhode Island and Massachusetts with maximum mortality occurring in 1881 (Chapin 1884) (**Figure 10**). Returning Federal soldiers from the Civil War were infected and carried their parasites into Connecticut and likely contributed immensely to the epidemics (Boyd 1941, Britton and Viereck 1904). By 1882, malaria was probably present in all Connecticut towns (Britton and Viereck 1904).

Malaria was a serious disease in the greater New Haven area beginning in the 1850s, although epidemics were not recorded until the 1860s according to Chamberlain (1881), who, at the time, was Secretary of the State Board of Health in Connecticut. In 1864, there were 70 cases near the Cove River, West Haven. In 1870, in Whitneyville, 71 cases occurred among 25–30 families, and throughout Hamden 2,000 citizens were reported to have had malaria, out of a population of 3,028.

In 1871, 75% of the inhabitants of West Haven (Orange) were afflicted. Epidemics seemed to follow the flooding of land and "upheaval of earth" (Chamberlain 1881) that resulted in "stagnant, shallow, still water filled with dead vegetable matter" (Chapin 1884). The epidemics were often near recently constructed dams and railroads and near mill ponds and swamps. In a twenty-town area, mortality from 1869 through 1880 totaled 862 cases, with the highest number of deaths documented in 1880. Mortality in the New Haven area from 1873 through 1880 totaled 100 cases. Deaths from malaria from 1894-1903 in Connecticut, as tabulated by the Connecticut State Board of Health, totaled 1,073 (Britton and Viereck 1904).

The Golden Age of Discovery

The late 1800s through 1901 was the golden age when mosquitoes and ticks were scientifically documented to transmit disease-causing pathogens to humans and animals (**Figure 11**). The Englishman, Sir Patrick Manson, demonstrated the development of a filarial parasite, *Wuchereria bancrofti*, which causes the disease lymphatic filariasis, in mosquitoes in 1877 (Cook 1993). The French physician Charles Louis Alphonse Laveran demonstrated the malaria-causing parasite (*Plasmodium*) in human red blood cells in 1880 (Laveran 1907). The American Theobald Smith demonstrated in the early 1890's that ticks transmitted the *Babesia* parasite causing Texas cattle fever and that the disease could be controlled through eradication of ticks (Smith and Kilborne 1893). Manson encouraged his

The Microbe Hunters – The Golden Age of Discovery

1877	1880	1893	1898	1898
				
Manson *mosquitoes as vectors of filaria parasites*	**Laveran*** *malaria parasite*	**Smith** *ticks as vectors of a parasite of cattle*	**Ross*** *mosquitoes as vectors of malaria parasites*	**Grassi** Anopheles *mosquitoes as vectors for human malaria*

***Recipients of the Nobel prize**

Figure 11.

Figure 12. "Conquerors of Yellow Fever" by Dean Cornwell (1939). Dr. Lazear (who died from yellow fever) is applying a vial with an infected mosquito to the arm of Dr. Carroll (who contracted the disease, but survived) on August 27, 1900. Dr. Reed (standing, in white), Dr. Agramonte (on left, holding his hat), and Dr. Finlay (with white hair, in civilian suit) look on. (The Yellow Fever Commission was composed of Reed, Lazear, Carroll, and Agramonte) (Smith 1985).

William Gorgas

William Gorgas

Mosquito and Disease Control Measures Used in Havana, 1901:

Surveillance	Quarantine
Drainage	Kerosene oil
Fumigation	Ordinance *(fines)*
Quinine	Education
Screening	

Results in Havana

- Mosquito breeding sites reduced
- Last case of yellow fever reported on September 1, 1901
- Follow-up programs prevented reintroduction from visiting ships

Panama Canal, 1915
Similar methods used in Panama to reduce mosquito-borne infections allowed the canal to be built.

Figure 13.

fellow countryman Ronald Ross to look at the importance of mosquitoes in transmitting the malaria parasite. Ross demonstrated the complete life cycle of bird malaria involving mosquitoes and birds in 1898 (Ross 1902). Battista Grassi reported in late 1898 to the Accademia dei Lincei that mosquitoes of the genus *Anopheles* were the vectors for the causative agent of human malaria (Cook 1993, de Kruif 1950). Laveran and Ross each received the Nobel Prize for their discoveries.

In 1900, Walter Reed and his Yellow Fever Commission, by using human volunteers, confirmed what the Cuban physician Carlos Finlay (Finlay 1881) had been stating for years: that yellow fever resulted from the bite of the mosquito, *Aedes aegypti*, and demonstrated that the disease was caused by a filterable agent, now known as yellow fever virus (Reed et al. 1900, Reed and Carroll 1902) (**Figure 12**).

The question then arose "could yellow fever be contained by controlling mosquitoes"? Major William Gorgas was given this task in Havana, Cuba. Within one year, the results were astounding (Anonymous 1902) (**Figure 13**). Prior to 1901, the average number of cases per year was 751. The last case was reported on September 1, 1901 (Gorgas 1904). Malaria also was reduced as it had been in Albanella, Italy, in 1900 by Grassi, who had people sleep inside screened houses (de Kruif 1950). Results of the mosquito control effort in Havana were so dramatic that Gorgas was later assigned, in 1904, to reduce yellow fever and malaria during the building of the Panama Canal. This, he and others did successfully (Warren 1951).

Public Health Entomology at the Experiment Station

First publications on mosquitoes

Wilton Everett Britton (**Figure 14**) was hired as horticulturist at the Experiment Station in 1894 after graduating from the New Hampshire College of Agriculture and Mechanic Arts in 1893 and studying under Liberty Hyde Bailey at Cornell University. He continued his graduate studies, while working at the Experiment Station, and received his Ph.D. from the Department of Botany at Yale University in 1903. From the time he arrived, Britton began studying a variety of important insect problems. In 1901, the Station's Board of Control appointed Britton as Entomologist of the Station and State Entomologist. In 1903, he began devoting attention to the salt marsh mosquito, *Aedes sollicitans* (Walker). In time, these studies led to the organization of state-wide marsh drainage programs and the law pertaining to mosquito elimination in 1915 (Friend 1939).

On December 15, 1903, in Hartford, Dr. Britton reported the importance of the landmark discoveries establishing the ability of mosquitoes to transmit the causative agents of malaria and yellow fever to humans, and methods of mosquito control, at a conference of Connecticut health officers (**Figures 11, 12, 13**), and the following year published, along with H. L. Viereck, the first Station publication in public health entomology (Britton and Viereck 1904). They reported 22 species of mosquitoes in Connecticut, results

Figure 14.
Wilton E. Britton

Figure 15. Draining a salt marsh ▶

of surveys of mosquito breeding areas in several towns, the need for and methods of controlling mosquitoes, and the offer to send a specialist to examine areas suspected of breeding mosquitoes. They wrote that mortality and prevalence of illness from malaria could be reduced through the elimination of mosquito breeding areas.

Mosquito investigations and control efforts were often limited in the immediate years that followed. In 1912, Britton published a paper describing the plague of mosquitoes along the coastal region of Connecticut (Britton 1912). He made clear that the 22,264 acres of salt or tide water marshes in Connecticut were the principal contributors to the hoards of mosquitoes in the southern portions of the state. He advocated the drainage of the marshes (**Figure 15**) for the control of mosquitoes and stated the application of oil to the breeding pools (**Figure 16**) was only a temporary measure to be used until the drainage of the marsh could be accomplished. He further discussed the need for cooperation within and among communities, and the need for legislation to accomplish drainage of the marshes.

Malaria in Greenwich

The last epidemic of malaria in Connecticut was documented in Greenwich in 1912 and 1913 (Trask 1916). Dr. E. O. Parker, chairman of Mosquito Committee of Greenwich, reported an unofficial record of 900 authentic cases of malaria in 1912 (Britton 1912). The Experiment Station conducted a survey at the request of the town for mosquito breeding areas within a radius of one mile of the Town Hall. In 1913, a private contractor was hired by the Town of Greenwich to drain and fill

Figure 16. Applying oil to pools with mosquito larvae with the "Double Forester" pump, 1912.

fresh water marshes for the control of malaria-causing *Anopheles* mosquitoes in the southern part of town, which was carried out during the summer, fall, and winter of 1913. Britton was called on to mediate differences between the town health officer and the contractor. Only 15 new cases were reported in 1914 (Britton 1914). This decrease in numbers of cases of malaria was attributed to the drainage of fresh-water marshes, which reduced the numbers of *Anopheles* mosquitoes.

Malaria was recorded as present throughout Connecticut in 1900 but absent in 1945 (**Figure 17**). Efforts to reduce malaria through mosquito control, as was done in Greenwich, were effective locally, but the recession of malaria throughout the United States in the twentieth century resulted from other causes. The tremendous amount of agricultural drainage in the central United States reduced numbers of *Anopheles* species and subsequent human disease. Other factors cooperatively contributing to the decline of malaria included the liberal use of quinine and overall medical assis-

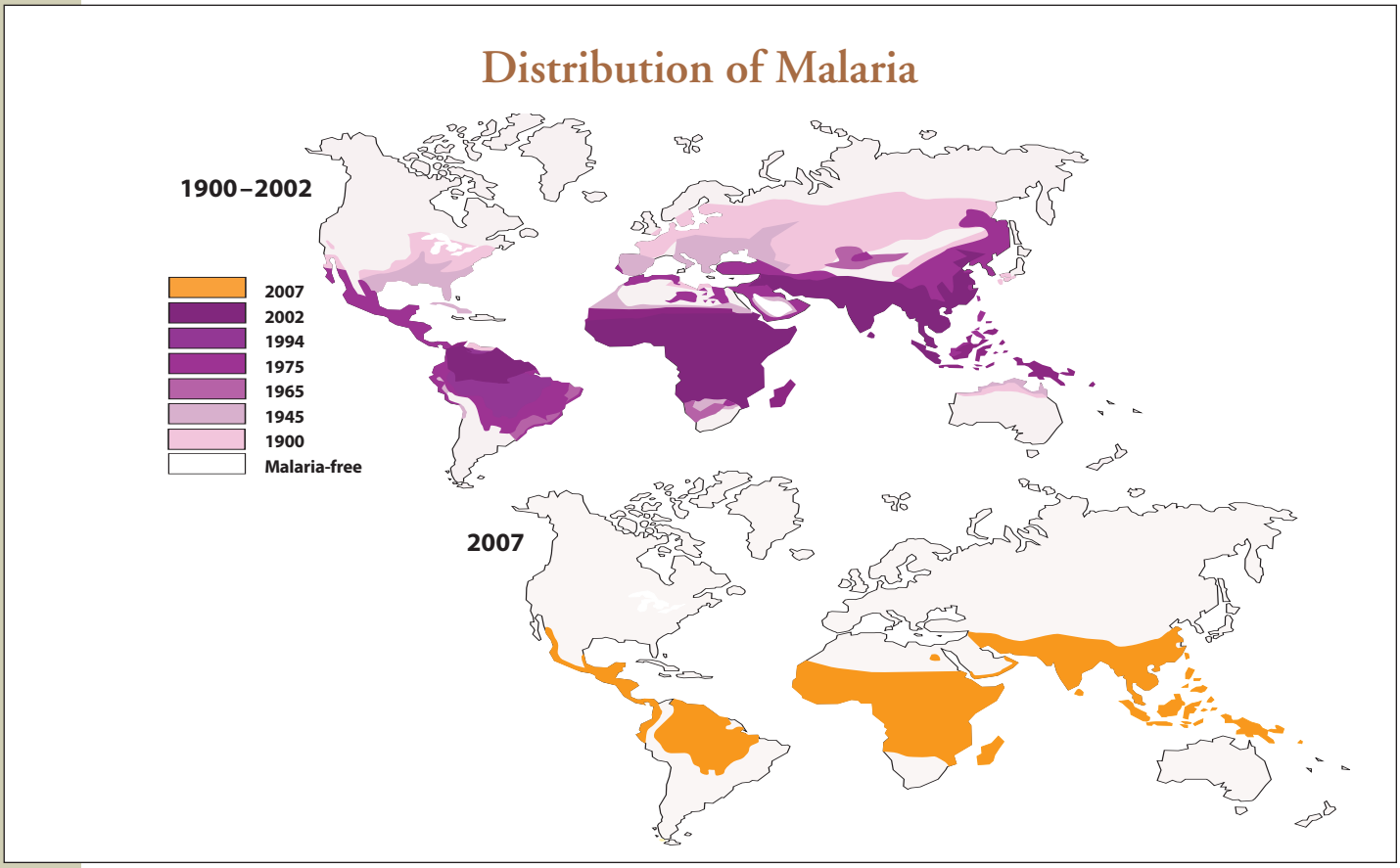


Figure 17. Note the distribution of malaria throughout Connecticut in the map of 1900 and its absence in 1945. Note the absence of malaria from the United States in 2007.

tance, and the general improvement of the standard of living, which resulted in people having better nourishment, housing (particularly the use of screening), and clothing (Barber 1929, Boyd 1941).

Mosquito control from 1915 through 1939

The Experiment Station focused on surveillance and control of mosquitoes during this 25-year period. In 1915, the Experiment Station Director (Edward H. Jenkins) was authorized by law to make rules and orders regarding the elimination of mosquitoes and to survey and eliminate by draining, filling or otherwise treating mosquito breeding areas (Britton 1915). Britton wrote that in 1915, "Seldom are mosquitoes so abundant along the Connecticut coast. *Aedes sollicitans* was breeding in nearly every un-drained salt marsh."

During the following year, 1916, the largest single contract up to that time for mosquito control in Connecticut was executed in Branford, Guilford, and Madison (Britton 1916). Approximately 2,668 acres of salt marsh were ditched to eliminate mosquito breeding (**Figure 18**). Funding was provided by the Connecticut Shore Mosquito Extermination Association, Inc. All monies were obtained by private subscription. The ditching work was to be approved by the Director of the Experiment Station and done under his direction. A contract was made with a New York firm and the work started without a survey for mosquitoes, and much ditching was done without keeping the Director informed. Numerous problems ensued, including objections by many property owners.

Nonetheless, the numbers of mosquitoes were greatly reduced, and the positive results of the work were apparent in all three towns. For example, the summer hotels were better patronized than in previous years. One hotel in 1915 was practically empty twice during the mosquito-breeding season, and the management resorted to offering special inducements to guests. During 1916, this hotel was filled throughout the entire summer and turned away many prospective customers.

In 1917, maintenance work on the ditches dug in the salt marshes was placed under the Experiment Station Director instead of the towns (Walden 1917). Furthermore, the amended Act stated that the Director may make rules and orders concerning the elimination

Figure 18. Skinner ditching spade, 1916

Figure 19. Draining the bottom land, East Hartford, 1935

of mosquitoes and mosquito breeding places, and he may enter upon any swamp, marsh or land to ascertain if mosquitoes breed thereon, or to survey, drain, fill or otherwise treat or make any excavation or structure necessary to eliminate mosquito breeding. Mosquito control, maintenance of drainage ditches, and survey work were carried out in several shoreline towns in 1917 and following years.

In 1923, Britton wrote, "The great mosquito plague of Connecticut is caused by the abundance of only a few kinds of mosquitoes. A few years ago in the southern half of the State, the salt marsh mosquitoes were the most prominent, and this is true today except in certain sections where the salt marshes have been ditched" (Britton 1923).

New Jersey light traps were used for the first time in 1932 in Connecticut to assess numbers of mosquitoes (Turner 1932). Similar but smaller light traps are still currently used to assess mosquito populations and prevalence of West Nile and eastern equine encephalomyelitis viruses throughout Connecticut (Andreadis et al. 2001b).

Beginning in November 1933, two Federal mosquito control projects were funded through the Civil Works Administration and administered by the Experiment Station (Botsford 1933). One was a project that authorized ditching of salt marshes and fresh water swamps and the repair or construction of tide gates and dikes. The other was a State project for ditching salt marshes. The aim, using these funds, was to complete the ditching of the remaining salt marsh areas, repair tide gates and dikes, and also focus on permanent drainage work in many towns where malarial mosquitoes, *Anopheles* sp., were breeding in fresh water.

Twenty-seven towns had salt marshes totaling about 20,000 acres. About 11,000 acres had been ditched from 1904-1933 and approved for state maintenance. The remaining 9,000 acres, in large part, were ditched from November 1933 through October 1934 with the help of Federal financing (Botsford 1934). Using the work-force paid with Federal funds, mosquito control work was carried out through 1935 in all shore line towns except Bridgeport, Groton, and Stonington, and efforts were completed in the inland towns of Ansonia, Derby, Shelton, New Canaan, Hamden, North Haven, Southington, East Hartford, Manchester, and Essex (Botsford 1935) (**Figure 19**).

Control efforts included surveying for mosquitoes, ditching of salt marsh areas and fresh water extensions, building masonry sea walls and sod dikes, installing tide gates with masonry abutments and in masonry manholes, building timber jetties to protect outlets of marshes, and laying of pipe outlets. In fresh water areas, mosquito control work included ditching fresh water swamps in populated places, filling sections impractical to drain, lowering improperly graded highway culverts and field drains which caused swampy places,

Yale Bowl: 1945
DDT for a Mosquito-Free Concert

Cooperative Effort with:

- **Connecticut Agricultural Experiment Station**
- **Federal Bureau of Entomology and Plant Quarantine**
- **U.S. Coast Guard**
- **Yale University**
- **New Haven Orchestra Association**

Mist blower

Helicopter spraying

Before Treatment: mosquitoes biting at rate of 5 bites per minute
After Treatment: 1 mosquito was seen during the concert

Figure 20.

constructing both open and closed storm drains, grading and straightening natural streams and waterways, including adding stones to sides to prevent erosion of banks. These efforts reduced the mosquito nuisance in the shore line and inland areas of Connecticut. It was stated that all of the work was engineered and constructed with the idea of permanency and satisfaction to all concerned. Not only did this work reduce the nuisance of mosquitoes, but it also improved sanitary and flood conditions.

About 11,500 acres of salt marsh in 16 towns, Stamford, Norwalk, Westport, Fairfield, West Haven, New Haven, Hamden, East Haven, Branford, Guilford, Madison, Clinton, Westbrook, Old Lyme, Groton, and Stonington, were ditched with funds raised locally. These ditching systems were accepted by the Experiment Station for maintenance, according to statute (Botsford 1936). However, ditching supported by Federal funds could not be maintained by the Experiment Station under the Mosquito Act, and upkeep of the drainage systems was left entirely in the hands of local governments.

In January 1936, the mosquito control project, which was administered by the Experiment Station, was transferred from the Civil Works Administration to the Works Progress Administration with an average of 600 men employed (Botsford 1937). This effort was continued through 1938. The September 21, 1938 hurricane caused significant damage to the mosquito control efforts in salt marshes. For example, the stone and earth dikes in Great Harbor and Shell Beach in Guilford were almost totally destroyed (Botsford 1938).

General Assembly legislation in 1939 transferred all phases of mosquito control work from the Experiment Station to the new Board of Mosquito Control (Botsford 1939). The Director of the Experiment Station (William L. Slate) was Chairman of this Board. Works Progress Administration projects, in cooperation with towns, continued under the supervision of the Experiment Station. In 1940, the Works Progress Administration projects were significantly reduced, and the Director of the Experiment Station continued as Chairman of the Board of Mosquito Control (Botsford 1940). Although the control of mosquitoes was no longer the responsibility of the Experiment Station, it is important to note that the State accepted for maintenance 11,000 acres of salt marsh and thereafter was legally obliged to keep the ditches, dikes, and tide gates in good condition (Botsford 1941).

Mosquito control remained under the direction of the State Board of Mosquito Control until 1950 when duties of the Board were transferred to the State Department of Public Health. The mosquito control program remained in the Department of Public Health until 1992 when responsibilities for wetlands restoration were funded by the Department of Environmental Protection. Mosquito control efforts were transferred to the Department of Environmental Protection in 1997, where it has remained to this day.

Figure 21. Dr. Robert C. Wallis collecting mosquitoes as they alight on his arm, 1953.

Figure 22. A female mosquito, **Aedes canadensis**, *collected in Connecticut and feeding on the arm of Dr. Louis A. Magnarelli. In the 1960s and 1970s, Magnarelli, Anderson, and Andreadis would routinely feed field-collected mosquitoes on themselves for experiments they were conducting. Laboratory animals are now used to feed mosquitoes.*

It is worth noting that Connecticut salt marshes were ditched in colonial times by farmers to increase yields of salt meadow cord-grass *(Spartina patens),* improve access of farm equipment, and to mark property boundaries (Rozsa 1995). Maintenance of ditches dug for mosquito control continues to this day, but beginning in 1985, open marsh water management methods were instituted by the Department of Public Health. These procedures are relatively effective in reducing salt marsh mosquitoes and are less intrusive in harming the ecology of the marsh. Abandoned ditches will fill slowly, allowing restoration of hydrologic flow.

Mosquito control, 1945

The Department of Entomology began testing chemicals and different methods of application for the control of several important insect pests, including mosquitoes. These studies included the application of DDT to about 85 acres of land in New Haven, including the Yale Bowl, for the control of mosquitoes (Botsford 1946, Friend 1946a).

The New Haven Orchestra scheduled six outdoor concerts at the Yale Bowl in July and August 1945. The Experiment Station, in cooperation with Federal agencies, Yale University, the New Haven Orchestra, and the United States Coast Guard, applied DDT shortly before the first and last concerts by helicopter and by mist blower before all six concerts. The mosquito density before the first concert was estimated to be about five biting mosquitoes per minute. During the concert, one mosquito was reported. Mosquitoes were virtually absent for about five days following each treatment. The audiences agreed that they were not annoyed by mosquitoes (**Figure 20**). DDT is no longer sold or used in the United States.

Mosquitoes, taxonomy, biology, and ecology

Fifty species of mosquitoes have been recorded in Connecticut (Andreadis et al. 2005). Taxonomic keys, listings of species, and the ecology of various Connecticut species have been published on four occasions since 1904 (**Table 1**). Dietrich Bodenstein (1945) conducted the first laboratory study of mosquitoes at the Experiment Station and reported on the growth of immature organs. Robert C. Wallis (**Figure 21**) began his studies on the ecology of Connecticut mosquitoes in 1953. He was followed by Calvin A. Lang, John F. Anderson, James T. Sheldahl, Louis A. Magnarelli, Theodore G. Andreadis, Charles R. Vossbrinck, Andrew J. Main, Philip M. Armstrong, Goudarz Molaei, and Shaoming Huang. The various studies on growth, genetics, larval development, effects on day-length and temperature on induction and termination of diapause, which governs the seasonal appearance of specific species, blood- and nectar-feeding needs and behavior, and field and seasonal ecology of various species were conducted to improve upon integrated pest management methods of control of many important species in Connecticut and to provide vital ecological information on the important vectors of human and veterinary viruses and pathogens (**Table 1**)(**Figure 22**). Additional contributions to the ecology of mosquitoes will be found under the sections entitled ***Mosquitoes, biological control*** and ***Mosquitoes, arthropod-borne viruses.***

Louis A. Magnarelli, a graduate of Cornell University, was hired in 1975. He wrote the initial scientific paper on the blood-feeding habits of Connecticut mosquitoes (Magnarelli 1977c), but after the arrival of West Nile virus in the United States in 1999, the urgent need of knowing the feeding habits of vectors of this

exotic virus became paramount. Dr. Goudarz Molaei, a graduate of the University of Toronto, Canada, was hired by Dr. Andreadis in 2004 to initiate studies on the identification of blood-meals ingested by mosquitoes in areas where West Nile virus was prevalent and humans were being infected in Connecticut and elsewhere.

These findings were extremely important in helping to identify where specific species of mosquitoes were acquiring the virus from birds in nature and how this virus was being transferred to humans. A relatively early paper identified robins as an important avian host for *Culex pipiens* (Molaei et al. 2006a), probably the most important mosquito vector of West Nile virus in Connecticut. This significant scientific manuscript published in the March 2006 issue of Emerging Infectious Diseases was recognized by *Discover* Magazine as one of the top 100 discoveries for the year 2005.

Table 1. Experiment Station publications on the taxonomy and biology of mosquitoes.

Mosquito species	Type of Study	Citation
Many	Taxonomy and biology	(Andreadis 2003, Andreadis et al. 2005, Britton and Viereck 1904, Matheson 1945, Wallis 1960)
Many	Field ecology, distribution, egg laying	(Anderson 1975, Andreadis 1988c, Magnarelli 1983b, Morrison and Andreadis 1992, Sheldahl 1974, Wallis 1955)
Many	Nectar feeding	(Magnarelli 1977a, 1978d, 1979a, 1983a, Magnarelli and Andreadis 1987)
Many	Blood feeding	(Magnarelli 1977c, 1979b, Molaei and Andreadis 2006, Molaei et al. 2006a, Molaei et al. 2006b, Molaei et al. 2007, Molaei et al. 2008, Molaei et al. 2009a, Molaei et al. 2009b)
Many	Genetics	(Anderson 1967b, Shepard et al. 2006)
Aedes aegypti (L.)	Growth, development, blood feeding, egg production and laying	(Bodenstein 1945, Lang 1956, Lang and Wallis 1956, Wallis 1956, Wallis and Lang 1956, Wallis 1961, 1962a)
Aedes albopictus (Skuse)	Field ecology, distribution	(Andreadis 2009)
Aedes atropalpus (Coquillett)	Growth and development	(Anderson 1966, Anderson 1968a, b)
Aedes canadensis (Theobald)	Nectar feeding, egg laying	(Magnarelli 1983a, Wallis and DeBishop 1957)
Aedes cantator (Coquillett)	Field ecology, nectar feeding	(Andreadis 1990c, Magnarelli 1978a, 1979a, Magnarelli and Andreadis 1984)
Aedes communis (De Geer)	Field ecology, distribution	(Andreadis 1986a)
Aedes japonicus (Theobald)	Field ecology, distribution, genetics	(Andreadis et al. 2001a, Andreadis and Wolfe 2010, Fonseca et al. 2001)
Aedes punctor (Kirby)	Field ecology, distribution	(Andreadis 1986a)
Aedes sollicitans (Walker)	Growth and development, nectar feeding	(Anderson 1970b, Magnarelli 1977b, 1979a)
Aedes stimulans (Walker)	Growth and development, nectar feeding	(Anderson 1967a, Magnarelli 1983a, 1990a)
Aedes triseriatus (Say)	Nectar feeding	(Magnarelli 1986)
Anopheles punctipennis (Say)	Blood feeding	(Magnarelli 1978b)
Culex pipiens L.	Genetics	(Huang et al. 2008, Huang et al. 2009)
Culex restuans Theobald	Ecology	(Wallis 1959b)
Culiseta melanura (Coquillett)	Ecology, genetics	(Andreadis and Munstermann 1997, Wallis 1953, 1962c)
Culiseta morsitans (Theobald)	Feeding habits	(Wallis 1957)
Psorophora ferox (Von Humboldt)	Field ecology and nectar feeding	(Magnarelli 1980)

Fig. 23. Centers for Disease Control mosquito identification forum, 2001. Back row (l to r): Theodore Andreadis (host), Doug Serafin, Lisa Ireland, Edward Briggs, John Turmel, Michael O'Connell, David Prodanas, Robin Lindsay. Front row (l to r): Michael Thomas (instructor), John Shepard (instructor), Lisa Mills, Justin O'Leary, John Anderson (host).

▲ *Figure 24. Dr. Andreadis at Electron Microscope, 1986*

◀ *Figure 25. The Experiment Station works closely with state, city, and town elected officials and employees. Drs. Anderson (l) and Andreadis (r) along with State Representative Terry Backer (c) identified a serious infestation of salt marsh mosquitoes, Stratford, 1996. They applied a biological insecticide to kill the mosquito larvae that same day.*

Drs. Theodore G. Andreadis and John F. Anderson hosted a Centers for Disease Control mosquito identification forum for northeastern United States and Canada during June 4 through June 8, 2001. Ten scientists participated in the training session. Dr. Harry M. Savage was the organizer for the Centers for Disease Control, and John J. Shepard and Michael C. Thomas were the primary instructors (**Figure 23**).

Mosquitoes, biological control

John F. Anderson, a graduate of the University of Illinois, was hired in 1964 to initiate studies on biological control of mosquitoes in an attempt to find alternatives to chemical insecticides. Pathogenic viruses, fungi, and microsporidia were identified (**Table 2**).

Theodore G. Andreadis, a graduate of the University of Florida, was hired in 1978. He has published extensively to the present day about natural enemies of mosquitoes (**Figure 24**). He described new species, evaluated patho-3gens in the laboratory and field for their efficacy in controlling mosquitoes, documented natural epizootics of these pathogens in the field, demonstrated their ultra structure, and described their complicated life cycles. Studies using molecular biology, often in collaboration with Charles R. Vossbrinck, a graduate of the University of Illinois who was hired in 1996, were used to identify the different forms of the pathogens in mosquitoes and the intermediate copepod host. These studies were important in identifying natural enemies of mosquitoes in Connecticut and the Northeast, unraveling their complex life cycles, assessing their importance in naturally reducing numbers of mosquitoes, and evaluating their possible use in integrated pest management programs for control of mosquitoes (**Figure 25**).

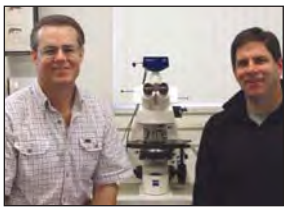
Mosquito identification, rearing, and laboratory experimental work shifted from the Jenkins Building to the second floor of the Slate Building in the 1990s. Mosquitoes were also reared in the insectary at Lockwood Farm in Hamden, Connecticut.

Table 2. Experiment Station publications on the biological control of mosquitoes, 1904-2009.

Mosquito species	Microbial pathogen or predator	Type of Study	Citation
Many	Fish	Predation	(Britton and Viereck 1904)
Many	Microsporidia	Molecular biology	(Baker et al. 1998, Vossbrinck et al. 1998, Vossbrinck et al. 2004)
Many	Microsporidia	Review article	(Andreadis 1987, 2007, Becnel and Andreadis 1999)
Aedes abserratus, (Felt and Young)	*Amblyospora abserrati*	Description, life cycle, transmission, pathology, prevalence of infection	(Anderson 1968c, Andreadis 1994b)
Aedes aegypti (L.)	*Edhazardi aedis*	Life cycle, transmission, pathology, prevalence of infection	(Andreadis 1994c)
Aedes aegypti	Iridescent virus	Transmission, pathology	(Tesh and Andreadis 1992)
Aedes albifasciatus (Macquart)	*Amblyospora albifasciati*	Transmission, prevalence of infection	(Micieli et al. 2001, 2009)
Aedes aurifer (Coquillett)	*Amblyospora auriferi*	Description, life cycle, transmission, pathology, prevalence of infection	(Andreadis 1994b)
Aedes canadensis (Theobald)	*Erynia aquatica*	Description, pathology, prevalence of infection	(Anderson and Ringo 1969, Anderson and Anagnostakis 1980)
Aedes canadensis	*Amblyospora canadensis*	Prevalence of infection, description, pathology	(Anderson 1968c, Andreadis 1993a)
Aedes canadensis	*Acanthocyclops vernalis, Diacyclops bicuspidatus thomasi*	Predation	(Andreadis and Gere 1992)
Aedes cantator (Coquillett)	*Amblyospora connecticus*	Description, life cycle, transmission, pathology, prevalence of infection, biological control	(Anderson 1968c, Andreadis 1982, 1983a, b, 1985a, b, 1986c, 1988a, b, 1989a, b, 1990a, Andreadis 1990b, Andreadis 1990d, 1991, 1994b, 2005, Lucarotti and Andreadis 1995)
Aedes cantator	*Erynia aquatica*	Description, pathology, prevalence of infection	(Andreadis and Magnarelli 1983)
Aedes cantator	*Coelomomyces*	Description, prevalence of infection	(Andreadis and Magnarelli 1984, Lucarotti and Andreadis 1995)
Aedes cantator	Cytoplasmic polyhedrosis virus	Description, pathology, prevalence of infection	(Andreadis 1981)
Aedes caspius (Pallas)	*Andreanna caspii*	Pathology	(Simakova et al. 2008)
Aedes cinereus Meigen	*Amblyospora cinerei*	Prevalence of infection, description	(Anderson 1968c, Andreadis 1993a, 1994c)
Aedes excrucians (Walker)	*Amblyospora excrucii*	Description, life cycle, transmission, pathology, prevalence of infection	(Anderson 1968c, Andreadis 1994b)
Aedes sollicitans (Walker)	*Coelomomyces*	Description, prevalence of infection	(Andreadis and Magnarelli 1984, Lucarotti and Andreadis 1995)
Aedes sticticus (Meigen)	*Amblyospora stictici*	Description, life cycle, transmission, pathology, prevalence of infection	(Andreadis 1994b)
Aedes stimulans (Walker)	*Amblyospora stimuli*	Description, life cycle, transmission, pathology, prevalence of infection	(Anderson 1968c, Andreadis 1985c, 1994b, 1999)
Aedes stimulans	Iridescent virus	Description, pathology, prevalence of infection	(Anderson 1970a)
Aedes stimulans	*Acanthocyclops vernalis, Diacyclops bicuspidatus thomasi*	Predation	(Andreadis and Gere 1992)
Anopheles punctipennis (Say)	*Amblyospora legeri*	Prevalence of infection, pathology	(Anderson 1968c)
Culex nigripalpus Theobald	Baculovirus, CuniNPV	Infection, pathology	(Andreadis et al. 2003)
Culex restuans Theobald	*Stempellia magna*	Prevalence of infection, transmission	(Anderson 1968c)
Culex restuans	Cytoplasmic polyhedrosis virus	Description, pathology, transmission	(Andreadis 1986b)
Culex salinarius Coquillett	*Amblyospora salinaria*	Description, life cycle, transmission	(Becnel and Andreadis 1998)
Culex territans Walker	*Amblyospora opacita*	Prevalence of infection, pathology	(Anderson 1968c)
Culiseta melanura (Coquillett)	*Hyalinocysta chapmani*	Life cycle, transmission, pathology, prevalence of infection	(Andreadis 1994a, 2002, Andreadis and Vossbrinck 2002, Andreadis 2005)
Culiseta morsitans (Theobald)	*Erynia aquatica*	Description, pathology, prevalence of infection	(Anderson and Ringo 1969, Anderson and Anagnostakis 1980)

Mosquito-Borne Viruses: Late 1990s and early 2000s

1996: Began surveillance for mosquitoes infected with Eastern Equine Encephalitis in southeastern Connecticut. We collected and identified the mosquitoes; viruses were isolated and identified at Yale University.



Michael Thomas (l), John Shepard
Mosquito identification

Bonnie Hamid

Jodie Correia

Shirley Tirrell

◀ **1998:** A laboratory, which had been used for Rocky Mountain spotted fever and Lyme disease studies, was converted to a virus isolation lab. Yale facilities were no longer used.

2004: Moved into new virus isolation lab in Johnson-Horsfall Laboratory. ▶

Angela Bransfield

Tanya Petruff

Shannon Finan

Figure 26.

Mosquitoes, arthropod-borne viruses (arboviruses)

Effects of arboviruses on humans range from subclinical to mild infections, to hemorrhagic disease, or to acute central nervous system disease involving encephalitis or meningitis, which may result in irreversible paralytic or other pathologic conditions or death (Work 1975). The first mosquito-associated virus isolated in Connecticut was eastern equine encephalomyelitis and was made from dying ring-necked pheasants by a group at Harvard University (Tyzzer et al. 1938). That same year, the first epidemic of this virus in humans was documented in Massachusetts (Fothergill et al. 1938, Howitt 1938).

Ten arboviruses have been isolated from mosquitoes in Connecticut. These viruses and the authors who made the first isolations (five were made initially by the Yale Arbovirus Research Unit, and five were made at the Experiment Station) include eastern equine encephalomyelitis (Wallis et al. 1960), Flanders (Main et al. 1979b), Jamestown Canyon (Sprance et al. 1978, Whitman et al. 1968), Highland J (Main et al. 1979c), trivittatus (unpublished data by the Experiment Station), Keystone (Main et al. 1979a), La Crosse (Armstrong and Andreadis 2006), Potosi (Armstrong et al. 2005), West Nile (Anderson et al. 1999), and Cache Valley (Main 1981). Nine (all but Keystone virus) of these viruses were isolated from mosquitoes collected, identified, and tested at the Experiment Station through 2009.

Flanders, Highland J, Keystone, trivittatus, and Potosi viruses are not known to cause human disease. Cache Valley virus has caused death in one human (Sexton et al. 1997), has caused congenital defects in lambs (Edwards 1994), and this virus may have similar effects in humans (Calisher and Sever 1995). Eastern equine encephalomyelitis, West Nile, and La Crosse viruses have caused serious illness, including death, in humans in the United States. West Nile virus has resulted in 69 reported cases and 3 fatalities in Connecticut.

With the looming closure of the Yale Arbovirus Research Unit in the mid 1990s (Anonymous 1994), which was a continuation of the Rockefeller Foundation Virus Program (Theiler and Downs 1973), Director Dr. John F. Anderson obtained permission in 1997 and 1998 from Professor Gregory H. Tignor to work with the last Yale technician still working with arboviruses, Shirley Tirrell. She had been trained under re-

Figure 27. Mayor Dannel Malloy of Stamford views the West Nile virus through the Experiment Station's electron microscope, 1999. The City of Stamford had initiated mosquito control to reduce risk of citizen-exposure to the virus, and Mayor Malloy visited Drs. Anderson and Andreadis to learn more about West Nile virus and the control of mosquitoes.

Figure 28. Dr. Theodore G. Andreadis (r), Governor John Rowland (l) and Sidney Holbrook (c), Commissioner of Department of Environmental Protection, at a news conference, Stonington, 1996.

tired Professor Robert E. Shope. It was in this Yale laboratory that Anderson learned procedures for safely handling viruses, their method of isolation, and the serology procedures used to identify them once they had been isolated and grown in tissue culture.

Anderson then set up a virus laboratory at the Experiment Station in Britton Building in 1998 where studies on Rocky Mountain spotted fever and Lyme disease previously had been conducted. Yale generously provided an important cell line of Vero cells and various needed reagents, including immune serum to specific viruses. Shirley Tirrell assisted Anderson for several months after the new laboratory had been established. Thereafter, all virus isolations from mosquitoes collected in Connecticut were made at the Experiment Station (**Figure 26**).

Surveillance for mosquitoes and their viruses has been performed annually from 1996 to the present (Andreadis et al. 1998). These scientific activities have been integral to the public health response to West Nile virus and eastern equine encephalomyelitis virus and have provided an early warning system that has directed targeted intervention strategies and helped prevent transmission of mosquito-borne infections to humans (**Figure 27**). More than two million mosquitoes have been trapped and tested. The seasons associated with increased risk of human exposure to specific viruses have been identified (Anonymous 2009).

Jamestown Canyon virus

Jamestown Canyon virus causes mild febrile illness and rarely encephalitis or aseptic meningitis (Grimstad 1988). Antibodies to Jamestown Canyon virus have been reported in several Connecticut residents according to a State Department of Public Health study (Mayo et al. 2001), and there has been one documented human case, which exhibited mild symptoms (Nelson et al. 2002). In a study comparing isolates of Jamestown Canyon virus over 40 years, Armstrong and Andreadis (2007) concluded that Jamestown Canyon virus was stably maintained in Connecticut in several mosquito species. In a ten-year study of Jamestown Canyon virus in Connecticut, Andreadis et al. (2008) reported the isolation of this virus from 22 species of mosquitoes collected throughout many different areas of Connecticut. The vast majority of isolations were from species of *Aedes.* The virus was isolated from June through September. White-tailed deer (*Odocoileus virginianus*), which have antibodies to Jamestown Canyon virus (Zamparo et al. 1997), are primary hosts for many *Aedes* species (Molaei et al. 2008) and are likely the principal amplification hosts for Jamestown Canyon virus (Andreadis et al. 2008). Jamestown

Figure 29. Dr. Anderson at Barn Island Wildlife Management Area, Stonington, where he was collecting mosquitoes for virus surveillance. This area was closed to the public because of infected mosquitoes that Anderson had collected earlier, 1996.

Figure 30. Dr. Philip Armstrong, 2007

Figure 31. Michael Vasil examines a CDC light trap for mosquitoes, which uses carbon dioxide as well as a light to attract mosquitoes. A fan draws the mosquitoes down into the netted cage, 2000.

Canyon virus likely overwinters in Connecticut, as it does elsewhere, in mosquito eggs infected by vertical transmission (Grimstad 1988).

La Crosse virus

La Crosse virus causes encephalitis, primarily in children, and is responsible for about 100 cases a year in the upper Midwest and Appalachian Mountains. There have been no human cases in Connecticut to date. This virus has been isolated from one pool of *Aedes triseriatus* (Say) (Armstrong and Andreadis 2006), a species that occurs throughout the state and is relatively abundant in suburban forests and some urban areas where the primary amplification hosts, eastern chipmunk *(Tamias striatus)* and eastern gray squirrel *(Sciurus carolinensis*), are present. La Crosse virus is vertically transmitted from infected females to eggs and survives the winter in mosquito eggs (Watts et al. 1973). La Crosse virus is a potential public health problem in Connecticut.

Eastern equine encephalomyelitis

An outbreak of eastern equine encephalomyelitis virus occurred among penned pheasants in Connecticut in 1951. Robert C. Wallis, a graduate of Johns Hopkins University, was hired in 1953 to focus on the role of mosquitoes in transmission of this virus and collaborated with colleagues at the University of Connecticut and other institutions (Jaynes et al. 1962, Jungherr and Wallis 1958, Satriano et al. 1958, Wallis et al. 1958a, Wallis et al. 1958b, Wallis 1959a, Wallis et al. 1960). These studies showed that intra-pen transmission by ring-necked pheasants of eastern equine encephalomyelitis virus was caused by feather picking and that debeaking prevented the spread of the virus within a pen. They also demonstrated that eastern equine encephalomyelitis virus was maintained longer in feather quills than in the blood stream and that pheasants do not serve as reservoirs for eastern equine encephalomyelitis virus because of low viremias (concentration of virus). Additionally, they documented that Connecticut's sylvan-swampland ecology enabled dissemination of eastern equine encephalomyelitis virus among birds and mosquitoes, and they isolated this virus from *Aedes vexans* (Meigen). After Wallis left the Experiment Station for Yale University in 1962, he and his students reported on the close association of the mosquito *Culiseta melanura* with an outbreak of eastern equine encephalomyelitis virus in pheasants and horses in Connecticut (Wallis and Main 1974).

An arbovirus surveillance program was initiated by the Experiment Station in 1991 and 1992 in collaboration with Paul M. Capotosto of the Department of Environmental Protection and Yale University (Andreadis et al. 1992, 1994). The epidemiology of eastern equine encephalomyelitis virus in Connecticut was reviewed in 1993 (Andreadis 1993b).

In 1996, eastern equine encephalomyelitis virus became wide-spread in mosquito populations in southeastern Connecticut. Working with Shirley Tirrell at Yale University, Andreadis and Anderson made multiple isolations of this virus from eight species of mosquitoes with

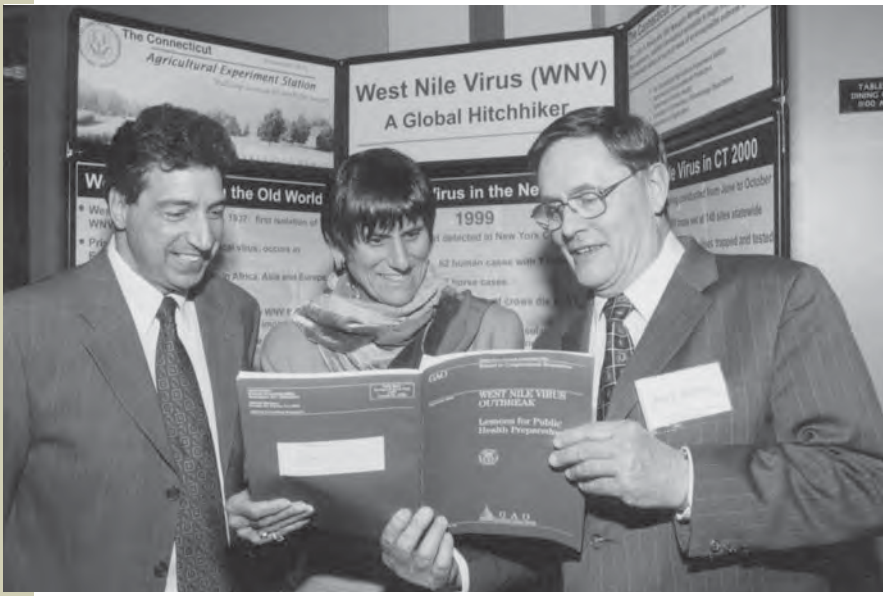


Figure 32. Dr. Theodore G. Andreadis (l), Connecticut U. S. Congresswoman Rosa DeLauro (c), and Director John F. Anderson (r) look at a General Accounting Office report on West Nile virus, which mentions work of the Experiment Station, at an exhibition on research by Land Grant Universities and agricultural experiment stations held on Capitol Hill in Washington, DC, 2001.

most isolations from *Culiseta melanura* (Andreadis 1998, Andreadis and Anderson 1998, Andreadis et al. 1998). Isolations were from mosquitoes captured in red maple/white cedar swamps and areas distant from these swamps. Connecticut Governor John Rowland became involved and with advice from the Departments of Health, Environmental Protection, Agriculture, and the Experiment Station ordered limited aerial and ground spraying of the insecticide Scourge in southeastern towns (**Figure 28**). Some outdoor state facilities were closed (**Figure 29**), and towns altered school programs to reduce risk of human exposure to mosquito bites. No humans contracted the virus.

As a result of the high prevalence of infected mosquitoes with eastern equine encephalomyelitis virus in 1996, "An Act Concerning Mosquito Control and Aerial Application of Pesticides", created the Mosquito Management Program the following year in 1997 to monitor mosquito breeding populations for the prevalence of infectious agents that can cause disease in humans and to determine when measures to abate any threat are necessary. The Experiment Station is responsible for the trapping, identification, and arbovirus testing of mosquitoes for the mosquito management program, which is administered by the Department of Environmental Protection.

This program is health-based and focuses on preventive efforts and mosquito monitoring for early detection of viruses that could cause human disease in Connecticut. It is based on an integrated pest management approach, which includes a combination of surveillance, education, source reduction, larval and adult mosquito control, and personal protection measures. Theodore G. Andreadis leads this program for the Experiment Station. A number of African penguins, *Spheniscus demersus*, housed at the Mystic Aquarium in Stonington, Connecticut, were reported in 2003 to have signs of disease. The disease was later shown in a joint study to be caused by eastern equine encephalomyelitis virus (Tuttle et al. 2005). The penguins were in an outdoor facility and likely were bitten by mosquitoes naturally infected with this virus.

Philip M. Armstrong, a graduate of Harvard School of Public Health and hired in 2004 (**Figure 30**), reported that eastern equine encephalomyelitis virus survives winters in northeastern United States and that this virus is reintroduced into Connecticut from nearby states (Armstrong et al. 2008).

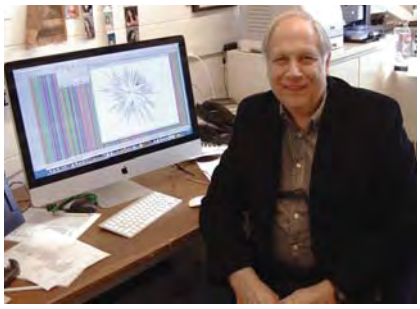
West Nile virus

With support from the Connecticut Department of Public Health, Director Anderson and Dr. Andreadis began trapping mosquitoes on Sunday, September 5, 1999, one day after mosquito-borne illnesses and deaths in New York City were reported, which initially were thought to be caused by St. Louis encephalitis virus (Gough 2000, White 2001). Mosquito traps (**Figure 31**) were placed in Greenwich, Connecticut, so as to be relatively close to New York City where humans were becoming ill.

With the help of the Greenwich Police, Health, and Parks and Trees Departments, Phyllis and Paul Mazik in Stamford, Connecticut, and the Innis Arden Golf Club in Greenwich, the Experiment Station made the first culture of the causative virus from North Ameri-

West Nile Virus: 1999

September, 1999: Cultures of an unknown virus were made from mosquitoes trapped near Ball Washer Number 4, Innis Arden Golf Club, Greenwich, Connecticut.



Dr. Charles Vossbrinck sequenced the RNA of the unknown virus. It was identified as West Nile virus, new to North America.

Isolation of West Nile Virus from Mosquitoes, Crows, and a Cooper's Hawk in Connecticut

John F. Anderson,[1*] Theodore G. Andreadis,[2*] Charles R. Vossbrinck,[2*] Shirley Tirrell,[3] Edward M. Wakem,[4] Richard A. French,[4] Antonio E. Garmendia,[4] Herbert J. Van Kruiningen[4]

West Nile (WN) virus, a mosquito-transmitted virus native to Africa, Asia, and Europe, was isolated from two species of mosquitoes, *Culex pipiens* and *Aedes vexans*, and from brain tissues of 28 American crows, *Corvus brachyrhynchos*, and one Cooper's hawk, *Accipiter cooperii*, in Connecticut. A portion of the genome of virus isolates from four different hosts was sequenced and analyzed by comparative phylogenetic analysis. Our isolates from Connecticut were similar to one another and most closely related to two WN isolates from Romania (2.8 and 3.6 percent difference). If established in North America, WN virus will likely have severe effects on human health and on the health of populations of birds.

An outbreak of arboviral encephalitis associated with mosquitoes was recognized in late August 1999 to be occurring in New York City (*1*). St. Louis encephalitis virus (SLE) was identified initially as the causative agent, but a Kunjin WN-like virus was later reported to be the likely etiologic agent (*2*). We began trapping mosquitoes for the testing of viruses on 5 September 1999 (*3*). Traps were placed first in the field in Greenwich, Con- ... as 12 additional towns in Fairfield County, Connecticut.

American crows, *Corvus brachyrhynchos* (*4*), were reported dying in Fairfield County, Connecticut, in the second week of September 1999. One crow was collected from Westport, Connecticut, on 13 September 1999 and was tested for virus. Subsequently, 30 additional dead crows from 18 additional towns in Fairfield and New Haven Counties and a Cooper's

The report of this new virus was published in *Science,* Volume 286, December 17, 1999

Winter 1999: Would the virus survive the winter? Dr. Theodore Andreadis, with help from Phyllis and Paul Mazik, collected over-wintering mosquitoes in Stamford, Connecticut. No positive mosquitoes were found in the few *Culex* mosquitoes collected that first winter.

Figure 33.

can mosquitoes, which turned out to be the exotic West Nile virus. At about the same time, the Department of Pathobiology at the University of Connecticut informed the Experiment Station that they had removed the brain of a dead crow that had died in Norwalk, Connecticut. The virus was isolated by the Experiment Station from the brain of this crow.

The viruses from the crow and the mosquitoes appeared to be similar. Charles Vossbrinck sequenced the RNA of the viruses, which were identified as West Nile virus, a pathogen that occurs naturally from northern to southern Africa and other parts of the Old World. The Experiment Station (Anderson et al. 1999) and Centers for Disease Control and Prevention (Lanciotti et al. 1999) independently published their separate findings of the introduction of the exotic West Nile virus into the New World in a December issue of *Science* magazine (**Figures 32** and **33**).

Our research initiatives have further elucidated the natural history and epidemiology of West Nile virus in the northeastern United States including the role of various mosquitoes and birds, evaluated the competence of various mosquitoes to transmit and serve as over-wintering hosts for West Nile virus, examined the feeding and biting behavior of the primary mosquito vectors of West Nile and other mosquito-borne viruses, developed more sensitive and rapid molecular diagnostic techniques to identify viruses, documented the introduction and establishment of two invasive mosquitoes from Asia, tested novel mosquito trapping methodologies to enhance the early detection of mosquito-borne viruses, and evaluated the efficacy of new and established biological agents to control mosquitoes (**Figure 34**).

The Experiment Station led research on many aspects of the epidemiology of this invasive virus and its mosquito vectors and participated in many experiments with Professor Erol Fikrig at Yale University and other collaborators. The virus was isolated from 17 species of mosquitoes from June through October, 1999-2003 and most frequently from specimens collected in densely populated areas of Fairfield and New Haven Counties where the highest rates of dead crow sightings were reported (Andreadis et al. 2001b, Andreadis et al. 2004). The largest numbers of isolates were from *Culex pipiens pipiens* (n=86), *Culex salinarius* (n=32), *Culex restuans* (n=26), *Culiseta melanura* (n=32), and *Aedes vexans*

Figure 34. Michael Misencik sampling larval mosquitoes in a catch basin treated with a biological control agent, Stratford, 2009.

Figure 35. Dr. Andrew Main, a graduate of Yale University, and who was trained in the Yale Arbovirus Research Unit, took a sabbatical leave from the American University in Cairo, Egypt where he was chairman of the Department of Biology. He worked with Dr. John F. Anderson at the Experiment Station in 2001-2002. He later worked at the Experiment Station both as a scientist and as a volunteer through 2009.

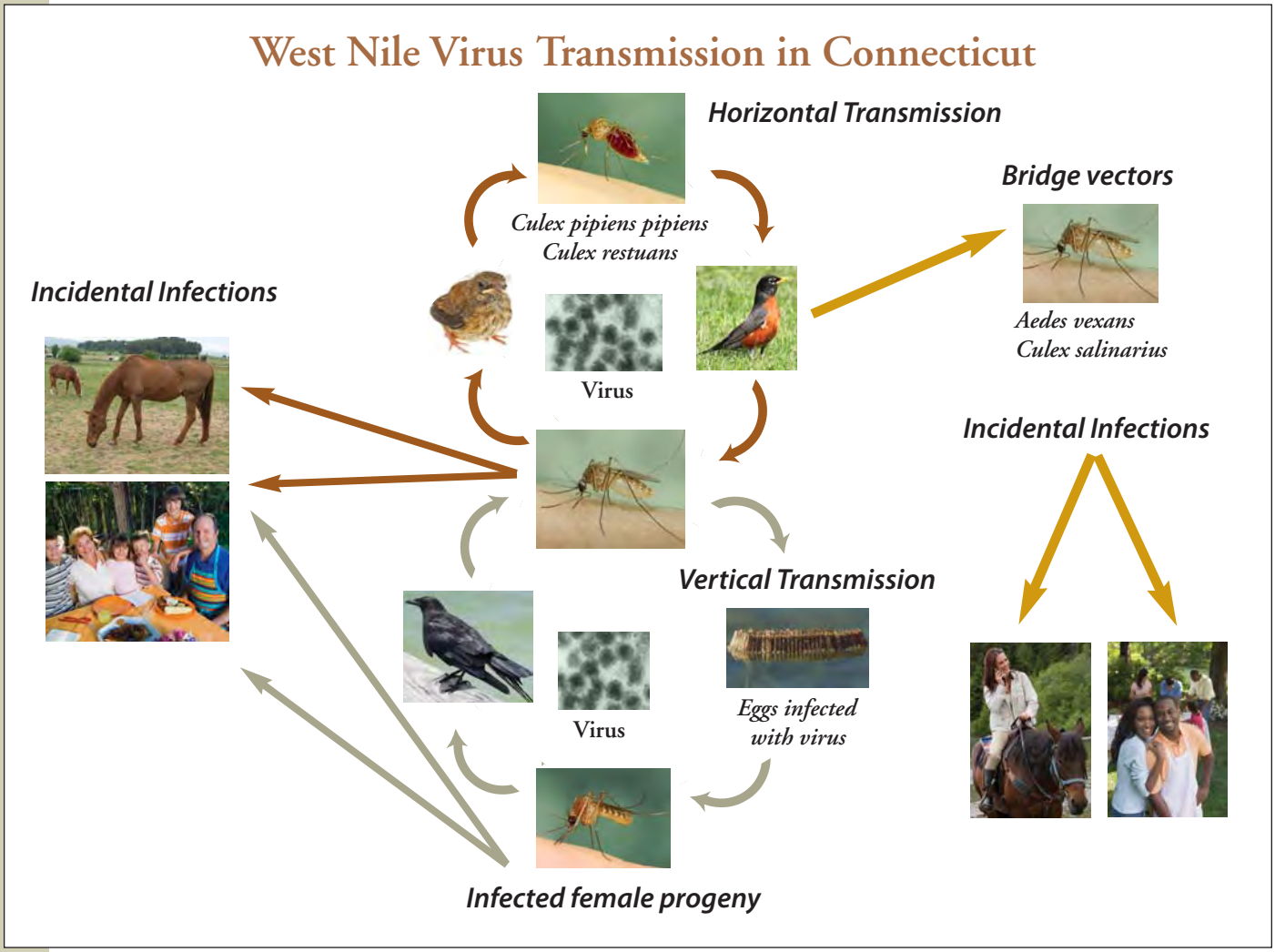


Figure 36. Data used to compile this figure are from publications by the Experiment Station and others. During summer, West Nile virus is transmitted among birds by horizontal transmission primarily by Culex pipiens pipiens *in tree canopies and at night, although other species of mosquitoes are likely involved. Occasionally, the virus is transmitted to humans and to horses. The virus survives during winter in vertically infected hibernating (diapausing)* Culex pipiens pipiens *that have not taken a blood meal. The following spring, vertically infected females emerge from hibernation and initiate amplification of the virus by horizontally transmitting the virus to birds.*

Figure 37. Dr. Goudarz Molaei stands by his thermocycler, which he uses to identify host animals fed upon by mosquitoes, 2010.

Figure 38. Dr. Francis J. Ferrandino, Experiment Station mathematician and statistician, assisted in the analysis of complex field and laboratory data, 2010. He is a graduate of Rensselaer Polytechnic Institute and was hired in 1982.

Figure 39. Receiving virus collection from Yale (Y). From left: Shannon Finan, Leigh Cash, Philip Armstrong, Martin Costello (Y), Deborah Ferry (Y), James Watkins (Y), Benjamin Fontes (Y), Robert Klein (kneeling) (Y), Bonnie Hamid, John Anderson, 2005.

(n=12). *Culex pipiens pipiens* was identified as the likely most important enzootic and epidemic vector. *Culex salinarius* was mentioned as a prime bridge vector (transmission from birds to mammals) late in the season. This species readily feeds on both birds and mammals, including humans. A correlation was made both temporally and spatially among isolations of West Nile virus from field-collected mosquitoes and subsequent human cases in coastal Fairfield and New Haven Counties and in central Hartford County where several human cases were documented. In a collaborative effort with members of the public health community, the Experiment Station reported that portions of the West Nile virus genome could be used to follow the geographical and temporal movement of variant strains in North America (Anderson et al. 2001a, b).

Ticks as well as mosquitoes were reported as vectors of West Nile virus in the Old World. Our studies in collaboration with Dr. Stephen K. Wikel at the University of Connecticut Health Center showed that common Connecticut ticks were not competent to transmit this virus and put an end to further discussion of the possible importance of hard-bodied ticks as vectors in the New World (Anderson et al. 2003).

West Nile virus has survived and caused human disease in northeastern United States from 1999 to the present even though mosquitoes are inactive during the winter. Three papers were published addressing how the virus survives from year to year in New England. In a joint study led by colleagues from the University of Connecticut, we reported that the virus was present in mid-winter in the tissues of a red-tailed hawk, suggesting that the virus could survive through transmission from prey to predator (Garmendia et al. 2000). In subsequent experiments, West Nile virus was documented to be naturally transmitted vertically from the female mosquito to her offspring and that this is the likely means by which this virus survives the winter in Connecticut (Anderson et al. 2006, Anderson and Main 2006) (**Figures 35** and **36**).

There are no effective antiviral compounds available to suppress infections of West Nile virus. Working with James J. Rahal, a physician at Weil Cornell University in New York City, Anderson reported on the efficacy of interferon alpha-2B against West Nile virus in cell culture (Anderson and Rahal 2002) and its use as therapy in humans diagnosed with St. Louis virus meningoencephalitis (Rahal et al. 2004).

Birds had been reported as important amplifying hosts for West Nile virus in Africa and Europe (Hayes 1989, Hubalek and Halouzka 1999). Crow deaths were proposed as a sentinel surveillance system in the northeast (Eidson et al. 2001), although in Connecticut intense epizootics among crows occurred without humans acquiring infection of West Nile virus in a study lead by the Connecticut Department of Public Health (Hadler et al. 2001). Molecular analysis of blood meals of field-caught mosquitoes showed that the important vectors in Connecticut, *Culex pipiens pipiens* and *Culex restuans,* fed extensively on birds and that *Culex salinarius* fed on both mammals and birds (Molaei et al. 2006a, Molaei et al. 2008) (**Figure 37**). Studies on analysis of mosquito-

▲ *Figure 40. Johnson-Horsfall Building, completed in 2003. New Horsfall wing (l), which houses the biosafety level-3 virus laboratory and original Johnson Building (r) with new elevator tower and atrium.*

Figure 41. Top: Dr. Magnarelli with an emergence trap for horse flies in a salt marsh; Bottom: Dr. Anderson cutting sod in a salt marsh for deer fly research, Milford, 1978. ▶

acquired bloods of other species in Connecticut and elsewhere are reviewed in the Section of this publication entitled ***Mosquitoes, taxonomy, biology and ecology.***

In a collaborative laboratory study led by scientists in the United States Army, the potential of 25 species of mosquitoes to transmit West Nile virus was reported (Turell et al. 2005). Nearly all *Culex* species tested were reported as efficient enzootic or amplifying vectors for the virus. Other information needed to assess the importance of a mosquito species as an efficient enzootic or amplifying vector for West Nile virus in the field include (1) its abundance, (2) host-feeding preferences, (3) involvement with other viruses, and (4) frequency of isolation of West Nile virus from field-caught specimens.

The relatively low numbers of human cases in Connecticut caused by West Nile virus is a result of infrequent feeding of *Culex pipiens pipiens* on humans. This mosquito not only feeds preferentially on birds, but also is much more abundant in the tree canopy compared to the ground where humans live (Anderson et al. 2004, Anderson et al. 2006, Andreadis and Armstrong 2007) and feeds almost exclusively at night when humans are indoors (Anderson et al. 2007) (**Figure 38**).

The extrinsic incubation period for West Nile virus in *Culex pipiens pipiens*, the interval between ingestion of an infectious bloodmeal and the time mosquitoes are capable of transmitting the virus, is important in the overall epidemiology of the virus. Studies determined that horizontal transmission rates increased with incubation, with 75% or more transmitting on days ≥16 after infection at 26°C. Females vertically transmitted West Nile virus following the second through fourth blood meals on days 13-33 after infection (Anderson et al. 2008). Several horses have contracted West Nile virus infections in Connecticut. Magnarelli et al. (2008) reported antibodies to this virus in vaccinated and non-vaccinated horses.

The Yale Arbovirus Research Unit discontinued operating in 1995 (Anonymous 1994). Years later, Professor Durland Fish and Michael H. Merson, Dean of the School of Public Health from Yale University, and Director John F. Anderson of the Experiment Station worked together to keep a significant portion of the virus collection in New Haven for research purposes. On April 1, 2005, 475 different species of viruses, which had been isolated primarily from arthropods from throughout the world, were transferred from Yale University to the Experiment Station's new biosafety level-3 laboratory (**Figure 39**) within the newly constructed Johnson-Horsfall Building (**Figure 40**).

Director Anderson participated in a number of studies on various aspects of the molecular biology of West Nile virus led by Professor Erol Fikrig at the Yale

Table 3. Experiment Station publications on the biology, control, and natural enemies of horse flies and deer flies.

Horse fly or deer fly species	Type of Study	Citation
Many	Blood and sugar feeding behavior, egg deposition	(Magnarelli and Anderson 1980b, 1981, Magnarelli 1985a)
Many	Review article on control	(Anderson 1985b)
Atylotus bicolor (Wiedemann)	Autogeny, nectar feeding	(Magnarelli 1988a)
Chrysops ater Macquart	Autogeny, nectar feeding	(Magnarelli and Burger 1984)
Chrysops atlanticus (Pechuman)	Mating, autogeny, biting behavior, nectar feeding, larval distribution, protozoan infection	(Anderson 1969, 1971, Anderson 1973a, Anderson 1973b, Anderson and Magnarelli 1978, Magnarelli and Anderson 1977, Magnarelli and Anderson 1978b, 1979b, Magnarelli et al. 1979b, Magnarelli and Anderson 1980a)
Chrysops cincticornis Walker	Fecundity and oviposition behavior	(Magnarelli et al. 1982b)
Chrysops fuliginosus Wiedemann	Biting and mating behavior, egg deposition, nectar feeding, larval distribution, control, protozoan infection	(Anderson and Kneen 1969, Anderson 1973a, Anderson 1973b, Anderson and Magnarelli 1978, Magnarelli and Anderson 1977, Magnarelli and Anderson 1978b, 1979a, Magnarelli et al. 1979b, Magnarelli and Anderson 1980a, Magnarelli 1985b)
Hybomitra aurilimba (Stone)	Male hovering and swarming	(Magnarelli 1984)
Hybomitra lasiophthalma (Macquart)	Male hovering and swarming	(Magnarelli 1984)
Tabanus nigrovittatus Macquart	Autogeny, nectar feeding, blood feeding, egg deposition, larval distribution, natural enemies	(Anderson 1971, Anderson and Magnarelli 1979, Magnarelli and Anderson 1977, Magnarelli and Anderson 1978b, Magnarelli et al. 1979b, Magnarelli and Anderson 1980a, c, Magnarelli and Stoffolano Jr. 1980)

School of Medicine (Bai et al. 2007, Gould et al. 2005, Kong et al. 2008, Town et al. 2009, Wang et al. 2001a, Wang et al. 2001b, Wang et al. 2002, Wang et al. 2003, Wang et al. 2004). Additional collaborative studies continued with Dr. Tian Wang when she joined the University of Colorado (Wang et al. 2006, Wang et al. 2008, Welte et al. 2008). Anderson also participated in studies initiated by L2 Diagnostics on development of a protective vaccine for West Nile virus (Bonafe et al. 2009, Ledizet et al. 2005). Dr. Andreadis collaborated with Yale scientists Scott O'Neil and Robert B. Tesh on insect densoviruses and culturing *Wolbachia* symbionts (O'Neill et al. 1995, O'Neill et al. 1997) and with Durland Fish and his students in modeling studies of West Nile virus (Brown et al. 2008, Diuk-Wasser et al. 2006).

Mosquitoes, dog heartworm

Dog heartworm is a serious disease of domestic and feral dogs. It is caused by a nematode, *Dirofilaria immitis*, transmitted among dogs by mosquitoes. Mature heartworms are found in the heart. Chemical therapy can be effective if infections are diagnosed relatively early in the disease. Magnarelli (1978c) studied the role of mosquitoes as vectors and concluded that at least six Connecticut species may be involved in transmission.

Horse flies and deer flies, biology and control

Horse flies and deer flies are serious biting pests of humans and domestic animals in coastal and inland regions of Connecticut. Louis A. Magnarelli and Anderson conducted extensive field and laboratory studies of important species primarily during the 1970s and early 1980s (**Figure 41**). These studies focused on the biting behavior, egg laying, hovering and swarming of males, distribution of larvae in marshes, control of immatures in salt marshes, autogeny (ability of females to lay their first batch of eggs without feeding on blood), the importance of sugars from floral sources for sustenance of the adults, and natural enemies (**Table 3**). These studies form a foundation for implementation of integrated pest management programs should abundance of specific species become intolerable.

Figure 42. Dr. Stephen Hitchcock sampling emerging adult midges, **Chironomus atrella**, *in Old Saybrook, 1966.*

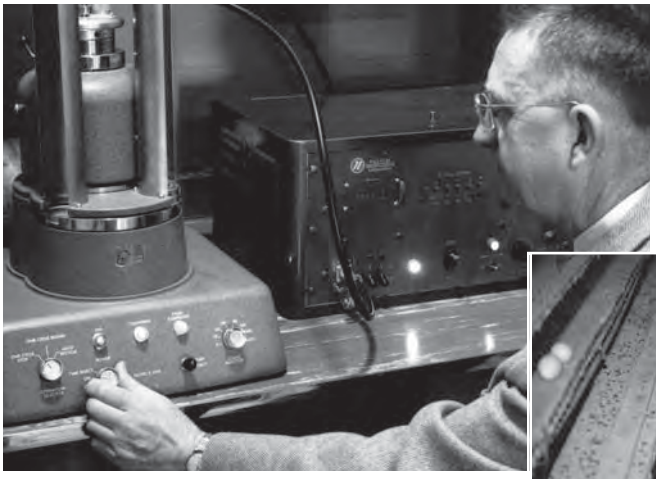


Figure 43. Dr. Raimon L. Beard, using a Thin-Window Counter (early radiation detector), 1961.

Figure 44. Dead house flies in walkways between chicken cages after Dr. Anderson applied a granular insecticide, 1984.

Culicoides *(no-see-ums), phlebotomine sand flies, black flies, non-biting midges, and house and other muscoid flies*

The no-see-ums (*Culicoides* species) are the smallest biting flies of humans in Connecticut. They can at times be extremely annoying, particularly along Connecticut coastal areas. Magnarelli (1981) studied sugar feeding and egg development of two common coastal species, *Culicoides hollensis* (Melander and Brues) and *Culicoides melleus* (Coquillett), and reported that both species were likely autogenous. Magnarelli et al. (1984f) reported on the autogenous and anautogenous development of eggs in the exotic phlebotomine sand flies *Phlebotomus papatasi* (Scopoli), *Lutzomyia longipalpis* (Lutz and Neiva), and *Lutzomyia anthophora* (Addis), and later with a colleague from Yale, he reported that sand flies fed repeatedly on sugars and blood in nature to obtain sustenance for survival and egg production (Magnarelli and Modi 1988). These sand flies are vectors of pathogens of humans in other parts of the world.

Black flies can be severe nuisances to humans living near or visiting streams during warmer months of the year. Magnarelli and Burger (1984) reported autogeny and the importance of sugars for longevity in *Simulium decorum* Walker.

Non-biting midges belonging to the genus *Chironomus* occasionally become a nuisance because of their excessive numbers as occurred near South Cove in Old Saybrook, Connecticut in the mid-1960s (**Figure 42**). Experiment Station scientists documented the biology of *Chironomus atrella* (Townes) and its susceptibility to chemical insecticides (Anderson and Hitchcock 1968, Hitchcock and Anderson 1966, Hitchcock and Anderson 1968). Dr. Stephen W. Hitchcock, a graduate of the University of California, Berkeley, was hired in 1958.

House flies, *Musca domestica* L., and other relatively large flies such as blow flies, *Lucilia* sp., *Phaenicia* sp., and *Phormia regina* (Meigan) have not only been a nuisance to Connecticut citizens from the earliest of times, but they also can carry human disease-causing organisms. These flies have often been called filth flies because of their development in manure, human excrement, garbage, and dead animals. Experiment Station scientists published two bulletins to keep citizens informed on the biology of these flies, the association of these flies with animal and human waste and garbage, and the methods of reducing their abundance through manure management, cleanliness, use of chemical insecticides, and biological control (Stafford III 2008, Wallis 1962b).

Extensive studies were carried out on insecticide resistance of house flies to chemical insecticides in the 1960s by Dr. Raimon L. Beard (Beard 1960, 1965a, d, e). Dr. Beard was a graduate of Yale University and was hired in 1943 (**Figure 43**). Additional studies were conducted in the laboratory on house flies to determine their role in degradation of poultry ma-

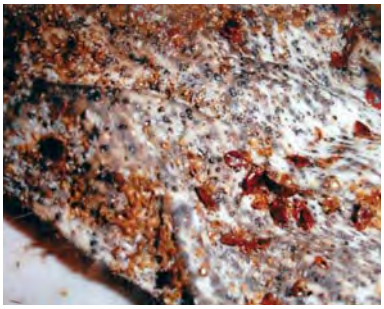


Figure 45. Bed bug fecal droppings, cast skins, and live bed bugs on a white sheet in an apartment in New Haven, 2007.

Figure 46. Dr. Richard S. Cowles applying an insecticide to be tested on bed bugs, 2009.

Figure 47. Dr. Gale Ridge (l) and Dr. Kirby C. Stafford (r) at a bed bug forum hosted by the Experiment Station in 2009.

nure (Beard and Sands 1973), response to high ozone environments (Beard 1965c), susceptibility to fungal toxins (Beard 1965b, Beard and Walton 1969), and suitability as hosts to insect parasites for biological control (Beard 1964a, b).

In the 1980s, extreme numbers of house flies were a nuisance to many suburban citizens living near poultry farms, primarily in eastern Connecticut. In collaboration with a colleague at the University of Connecticut, Dr. Aaron Spandorf, Experiment Station scientists developed manure management procedures for control, demonstrated the efficacy of an insecticide that was applied to the feed of chickens, and documented the utility of applying other insecticides to selected areas within the coops or immediately outside the coops on the farm property (Anderson 1985c, Anderson et al. 1986f) (**Figure 44**). These efforts significantly reduced the numbers of flies escaping from farms and reduced citizen complaints.

Bed bugs

Bed bugs, *Cimex lectularius* L., are invasive and were probably brought to the New World on sailing ships in Colonial times. The first research on bed bugs in Connecticut was conducted by B. H. Walden in 1906. He used hydrocyanic acid to fumigate a house and eradicated the bed bugs (Walden 1907). Subsequently, he treated five additional houses (Walden 1910). It is worth noting that fumigation of buildings with Vikane (sulfuryl fluoride) for control of bed bugs is currently being used in other states. In 1945, a practical experiment using DDT against bed bugs was conducted in cooperation with the Ensign Bickford Company of Simsbury (Friend 1946b). DDT was the treatment of choice for control of bed bugs throughout the country for many years following World War II, and bed bugs all but disappeared as a problem in Connecticut and elsewhere.

Bed bugs, however, have resurged in relatively recent years and at times in great numbers (**Figure 45**). Dr. Gale E. Ridge and Rose T. Hiskes reported that the number of samples of bed bugs brought or sent to the Kenneth A. Welch Insect Inquiry Office of the Experiment Station increased from one in 1996 to 70 in 2007. Infestations in many apartment buildings and some hotels in several Connecticut cities were reported in 2007-2009. The Experiment Station initiated investigations with colleagues from the private sector and reported on a carbon dioxide, heat and chemical lure trap for capturing bed bugs in buildings (Anderson et al. 2009). A Connecticut company, BioSensory, commercialized the trap.

Anderson and Dr. Richard S. Cowles, a graduate of Michigan State University and hired in 1994, began testing the efficacy of different insecticides to kill bed bugs in 2008 (**Figure 46**). Dr. Gale Ridge, who was hired in 1998 and is a graduate of the University of Connecticut, organized two forums on bed bugs in 2009 (**Figure 47**). The Donald F. Jones Auditorium at the Experiment Station was filled to capacity with interested citizens on both occasions.

An ecological diagram of the life cycle of the bed bug in an apartment in Connecticut is shown in **Figure 48**. The five nymphal stages and male and female adults must feed on blood for survival, growth, and reproduction. All that is needed is a single human to serve as the host, and without a concerted effort to control bed bugs, populations can become enormous and,

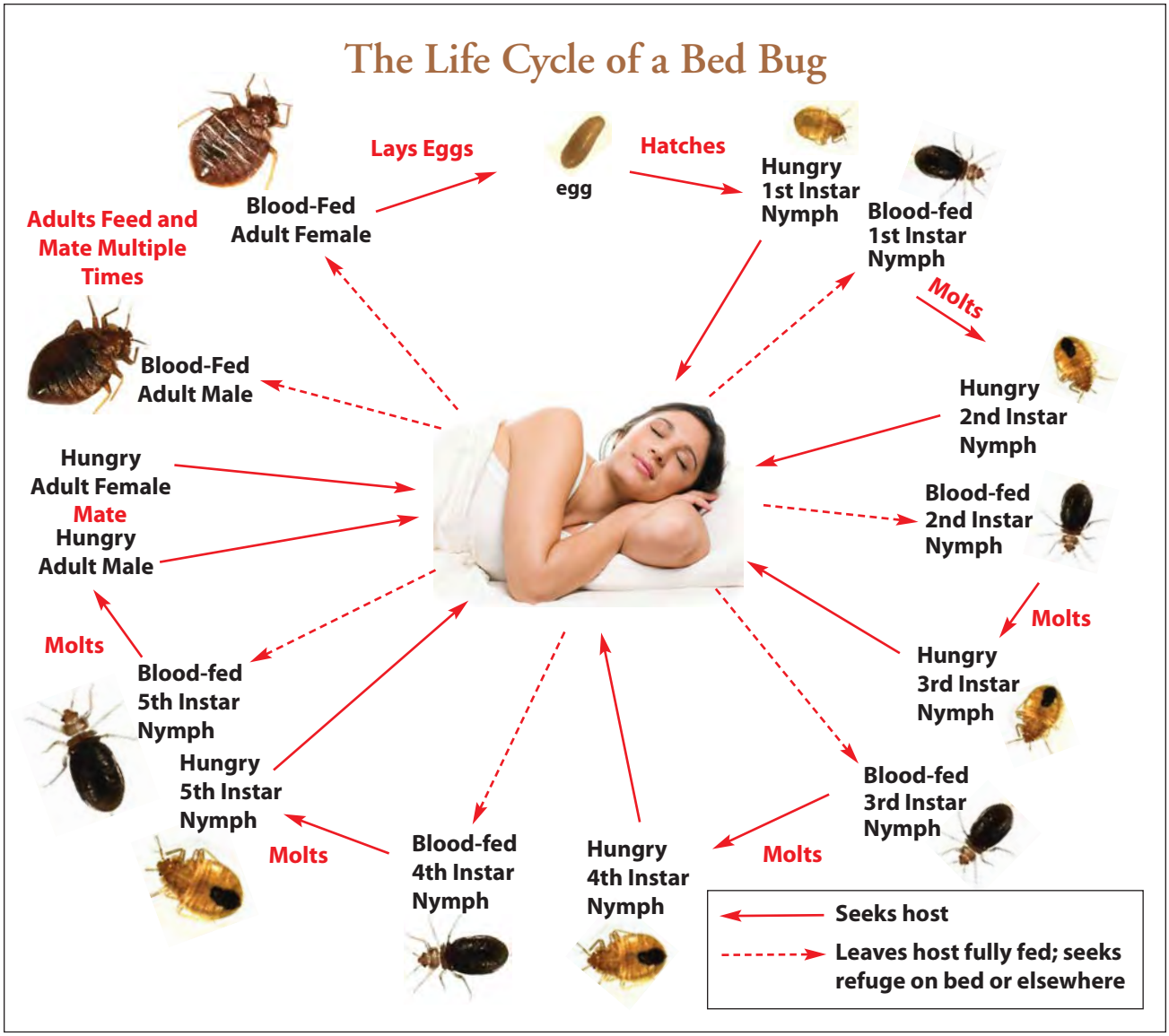


Figure 48. Natural history of the bed bug in a bedroom in Connecticut.

in extreme cases, result in the infestation shown in **Figure 45.** Unlike mosquitoes and ticks, bed bugs are not known to transmit pathogens to humans.

Urticaria, myiasis, and caterpillar infestations in humans

Insects cause discomfort to humans and animals not only by their feeding and stinging habits, but also by having immature stages feed directly in the body or by having setae and spines of immature Lepidoptera cause eruptions of transitory itchy wheals. An epidemic of urticaria among children caused by excessive numbers of wind-blown first-instar larvae of gypsy moths, *Lymantria dispar* L., was documented in Newtown, Bristol, and Burlington, Connecticut in the spring of 1981 (Anderson and Furniss 1983). Vesicular and filamentous setae of the larvae are attached to large gland-like cells, which suggested that one or both of the setae may have been responsible for the urticaria. Larvae or maggots in the order Diptera feed, at times, on human or animal (living or dead) tissues, liquid body substances, or ingested food. This disease is called myiasis. Four human cases of furuncular, traumatic, and nasal myiasis caused by *Sarcophaga* species, *Musca domestica* (house fly), *Cuterebra* species (bot fly), and *Phaenicia sericata* (Meigen) (blow fly), were reported in Connecticut in 1980 (Magnarelli and Andreadis 1981). In 1983, the Experiment Station documented a case of myiasis in the nose of a patient who had undergone open heart surgery in a Connecticut hospital and likely acquired the infestation in the hospital (Anderson and Magnarelli 1984b). Dozens of second-stage larvae of *Phaenicia sericata* were removed from this patient. Also in 1983, a leaf miner (Lepidoptera: Gracillaridae) was reported living in the wound of a hospitalized patient in Connecticut (Anderson et al. 1984a).

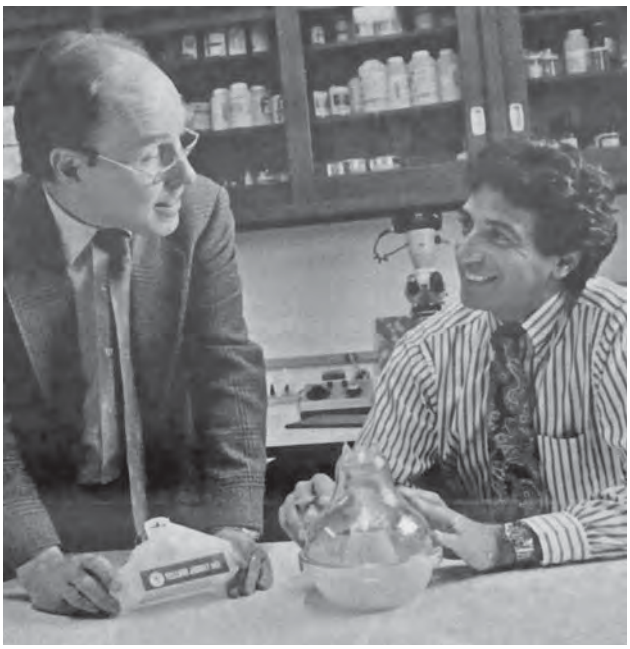


Figure 49. Kenneth A. Welch and Dr. Theodore Andreadis displaying wasp traps, 1992.

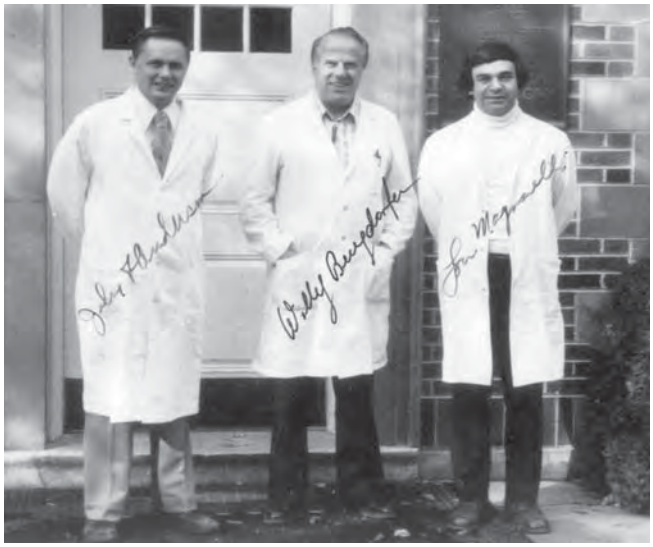


Figure 50. John F. Anderson, Willy Burgdorfer (Rocky Mountain Laboratories), and Louis A. Magnarelli (l. to r.) at the Rocky Mountain Laboratories, U.S. Public Health Service, National Institutes of Health, Hamilton, Montana, October, 1977. Dr. Burgdorfer urged Drs. Magnarelli and Anderson to develop their own serologic and isolation facilities.

Yellowjackets and wasps

Yellowjackets *(Vespula* spp.) and paper wasps (*Polistes* spp.) are valuable scavengers and predators of many insect pests, but they can become serious pests of man. In August of 1991, excessive numbers of these insects annoyed and stung patrons at the Connecticut Tennis Center in New Haven. Dr. Theodore Andreadis and Kenneth A. Welch identified the insects, determined locations of their nests, and developed highly effective methods of reducing their numbers (Andreadis and Welch 1992) (**Figure 49**). Kenneth A. Welch was a graduate of Southern Connecticut State University and was hired in 1967.

Ticks, ecology and control

Ticks were becoming abundant in Connecticut in the 1970s, and with the support of Experiment Station Director Paul E. Waggoner, Magnarelli and Anderson began their studies on the ecology of ticks, particularly *Dermacentor variabilis* (Say), and shortly thereafter, *Ixodes scapularis* Say, in the mid to late 1970s. These studies documented the tick species present in Connecticut, their geographic and seasonal distributions, and their host animals, including those that feed on humans. At the same time, Magnarelli and Anderson initiated studies on Rocky Mountain spotted fever and babesiosis, and with the scientific assistance from the Rocky Mountain Laboratories of the National Institutes of Health in Hamilton, Montana, the Yale Arbovirus Research Unit in New Haven, and the Connecticut Department of Public Health in Hartford, the two used current serologic procedures and methods of isolating the causative agents of human and veterinary disease (**Figure 50**). In time, with support of the Experiment Station's Board of Control, they established serology and isolation facilities. The serology laboratory was established on the second floor of the Jenkins Building, and an isolation laboratory for tick-associated human and veterinary pathogens was built on the first floor of the Britton Building.

In their first paper, Anderson and Magnarelli (1980) reported 15 species of ticks to be present in the state. Ticks were obtained from small and medium-sized mammals collected throughout the state, from deer examined at deer-check stations operated by the Department of Environmental Protection during the hunting seasons, from veterinarians, and from citizens. Five of the species were reported to feed on humans. Three of the species, *Dermacentor variabilis*, *Ixodes (dammini* =) *scapularis* and *Amblyomma americanum* (L.) feed readily on humans. *Ixodes cookei* Packard and *Rhipicephalus sanguineus* (Latreille) feed on humans less frequently. *Dermacentor variabilis* was prevalent throughout Connecticut; *Ixodes scapularis* was predominately abundant in southeastern Connecticut, although specimens were collected elsewhere (**Figure 51**). It was noted that both *Dermacentor variabilis* and *Ixodes scapularis* were not abundant in Connecticut in the

Figure 51. Adult female **Ixodes scapularis** *(l) and* **Dermacentor variabilis** *(r)*

Figure 52. Dr. Kirby C. Stafford III feeding ticks on laboratory mice in the insectary at Lockwood Farm, 1990.

Figure 53. From left, Dr. Anuja Bharadwaj, Tara Raftery, and Heidi Stuber collect ticks from a flannel cloth. The ticks crawled onto the cloth as it was dragged over the ground, Bridgeport, 2007.

early part of the 1900s. The increase in dog populations from 1950 to 1980 and the abundance of raccoons were suggested as possible reasons for the increase in *Dermacentor variabilis*. The increase in the population of white-tailed deer was the likely reason for the increase in populations of *Ixodes scapularis*.

In subsequent years, ticks from other continents were reported feeding on exotic snakes in Connecticut (Anderson et al. 1981b, 1984b), on humans who had recently been in other countries before coming to Connecticut (Anderson et al. 1981a), and on an imported dog (Anderson et al. 1984b). Such ticks could become established and possibly serve as vectors of exotic or established human or domestic animal-causing pathogens. For example, a dog purchased in South Africa and brought into New Preston, Connecticut, was infested with numerous specimens of the tick species *Haemaphysalis leachi* (Audouin) and died from *Babesia canis* (Anderson et al. 1984b). A Connecticut citizen parasitized by *Rhipicephalus simus* Koch was diagnosed with boutonneuse fever, an African disease caused by *Rickettsia conori* (Anderson et al. 1981a). Additionally, eight *Ixodes ricinus* were identified off humans returning from Europe from 1990 through 2009 of which one was infected with borreliae. Currently, the brown dog tick, *Rhipicephalus sanguineus*, is the only known exotic tick established in Connecticut.

The host-animals for the various feeding stages of *Ixodes scapularis* and related species prevalent in western North America, Europe, and Asia were reported in several papers (Anderson and Magnarelli 1984a, Anderson et al. 1986c, Anderson 1988, 1989a, Anderson et al. 1990c, Anderson 1991, Anderson and Magnarelli 1993c). As noted in these papers, the species of *Ixodes* that are the primary vectors of *Borrelia burgdorferi* and other causative agents of human disease have the largest number of different vertebrate host species of all known species of ticks.

The hosts for *Ixodes scapularis*, *Ixodes ricinus*, *Ixodes persulcatus* Schulze, and *Ixodes pacificus* Cooley and Kohls are extensive and include mammals, birds, and reptiles, and each feeds on more than a hundred different species of vertebrate animals. The importance of white-footed mice as hosts for larval and nymphal *Ixodes scapularis* and of white-tailed deer for adult *Ixodes scapularis* was emphasized in relatively early papers (Anderson and Magnarelli 1980, 1984a). Birds were reported as a natural means of passively transporting ticks relatively long distances, thereby enabling ticks to establish new colonies and exposing humans to pathogens carried by ticks (Anderson and Magnarelli 1984a, Anderson et al. 1990c, Magnarelli et al. 1992c, Stafford III et al. 1995).

Kirby C. Stafford III (**Figure 52**), a graduate of Texas A&M University, began his studies at the Experiment Station in 1987. He focused his laboratory and field studies on the control and ecology of *Ixodes scapularis*. The abundance of specific stages of ticks at certain times of the year in yards, including lawns, playground areas, gardens, paths, and lawn-forest areas is crucial information for developing integrated pest management programs that reduce risk of exposure to tick bites (Stafford III 1992a, Stafford III and Magnarelli 1993, Stafford III 1994, 2007) (**Figure 53**).

Figure 54. Dr. Kirby C. Stafford III (r) testifying before a Connecticut Department of Public Health and Attorney General hearing on Lyme disease at the Legislative Office Building 29 January, 2004. Dr. James Hadler, State Epidemiologist, is on the left.

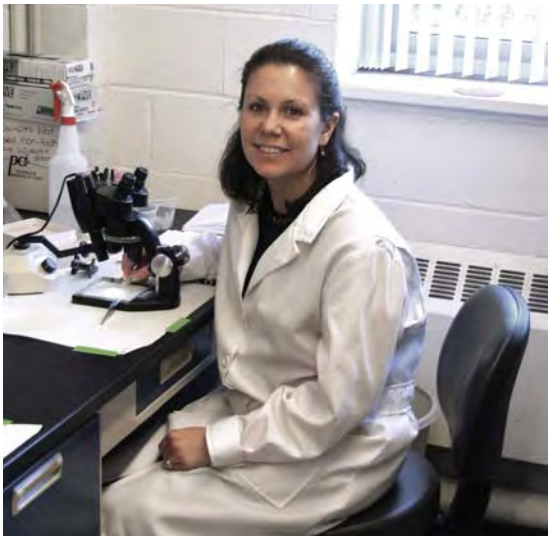


Fig. 55. Elizabeth Alves, tick-testing laboratory in Slate Building, identifying a tick with the aid of a binocular microscope, 2010.

Several studies were completed on methods of reducing numbers of ticks and, therefore, reducing risk of exposure to Lyme disease and related tick-associated illnesses through application of pesticides, burning of ground cover, reduction of the invasive Japanese barberry shrub, and exclusion of deer by electric fencing (Brei et al. 2009, Dolan et al. 2004, Hoen et al. 2009, Pound et al. 2009, Stafford III 1991a, b, 1992b, 1993, 1997, Stafford III et al. 1998b, Stafford III et al. 2009, Williams et al. 2009).

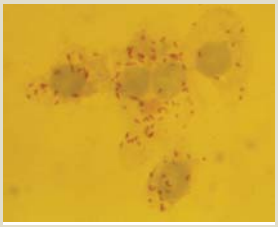
Dr. Stafford's research demonstrated that the most effective way to reduce ticks and reduce risk of acquiring a tick-associated illness was to apply an insecticide (acaricide) to the lawn and shrubs at the appropriate time of year coupled with changes in landscaping to reduce prime habitats of ticks (Stafford III 1991b, Stafford III and Magnarelli 1993, Stafford III 2007). Relatively small amounts of insecticide are usually needed when applied during the beginning of the nymphal period in May or early June, and if needed during the adult season in the fall in October or in spring if no fall application was made. Applications were shown to be most effective when directed along the perimeter of the lawn and woodland edges or other areas known to harbor ticks. Many commercial applicators of pesticides and homeowners rely upon the information provided by Stafford III (1997) (**Figure 54**).

Successful topical treatment of white-tailed deer with a pesticide to kill adult *Ixodes scapularis* in Old Lyme, Connecticut also was reported (Brei et al. 2009, Hoen et al. 2009, Pound et al. 2009, Stafford III et al. 2009). Over a five-year period, up to 24 "4-Posters" were distributed within a 5.2 km^2 area and maintained with feed (corn) to attract deer and apply the pesticide (amitraz) to the anterior part of the deer during the active adult tick season. This treatment significantly reduced the numbers of nymphal ticks for a six-year period, compared to an untreated area in adjacent Old Saybrook, Connecticut. This passive topical treatment of the primary host for adult ticks reduced the numbers of nymphs in subsequent years, thereby reducing risk of exposure of humans to tick-associated pathogens.

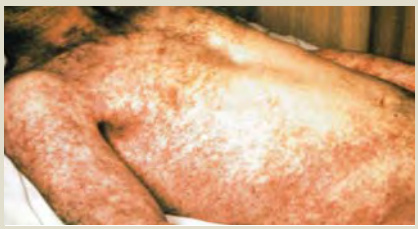
Biological control of ticks using natural enemies, such as a parasitic wasp, *Ixodiphagus hookeri* Howard, and pathogenic fungi, was also explored (Stafford III et al. 1996, Stafford III et al. 2003, Tuininga et al. 2009). The efficacies of applications of imidacloprid/permethrin to dogs to prevent transmission by ticks of *Anaplasma phagocytophilum* and *Borrelia burgdorferi* were also studied and reported (Blagburn et al. 2004, Spencer et al. 2003). In addition, scientists at the Experiment Station wrote review articles on the control of ticks (Anderson 1989d, Ginsberg and Stafford III 2005, Stafford III 1989, Stafford III and Kitron 2002, Stafford III 2007).

Three review articles on ticks, covering major aspects of their life history and ecology throughout the world were published (Anderson 2002, Anderson and Magnarelli 2008, Stafford III 2007).

Ticks as Vectors of Rocky Mountain Spotted Fever: 1970s



The Pathogen:
Rickettsia rickettsii
(red dots)



The Disease:
Rocky Mountain spotted fever rash

The Vector: American dog tick
Dermacentor variabilis

- Established a lab at the Experiment Station for work with human pathogens.
- With National Institutes of Health, made first isolation of causative agent of Rocky Mountain spotted fever from a Connecticut patient.
- With National Institutes of Health, made first isolations of causative agent of Rocky Mountain spotted fever from Connecticut ticks.
- Developed antibody-detecting tests for Rocky Mountain spotted fever in wildlife.

Carol Lemmon inoculating a flask in a biosafety cabinet

Figure 56.

Ticks, identification and testing for Borrelia burgdorferi *for citizens*

In 1983, Connecticut citizens requested that the Experiment Station identify and test ticks off humans and pets for the causative agent of Lyme disease, *Borrelia burgdorferi*. We agreed to perform this service freely. We were able to identify all submitted ticks, but initially we were only able to test live ticks for the spirochetes that caused Lyme disease. Our only means of testing ticks for spirochetes was by culture or by an indirect fluorescent antibody (IFA) test.

In the late 1980s, Director John Anderson began working in the laboratory of Dr. David H. Persing and with his technician Paul N. Rys at the Yale School of Medicine to learn the protocol for the polymerase chain reaction, which enabled us to detect spirochetes in dead ticks (Persing et al. 1990). This procedure, which is still used today, enabled us to test almost all submitted ticks.

Currently, citizens are encouraged to submit their specimens to their local health department, which then forwards the ticks to the Experiment Station (**Figure 55**). Since 1990, 90,408 ticks representing 18 species have been identified. Almost all of the specimens were feeding on humans. *Ixodes scapularis* was the most common species submitted [N=83,211 (91%)]. Nine of the species were not native to Connecticut.

This service is important because it (1) provides an accurate identification to species and stage of the tick, (2) provides the approximate time the tick was attached (based upon the approximate quantity of blood in the midgut), and (3) determines whether the tick was infected with borreliae. This information was often then used by the citizen, in consultation with his/her physician, to determine whether antibiotics would be administered. We currently do not test recently attached ticks because they were not feeding for a long enough period of time to transmit borreliae. Local health departments were discouraged from sending *Dermacentor variabilis* ticks. *Dermacentor* ticks, which are not competent to transmit *Borrelia burgdorferi*, were identified when submitted, but they were not tested for borreliae.

Table 4. Connecticut mammalian sera with positive antibody titers to **Rickettsia rickettsii antigen,** *1976-1982.*

Common Name	Scientific Name	No. positive sera/ Total sera tested (%)
Dog	*Canis lupus familiaris* L.	174/1576 (11.0)
Eastern chipmunk	*Tamias striatus* (L.)	7/20 (35)
Eastern woodrat	*Neotoma floridana* (Ord)	1/1 (100)
Eastern gray squirrel	*Sciurus carolinensis* Gmelin	36/79 (46)
Meadow vole	*Microtus pennsylvanicus* (Ord)	4/24 (16.7)
Raccoon	*Procyon lotor* (L.)	106/315 (33.6)
Short-tailed shrew	*Blarina brevicauda* (Say)	1/5 (20)
Striped skunk	*Mephitis mephitis* (Schreber)	4/24 (16.7)
Virginia opossum	*Didelphis virginiana* Kerr	8/36 (22.2)
White-footed mouse	*Peromyscus leucopus* (Rafinesque)	68/995 (6.8)
White-tailed deer	*Odocoileus virginianus* (Zimmermann)	14/549 (2.6)
Woodchuck	*Marmota monax* (L.)	4/14 (28.6)
Woodland jumping mouse	*Napaeozapus insignis* (Miller)	2/3 (66.7)

Ticks, bacterial and protozoan pathogens

Rocky Mountain spotted fever

In 1977, Magnarelli suggested to Anderson that the two of them initiate a study of Rocky Mountain spotted fever (Magnarelli and Anderson 1978a). Rocky Mountain spotted fever is a tick-associated disease caused by a bacterium, *Rickettsia rickettsii*. A number of cases had recently been reported on Long Island, New York (Benach et al. 1977) and a few cases had been reported in relatively recent years by the Connecticut Department of Public Health. These bacteria are relatively small and appear as thin or short rods (1µ to 2µ in length) or as spheres (0.3µ in diameter) and live within cells. They occur naturally in certain species of ticks, particularly in *Dermacentor variabilis* in the eastern United States.

Humans are accidental hosts and become infected by a tick bite. Onset of disease may manifest itself initially by a few days of general malaise or it may be sudden. The first signs may often include a splitting headache accompanied by pains in the back, joints, and legs (Raoult and Walker 1990). The patient may have a stiff neck and light is painful to the eyes. Temperature rises rapidly to 102° F or greater, and the patient may suffer episodes of delirium. As the infection progresses, endothelial cells lining the capillaries burst, blood seeps through the capillary walls and causes hemorrhages that appear as the characteristic spots on the skin. The rash appears first on the wrists and ankles and later on the limbs, trunk and face. They often appear on the palms of the hands and soles of the feet. Mortality in untreated patients is slightly over 20%. Effective antibiotics are chloramphenicol and tetracyclines.

In collaboration with colleagues from the National Institute of Allergy and Infectious Diseases, National Institutes of Health, Rocky Mountain Laboratories, Hamilton, Montana and with the support of the Connecticut Department of Public Health, Magnarelli and Anderson collected and tested several thousand ticks for the presence of spotted-fever group rickettsiae. Ticks were collected by moving a flannel cloth over vegetation, by public referral, and by examination of wild and domestic animals. Spotted-fever group rickettsiae were reported in 0.8% to 2.8% of the *Dermacentor variabilis* tested (Magnarelli et al. 1979a, 1981a, Magnarelli et al. 1981b, Magnarelli et al. 1982a, Magnarelli et al. 1985a, Magnarelli and Anderson 1989a). Rates of infection varied according to the stage of tick collected, method of collection, and the sampling site.

In Connecticut, 15 cases of Rocky Mountain spotted fever had been reported by the Connecticut Department of Public Health from 1965-1977. Travel histories indicated that all had likely contracted their illness locally (Magnarelli et al. 1979a, 1981a). Residences of patients were in 12 towns and were scattered from Darien in southwestern Connecticut to Putnam in

northeastern Connecticut. The causative agent of Rocky Mountain spotted fever, *Rickettsia rickettsii*, was isolated from the blood of an infected child who lived in West Hartford (Magnarelli et al. 1981b) and from four *Dermacentor variabilis* and one *Ixodes texanus* Banks collected in Newtown, where 6 humans likely contracted Rocky Mountain spotted fever (Anderson et al. 1986e). These are the only isolations of *Rickettsia rickettsii* to have been made in Connecticut. *Rickettsia montana,* a spotted fever-group *Rickettsia* that is not known to cause disease in humans, was isolated from *Dermacentor variabilis* collected in locations where Rocky Mountain spotted fever was not prevalent (Anderson et al. 1986e, Magnarelli et al. 1981b). Both disease-causing and non-disease-causing spotted fever-group rickettsiae occurred naturally in Connecticut ticks (**Figure 56**).

Hundreds of wild animals were captured to determine the stages and species of ticks feeding on small and medium sized mammals at various times during the year and to obtain blood samples to test for the animals' prior exposure to spotted-fever group rickettsiae. Antibodies to spotted fever-group rickettsiae were detected from 1976-1982 in sera collected from 12 wild mammals, including white-tailed deer, and from dogs (Magnarelli et al. 1981b, Magnarelli et al. 1983, Magnarelli et al. 1984b) (**Table 4**).

Several of these animals may be good indicators of rickettsial activity in specific foci, although, because more than one species of *Rickettsia* are present in ticks, the reactions of sera to *Rickettsia rickettsii* may not be specific. Inasmuch as *Rickettsia rickettsii* is vertically transmitted by infected female ticks to offspring via eggs (Burgdorfer and Varma 1967), we do not know if these animals are amplifying hosts and are important in the epidemiology of *Rickettsia rickettsii* other than serving as host animals for the tick vector, *Dermacentor variabilis.*

Data on the prevalence of ticks infected with spotted-fever group organisms, the prevalence of wild and domestic animals with antibodies to *Rickettsia rickettsii*, and the locations of the residences of patients diagnosed with Rocky Mountain spotted fever led us to conclude that spotted-fever group rickettsiae were present in inland and coastal regions of Connecticut and that spotted fever-group rickettsiae were distributed in separate foci in the state (Magnarelli et al. 1981b).

Human granulocytic anaplasmosis, human monocytic ehrlichiosis, and domestic animal ehrlichiosis

Diseases in domestic animals are often recognized before similar diseases are reported in humans. This was the case with human monocytic ehrlichiosis and human granulocytic anaplasmosis. Members of the genus *Ehrlichia*, a closely related genus to *Anaplasma*, were reported to infect dogs as early as 1935 (Keefe et al. 1982). The infecting species was *Ehrlichia canis*. Later, equine monocytic ehrlichiosis, caused by *Ehrlichia risticii*, was discovered in Maryland and Virginia (Knowles et al. 1983). Human granulocytic anaplasmosis, initially called human granulocytic ehrlichiosis and caused by *Anaplasma phagocytophilum*, was reported in the upper Midwestern United States in 1994 (Bakken et al. 1994), seven years after human monocytic ehrlichiosis, caused by *Ehrlichia chaffeensis*, had been first reported from a human living in Arkansas (Maeda et al. 1987).

Anaplasma phagocytophilum is an obligate, intracytoplasmic bacterium that is transmitted to humans by a tick bite (Bakken and Dumler 2008). Infections range from asymptomatic to fatal disease. Symptomatic patients often present with a nonspecific febrile illness with shaking chills, myalgia, and headache. Tetracycline antibiotics and rifampin are effective in treating infections.

Louis A. Magnarelli and colleagues from the Experiment Station, Yale University, and other institutions set out in the late 1980s to determine the possible importance of *Ehrlichia* and *Anaplasma* pathogens in causing human and veterinary disease in Connecticut, the role of ticks in transmitting these organisms, and the role of wild animals in maintaining these pathogens.

Human studies

In a collaborative retrospective study led by the Centers for Disease Control, human monocytic ehrlichiosis was reported in United States Army reservists from Connecticut after a field training exercise in New Jersey (Petersen et al. 1989a). These reservists had serologic evidence of *Ehrlichia* infection. Later, evidence for antibodies to *Ehrlichia chaffeensis* and *Ehrlichia equi* in humans living in Connecticut and Minnesota that were diagnosed with Lyme disease was reported by Magnarelli et al. (1995d), thereby suggesting that patients with Lyme disease may also have had exposure to *Ehrlichia* (*Anaplasma*). IFA staining methods and Western blot

analyses were used to reveal probable human cases of human granulocytic anaplasmosis infection in Connecticut in 1995 and 1996 (Magnarelli et al. 1998a, Magnarelli et al. 1998b). Many of these patients also had antibody to the etiologic agents of human monocytic ehrlichiosis, babesiosis, or Lyme disease.

These findings led the authors to suggest that when one of these tick-borne diseases is clinically suspected or diagnosed, clinicians should consider the possibility of other current or past tick associated infections. Additional collaborative studies led by scientists elsewhere developed and standardized an IFA assay for the detection of human antibodies to the agent of human granulocytic anaplasmosis (Nicholson et al. 1997), and still another investigation demonstrated that the human granulocytic anaplasmosis agent did not produce significant antibody to *Borrelia burgdorferi* (Bunnell et al. 1999). Joint studies with scientists at the University of Texas, Galveston led to a publication on the ultrastructure of different genogroups of *Ehrlichia* (Popov et al. 1998).

Additionally, Magnarelli working in collaboration with colleagues at the Yale School of Medicine reported that a 44kDa antigen from the human granulocytic anaplasmosis agent reacted with immunoglobulin G (IgG) antibodies in 18 patients diagnosed with human granulocytic anaplasmosis (IJdo et al. 1997). This finding suggested that this protein might be useful in diagnosis of this disease. The gene encoding this 44kDa protein was then cloned and a fusion protein was shown to be useful in helping to diagnose human granulocytic anaplasmosis in humans (IJdo et al. 1998, IJdo et al. 1999). An additional study demonstrated that this disease was causing illness in a 12-town area around Lyme, Connecticut in 1997-1999 (IJdo et al. 2000a). In a related study, the DNA of *Ehrlichia chaffeensis* was detected in *Amblyomma americanum* ticks feeding on humans in Connecticut and Rhode Island, thereby suggesting that human monocytic ehrlichiosis may be occurring in southern New England (IJdo et al. 2000b).

Domestic animal studies

The first case of canine ehrlichiosis in Connecticut was reported by Magnarelli et al. (1990d). Antibodies to *Ehrlichia canis* and *Ehrlichia risticii* were later reported in a retrospective study to be present in dog and horse sera from Connecticut and New York (Magnarelli and Anderson 1993). We reported that 11.7% of the dog sera had antibodies to *Ehrlichia canis* and 9.1% of the horse sera contained antibodies to *Ehrlichia risticii.* The two studies were the first indication that these two species of *Ehrlichia* possibly were infecting domestic animals in northeastern United States. Later, more extensive studies of ill and clinically normal dogs and horses supported these earlier findings that domestic animals living in tick-infested areas were being exposed to *Ehrlichia* (Magnarelli et al. 1997c, Magnarelli et al. 1999c, Magnarelli et al. 2000b). A fusion protein, initially developed for use with humans (IJdo et al. 1998), was then shown to be useful in detecting antibodies of granulocytic ehrlichiosis in dogs and horses (Magnarelli et al. 2001a, Magnarelli et al. 2001b). Cattle were also reported to being exposed to *Ehrlichia* (Magnarelli et al. 2002a). Duration of the antibody response in horses to *Ehrlichia equi* was also reported (Van Andel et al. 1998).

Figure 57. Dr. Kirby C. Stafford III placing Sherman box traps to capture white-footed mice alive in Lyme, Connecticut, 1990.

Wild animal studies

Magnarelli et al. (1995e) reported *Ehrlichia*-like organisms in ticks from five different states, including Connecticut, and the Canadian Province of British Columbia and the detection of DNA of the human granulocytic ehrlichiosis pathogen. With the establishment of these organisms in ticks, serosurveys were undertaken of wildlife upon which the ticks feed. A retrospective study of sera from white-footed mice captured in Connecticut in the 1980s and early 1990s revealed antibodies that reacted with *Ehrlichia chaffeensis* and *Ehrlichia equi* antigens along with those of *Babesia microti* and *Borrelia burgdorferi* (Magnarelli et al. 1997a). This study revealed that white-footed mice probably are important in the epizootiology of all four human pathogens. A follow-up study detected antibodies to the agent of human granulocytic anaplasmosis in small rodents as far south as Florida (Magnarelli et al.

1999b). In a related study, Stafford III et al. (1999) reported antibody to the human granulocytic anaplasmosis agent in about 50% of the white-footed mice captured in Connecticut in 1997 and 1998 (**Figure 57**). Moreover, many of the mice also had antibodies to *Borrelia burgdorferi* and *Babesia microti*. The DNA of the human granulocytic anaplasmosis agent was detected in 17 of 47 (36%) of the mice, but only 4 (24%) of the mice were positive at each capture, leading the authors to conclude that infection of granulocytic *Anaplasma* in mice may be transient. *Ehrlichia* organisms were also cultured from three of the mice. A recombinant protein of *Anaplasma phagocytophilum* also showed that white-footed mice captured in southern and northern portions of Connecticut had past or current infections (Magnarelli et al. 2006). Genetic variants of *Anaplasma phagocytophilum* were reported in a collaborative study led by the Centers for Disease Control from *Ixodes scapularis* and small mammals from Connecticut and Rhode Island (Massung et al. 2002). Some of these variants may interfere with the maintenance and transmission of the true agent that causes human disease. Sera from deer also had antibodies to *Anaplasma phagocytophilum* (Magnarelli et al. 1999a, Magnarelli et al. 2004b). A study with scientists from the Universities of Minnesota and Rhode Island resulted in the culturing of an intracellular prokaryote from *Ixodes scapularis* (Kurtti et al. 1996).

Babesiosis

Babesiosis is primarily a disease of animals and is caused by protozoa belonging to the genus *Babesia*, which are obligate parasites of red blood cells. More than 100 species are recognized, and all are transmitted by ticks. The first cases in the United States in humans with intact spleens were reported on Nantucket Island, Massachusetts (Western et al. 1970). The etiologic agent was identified as *Babesia microti*. The mammalian reservoir and tick vector were documented to be the white-footed mouse, *Peromyscus leucopus* (Healy et al. 1976), and *Ixodes scapularis* (Spielman 1976), respectively.

Symptoms of infected patients range from asymptomatic to severe disease that may result in death (Vannier et al. 2008). Most cases present with mild illness characterized by malaise and fatigue, which may include intermittent fever with accompanying chills, sweats, headache, arthralgia, myalgia, anorexia, and cough. The disease may become severe in persons with immunosuppressive conditions. Treatment regimens include the combination of atovaquone and azithromycin, or the combination of clindamycin and quinine (Vannier et al. 2008).

Anderson and Magnarelli began their studies in the late 1970s by attempting to find the etiologic agent, *Babesia microti*, in white-footed mice and other small rodents in Connecticut. Antibodies to *Babesia microti* were detected in field-caught white-footed mice, particularly in New London County (Anderson et al. 1979b). We first isolated *Babesia microti* in hamsters from bloods we had collected from white-footed mice and meadow voles, *Microtus pennsylvanicus*, collected on Prudence Island in Narragansett Bay, Rhode Island (Anderson and Magnarelli 1983). We further reported the co-infection of these two rodents with *Babesia microti* and *Borrelia burgdorferi* and suggested that larval *Ixodes scapularis* could ingest both pathogens and subsequently transmit both during feeding as a nymph (Anderson et al. 1986d). The transmission of both pathogens during a single tick bite was reported by a group at Harvard University (Piesman et al. 1986). Anderson, Magnarelli and colleagues from the Rhode Island Department of Environmental Protection and the University of Minnesota (1987d) reported *Babesia microti* to be present only on islands in Narragansett Bay, Rhode Island with white-tailed deer and the tick *Ixodes scapularis*. Both this tick and *Babesia microti* were absent in islands without white-tailed deer. This study convincingly demonstrated that human babesiosis would occur primarily in areas where white-tailed deer were relatively abundant.

The first case of human babesiosis in Connecticut occurred in 1988 in New London County (Gadbaw et al. 1989), where we had detected antibody in white-footed mice in 1976 and 1977 (Anderson et al. 1979b). These studies were in collaboration with investigators at the Lawrence and Memorial Hospital in New London and the State Department of Public Health. Thirteen patients were diagnosed with babesiosis in 1988-1990 (Anderson et al. 1986d). Five of eight patients also had significant IgG or IgM titers to *Borrelia burgdorferi*, the causative agent of Lyme disease, thereby suggesting that these patients may have had co-infections of both pathogens. We isolated *Babesia microti* from the bloods of seven patients and from 27 mice captured in the yards of persons diagnosed with babesiosis. These data strongly suggested that patients were likely being bitten by ticks acquired around their homes. This was the largest number of human cases infected with *Babesia microti* reported on the mainland of the United States to that date; almost all other cases had been reported in people living on or

visiting islands. Infection rates in white-footed mice captured in southeastern Connecticut remained relatively high in subsequent years, indicating that this pathogen is persisting and well established in this part of the state (Stafford III et al. 1999).

In 2002, four patients from Greenwich, which is located in the southwestern part of Connecticut, adjacent to New York State, were diagnosed with babesiosis. Two of the patients had no travel history away from Greenwich prior to their illness. *Babesia microti* was isolated from white-footed mice and eastern chipmunks, *Tamias striatus*, captured in the yards of these two patients (Anderson and Magnarelli 2004). These data showed that a new focus of *Babesia microti* had been established in Connecticut, and we predicted that this disease would become more prevalent in southwestern Connecticut and adjacent New York State. An earlier study had reported antibody to *Babesia microti* in mice collected in Bridgeport (Stafford III et al. 1999).

In 1989, an apparently healthy regular blood donor gave blood that was transfused into a patient without a spleen in Waterbury Hospital. The patient became ill with babesiosis. In a collaborative study with the State Department of Public Health and the Connecticut Blood Bank, blood was subsequently drawn from the donor and inoculated into a laboratory hamster. The hamster developed a *Babesia microti* infection, thereby confirming that the blood donor had an asymptomatic infection and that *Babesia microti* had been transmitted to the patient by blood transfusion (Mintz et al. 1991). This was the first case of babesiosis being transmitted by transfusion in Connecticut. Blood donors at risk to tick bites are now screened for infection with *Babesia microti*.

Babesia gibsoni, a pathogen of dogs in Asia, was isolated from a Connecticut dog that summered on Cape Cod, Massachusetts. In a collaborative study with Harvard University and a private veterinarian, the isolate was identified (Anderson et al. 1979a). This was the first report of this species of *Babesia* in a North American dog that had not traveled outside of the country. This disease is now commonly reported in dogs in southern United States and elsewhere in the country. A later study showed this *Babesia* to be genetically distinct from *Babesia microti* (Conrad et al. 1992). An IFA test for this *Babesia* was developed in collaboration with the Centers for Disease Control (Anderson et al. 1980). This pathogen was later shown in another study with the Department of Pathobiology at the University of Connecticut to be infectious to coyotes and coydogs (Roher et al. 1985).

We discovered a previously unknown species of *Babesia* infecting raccoons, *Procyon lotor*, and named it *Babesia lotori* (Anderson et al. 1981c). The possible tick vector is *Ixodes texanus*.

Lyme disease

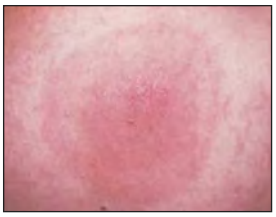
Lyme disease is caused by a spirochete that is transmitted from white-footed mice to humans by the bite of a hard-bodied tick, *Ixodes scapularis*. However, the causative agent, the tick vector, and the role of wild animals in the epidemiology of this disease were unknown when a clustering of arthritic children was initially described from the Connecticut towns of Old Lyme, Lyme, and East Haddam in 1977 (Steere et al. 1977) and the skin lesion known as erythema migrans had been reported in southeastern Connecticut (Mast and Burrows 1976).

Lyme disease is a multisystemic disorder that occurs in stages and affects the skin, heart, nervous system, and joint tissues (Steere 2001). Antibiotics, including tetracyclines, penicillins, and cephalosporins are often prescribed. Patients treated during early stage Lyme disease usually recover completely. A few persons, particularly those diagnosed with later stages of the disease, may have persistent or recurrent neurological and arthritic symptoms. One to four thousand cases of Lyme disease are reported annually by the Connecticut Department of Public Health (www.ct.gov/dph). Louis A. Magnarelli and John F. Anderson were studying Rocky Mountain spotted fever in Old Lyme at the time Lyme disease was described and began looking for organisms in ticks that might be associated with this newly described disease. At a meeting of the American Society of Rickettsiology in Atlanta, Georgia, in late 1981, Willy Burgdorfer informed Magnarelli and Anderson that he had discovered the causative agent of Lyme disease, a spirochete, and let them read a draft of the paper that had been accepted but not yet published in *Science* magazine (Burgdorfer et al. 1982).

Magnarelli and Anderson, who were sharing a hotel room, stayed up that night and into the early hours of the next morning in Atlanta discussing how they would begin field and laboratory studies of this newly

Lyme Disease: Its Vectors and Natural Hosts: 1980s

Michael Vasil trapping mice

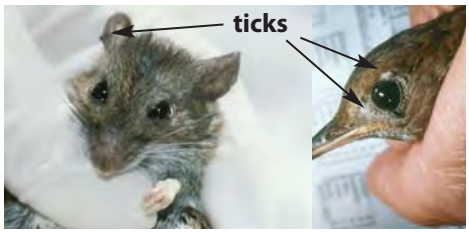


Erythema migrans seen as annular erythematous patch

Elizabeth Wehrli, Carol Lemmon removing ticks from a raccoon

We showed the wide range of hosts available to the vector tick and the Lyme disease-causing spirochetes. We demonstrated that white-footed mice were the main natural hosts for the spirochetes and that birds could disperse both the ticks and the spirochetes.

Borrelia burgdorferi, causative agent of Lyme disease



Ixodes scapularis nymphal tick

Figure 58.

discovered spirochete that later would be described by Russell C. Johnson of the University of Minnesota and named *Borrelia burgdorferi*, in honor of Willy Burgdorfer (Johnson et al. 1984). Upon returning from the meeting in Atlanta, Magnarelli began his efforts on serological studies, and Anderson began his efforts to find and culture the spirochetes from ticks and wild animals.

Ecology and Epidemiology of Lyme disease

The Experiment Station, in collaboration with the National Institutes of Health, Rocky Mountain Laboratories, was one of two laboratories that first isolated *Borrelia burgdorferi* from wild mammals. This study was important in demonstrating that wild animals, particularly white-footed mice, were the important reservoirs for this spirochete (Anderson et al. 1983). The study also reported that 35% of the *Ixodes scapularis* ticks tested from East Haddam and Lyme, Connecticut were infected with spirochetes (**Table 5**). The spirochetes from wild animals and ticks reacted with sera from humans that had been diagnosed with Lyme disease, thereby further supporting the claim that a spirochete was the causative agent of Lyme disease (**Figure 58**). The spirochete was also isolated from ticks collected in Rhode Island (Anderson and Magnarelli 1983).

Anderson and Magnarelli (1984a) reported both mammalian and avian hosts for spirochete-infected *Ixodes scapularis* and published the first composite ecological diagram showing the ecology of the tick in relation to its numerous vertebrate hosts. This diagram, which showed the importance of various mammals and birds in maintaining and establishing tick colonies and in the dispersal of ticks, is as true today as it was when it was published more than a quarter of a century ago. Many studies followed and reported on prevalence of infected questing and feeding ticks on mammalian and avian hosts geographically and throughout the year in Connecticut (**Figure 59**). Additionally, prevalence of antibody to *Borrelia burgdorferi* was determined in many domestic and wild animals, and antibody tests were developed for humans.

Scientists at the Experiment Station made the first isolation of *Borrelia burgdorferi* from a wild bird and demonstrated that the spirochete from the bird was infectious to a laboratory mammal (Anderson et al. 1986c). This study and others showed that birds could become infected with *Borrelia burgdorferi*, transport the Lyme disease-causing agent relatively long distances, and infect juvenile *Ixodes scapularis* and *Ixodes ricinus* feeding on infected birds (Anderson and

Figure 59. Dr. Magnarelli (standing) and Dr. Anderson viewing spirochetes using dark-field microscopy, 1986.

Figure 60. Drs. Magnarelli (l) and Anderson (r) stand outside the Town Hall of Old Lyme, Connecticut, 1993. Lyme disease was named after the towns of Old Lyme and Lyme, Connecticut. Magnarelli, Anderson, and their technicians spent hundreds of hours collecting ticks, mammals, and birds in the woodlands of Old Lyme and surrounding towns and analyzing samples in their laboratories to help understand the natural history of Lyme disease and to help reduce risk of human illness from the causative agents of this and related tick-associated diseases. Dr. Kirby C. Stafford III, not shown in the picture, conducted numerous studies on the control of ticks in Old Lyme and nearby communities.

Magnarelli 1984a, Anderson et al. 1990c, Hubalek et al. 1996, Magnarelli et al. 1992c, Stafford III et al. 1995).

Several additional ecological studies of *Borrelia burgdorferi* were published. Prevalence of infection of *Borrelia burgdorferi* in mice collected in areas with and without Lyme disease was documented and found to be highest in areas where Lyme disease was most common (Anderson et al. 1986b). However, spirochetes were isolated from mice and ticks in Fairfield County, Connecticut where the disease was not yet known in 1984, and we then accurately predicted that this was a developing focus of Lyme disease. In a related study conducted on islands within Narragansett Bay, Rhode Island, *Borrelia burgdorferi* was present only on islands infested with *Ixodes scapularis,* and this tick was present only on islands with deer (Anderson et al. 1987d). This study suggested to us that the risk of acquiring Lyme disease and babesiosis could be reduced through elimination of deer. Stafford III (1993) demonstrated that excluding deer by electric fencing reduced numbers of *Ixodes scapularis*. Another study revealed that *Borrelia burgdorferi* infected white-footed mice at all seasons of the year in Connecticut, but prevalence of infection was two-fold lower in winter, when nymphs are absent, than in summer when nymphal ticks were abundant and feeding on and infecting mice (Anderson et al. 1987b). Larval ticks are most abundant from July to September and become infected while feeding on infected mice. The relatively high prevalence of Lyme disease in humans was reported by Stafford III et al. (1998a, 1999) to be correlated with abundance of infected ticks. The major method of transmission of *Borrelia burgdorferi* in Connecticut is by larval *Ixodes scapularis* feeding upon infected white-footed mice and later transmitting the spirochete as nymphs, but one study suggested that vertical transmission, that is the passage of the spirochete from the female tick to her offspring, can occur, although it is relatively rare (Magnarelli et al. 1987a).

The geographical and seasonal distributions of this spirochete in juvenile and adult ticks collected by dragging flannel cloth over vegetation and off humans, mammals, and birds were reported for Connecticut and elsewhere (Anderson and Magnarelli 1984a, Anderson et al. 1986b, Anderson et al. 1986d, Anderson et al. 1987a, Magnarelli and Anderson 1984, Magnarelli et al. 1984a, Magnarelli et al. 1986a, Magnarelli and Anderson 1989a, Magnarelli et al. 1991a, Magnarelli et al. 1995c, Stafford III et al. 1995) (**Figure 60**). *Ixodes scapularis* has moved west and north in relatively recent years from southeastern Connecticut, where it was initially relatively abundant.

John F. Anderson and Magnarelli, in an effort to further understand the epidemiology of Lyme disease, collaborated with colleagues located elsewhere in the United States and reported on prevalence of infected

Table 5. Experiment Station publications on the isolation or detection of **Borrelia burgdorferi** *from blood or tissues of wild animals and humans and from attached ticks on humans and wild and domestic animals.*

Animal	Type of Study	Citation
Cat *Felis catus* L.	Prevalence of infected ticks	(Magnarelli et al. 1990a)
Dog *Canis lupus familiaris* L.	Prevalence of infected ticks	(Anderson and Magnarelli 1983)
Eastern chipmunk *Tamias striatus* (L.)	Prevalence of infection as determined by isolation of *Borrelia burgdorferi* and prevalence of infected ticks	(Anderson et al. 1983, Anderson et al. 1985, Anderson et al. 1987e)
Human *Homo sapiens* L.	Prevalence of infection as determined by isolation of *Borrelia burgdorferi* and prevalence of infected ticks	(Anderson et al. 1996, Magnarelli and Anderson 1989a, Nadelman et al. 1990)
Meadow vole *Microtus pennsylvanicus* (Ord)	Prevalence of infection as determined by isolation of *Borrelia burgdorferi* and prevalence of infected ticks	(Anderson et al. 1986d, 1987d)
Raccoon *Procyon lotor* (L.)	Prevalence of infection as determined by isolation of *Borrelia burgdorferi* and prevalence of infected ticks	(Anderson et al. 1983)
Red squirrel *Tamiasciurus hudsonicus* (Erxleben)	Prevalence of infected ticks	(Anderson et al. 1983)
Veery (song bird) *Catharus fuscescens* (Stephens)	First isolation of *Borrelia burgdorferi* from a wild bird	(Anderson et al. 1986c)
Virginia opossum *Didelphis virginiana* Kerr	Prevalence of infected ticks	(Anderson et al. 1987e)
White-footed mouse *Peromyscus leucopus* (Rafinesque)	Prevalence of infection as determined by isolation of *Borrelia burgdorferi* and prevalence of infected ticks	(Anderson and Magnarelli 1983, Anderson et al. 1983, Anderson et al. 1985, 1986b, Anderson et al. 1986d, Anderson et al. 1987a, Anderson et al. 1987b, Anderson et al. 1987e, Anderson et al. 1991, Magnarelli and Anderson 1988b, Magnarelli et al. 1995c)
White-tailed deer *Odocoileus virginianus* (Zimmermann)	Prevalence of infected ticks	(Anderson and Magnarelli 1983, Anderson et al. 1987a, Anderson et al. 1987e, Magnarelli et al. 1984d, Magnarelli et al. 1986a, Magnarelli et al. 1993, Magnarelli et al. 1995c)
Woodchuck *Marmota monax* (L.)	Prevalence of infected ticks	(Magnarelli and Swihart 1991)
Woodland jumping mouse *Napaeozapus insignis* (Miller)	Isolation	(Anderson and Magnarelli 1984a)
Bank vole *Clethrionomys glareolus* (Schreber)	Prevalence of infected ticks	(Anderson et al. 1986a)
Wood mouse *Apodemus sylvaticus* (L.)	Prevalence of infected ticks	(Anderson et al. 1986a)
Yellow-necked mouse *Apodemus flavicollis* (Melchior)	Prevalence of infected ticks	(Anderson et al. 1986a)
Birds (many species)	Prevalence of infected ticks	(Anderson and Magnarelli 1984a, Anderson et al. 1986c, Anderson et al. 1990c, Hubalek et al. 1996, Stafford III et al. 1995)
Mammals (many species)	Prevalence of infected ticks	(Oliver et al. 1999)

ticks and animals and the presence of antibodies to *Borrelia burgdorferi*. These locations included Rhode Island (Anderson and Magnarelli 1983, Anderson et al. 1986d), New York State (Anderson et al. 1987e, 1988, Magnarelli et al. 1986a, Magnarelli et al. 1995b), North Carolina (Magnarelli et al. 1986a, Oliver et al. 1999), New Hampshire (Anderson et al. 1987e), Wisconsin (Anderson et al. 1987a), Pennsylvania (Anderson et al. 1990b), Maryland (Magnarelli et al. 1991b), Georgia (Magnarelli et al. 1991b), Florida (Magnarelli et al. 1991b), Illinois (Nelson et al. 1991), South Carolina (Magnarelli et al. 1992b), Alabama (Magnarelli et al. 1992b), Mississippi (Magnarelli et al. 1992b), and Ontario, Canada (Gallivan et al. 1998).

Several review articles on serology, isolation, and epizootiology of borreliae and Lyme disease were published (Anderson 1985a, 1988, 1989a, b, c, d, Anderson et al. 1989, Anderson 1991, Anderson and Magnarelli 1992, 1993a, b, c, Anderson et al. 1994, Anderson and Magnarelli 1994, 1998, 1999, Burgdorfer et al. 1991, Magnarelli 1989a, 1991, 1997, 2009, Wilske et al. 1991).

Genetic variants of *Borrelia burgdorferi* were also reported by Experiment Station scientists. One was from upstate New York (Anderson et al. 1988) and later identified as *Borrelia bissettii*. Another was isolated from cottontail rabbits and *Ixodes dentatus* (Anderson et al. 1989). This was later described and named *Borrelia andersonii* in recognition of John F. Anderson (Marconi et al. 1995). Still another was infectious but nonpathogenic in mice (Anderson et al. 1990a), and others were recovered from *Ixodes scapularis* and *Ixodes dentatus* Marx feeding on humans (Anderson et al. 1996). Genetic variability of these isolates was later reported in comparison to isolates from throughout the United States (Mathiesen et al. 1997) and from Europe (Zingg et al. 1993). These isolates also were screened in vaccine studies (Schaible et al. 1993, Zhang et al. 1997).

Although *Ixodes scapularis* is the primary vector of *Borrelia burgdorferi*, Experiment Station scientists reported finding this spirochete in insects [fleas, *Orchopeas leucopus* (Baker), and botflies, *Cuterebra fontinella* Clark (Anderson and Magnarelli 1984a), deer flies, horse flies, and mosquitoes (Magnarelli et al. 1986b, Magnarelli and Anderson 1988b)] and suggested that some of these biting arthropods may be secondary vectors. Deer flies, horse flies, and mosquitoes have been reported to be possible vectors of borreliae in Europe (Hard 1966, Stanek et al. 1987), and in a collaborative study with scientists in a laboratory in France, we reported an instance of possible transmission by black flies (*Simulium* sp.) (Doby et al. 1987). Laboratory studies demonstrated that borreliae could survive for up to six days in adult mosquitoes (Magnarelli et al. 1987d). At the Experiment Station, this spirochete was isolated from engorging but not questing *Dermacentor variabilis* (Anderson et al. 1985, Magnarelli and Anderson 1988b). This tick is not a competent vector. Spirochetes were also found in the tick, *Ixodes cookei* (Magnarelli and Swihart 1991).

Figure 61. Tia Blevins using an ELISA plate reader in the serology laboratory, 2010.

In 1986, in a joint study with scientists from France, an Experiment Station publication reported the first isolations of *Borrelia burgdorferi* in France from *Ixodes ricinus* (Anderson et al. 1986a), including a novel isolate, which was later described as a new species, *Borrelia garinii*, an important human pathogen (Baranton et al. 1992). John F. Anderson also worked with Zdenek Hubalek on the ecology of *Borrelia burgdorferi* in the Czech Republic (Hubalek et al. 1996).

A new genus and species of spirochete was isolated from short-tailed shrews and white-footed mice collected in Connecticut and Minnesota (Anderson et al. 1987c). This spirochete was later characterized and named *Brevinema andersonii* in recognition of John F. Anderson, who first isolated this spirochete (Defosse et al. 1995). It is not known to cause human or veterinary disease.

Antibody studies of Borrelia burgdorferi *and other bacteria in wild and domestic animals*

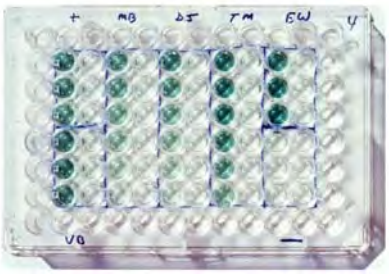
The first serologic tests for detecting *Borrelia burgdorferi* antibodies in wild animals were reported by Magnarelli et al. (1984a, 1984c, 1984d) (**Table 6**) (**Figure 61**).

Antibody was present in small, medium, and large wild animals in areas where *Ixodes scapularis* and human disease were prevalent and to be virtually absent in animals where ticks were scarce and Lyme disease was not reported (Magnarelli and Anderson 1984). They suggested that antibody testing of white-footed mice be included in monitoring programs for Lyme disease and also be used to assess the efficacy of programs aimed at controlling ticks (Magnarelli et al. 1988a). Additional studies were performed with cottontail rabbits (Magnarelli et al. 1990b). Subsequent studies were focused on improvement of serologic procedures, assessing different strains of borreliae to sera from different geographic areas, testing recombinant antigens, and detecting antibodies to multiple tick-associated human pathogens (Fikrig et al. 1993, Gallivan et al. 1998, Magnarelli et al. 1991b, Magnarelli et al. 1995a, Magnarelli et al. 1995b, Magnarelli et al. 1995c, Magnarelli et al. 1997a, Magnarelli et al. 1997b, Magnarelli et al. 1999a, Magnarelli et al. 2006, Oliver et al. 1999, Stafford III et al. 1999).

Scientists at the Experiment Station were among the first to report Lyme disease in dogs (Magnarelli et al. 1985b, Magnarelli et al. 1987c). The serologic tests that were developed were used by veterinarians to confirm canine infections wherever Lyme disease was prevalent (Levy and Magnarelli 1992, Magnarelli et al. 1990c). Also, IFA and enzyme-linked immunosorbent assay (ELISA) tests were developed to detect antibodies to *Borrelia burgdorferi* in horses and to document the presence of antibody with reported lameness (Magnarelli et al. 1988b, Magnarelli and Anderson 1989b). Similar studies were reported for cats (Magnarelli et al. 1990a)

Table 6. Experiment Station publications on serologic studies of wild and domestic animals for detection of **Borrelia burgdorferi** *and other bacteria.*

Animal	Type of Study	Citation
Cotton mouse *Peromyscus gossypinus* (LeConte)	Prevalence of antibody	(Magnarelli et al. 1992b)
Eastern cottontail *Sylvilagus floridanus* (J. A. Allen)	Prevalence of antibody	(Fikrig et al. 1993, Magnarelli et al. 1990b, Magnarelli et al. 1995b)
Eastern chipmunk Tamias striatus (L.)	Prevalence of antibody	(Magnarelli et al. 1984a)
Eastern gray squirrel *Sciurus carolinensis* Gmelin	Prevalence of antibody	(Magnarelli et al. 1984a)
Raccoon *Procyon lotor* (L.)	Prevalence of antibody	(Magnarelli et al. 1984a, Magnarelli et al. 1984c, Magnarelli et al. 1991b, Magnarelli et al. 1995a, Magnarelli et al. 1995b)
Virginia opossum *Didelphis virginiana* Kerr	Prevalence of antibody	(Magnarelli et al. 1984a)
White-footed mouse *Peromyscus leucopus* (Rafinesque)	Prevalence of antibody	(Magnarelli et al. 1984a, Magnarelli et al. 1984c, Magnarelli et al. 1988a, Magnarelli et al. 1992b, Magnarelli et al. 1995a, Magnarelli et al. 1995b, Magnarelli et al. 1997a, Magnarelli et al. 2006, Stafford III et al. 1999)
White-tailed deer *Odocoileus virginianus* (Zimmermann)	Prevalence of antibody	(Gallivan et al. 1998, Magnarelli et al. 1984d, Magnarelli et al. 1986a, Magnarelli et al. 1991b, Magnarelli et al. 1993, Magnarelli et al. 1995b, Magnarelli et al. 1995c, Magnarelli et al. 1999a, Magnarelli et al. 2004b)
Wild mammals (many species)	Prevalence of antibody	(Oliver et al. 1999)
Domestic cat *Felis catus* L.	Prevalence of antibody; disease	(Magnarelli et al. 1990a, Magnarelli et al. 2005, Magnarelli et al. 2007)
Domestic cow *Bos taurus* L.	Prevalence of antibody	(Magnarelli et al. 2004a)
Domestic dog *Canis lupus familiaris* L.	Prevalence of antibody; disease	(Fikrig et al. 1993, Levy and Magnarelli 1992, Magnarelli et al. 1985b, Magnarelli et al. 1987c, Magnarelli et al. 1990c, Magnarelli et al. 1990d, Magnarelli et al. 1997b, Magnarelli et al. 2001c)
Domestic horse *Equus ferus caballus* L.	Prevalence of antibody; disease	(Fikrig et al. 1993, Magnarelli et al. 1988b, Magnarelli et al. 1997b, Magnarelli et al. 2000b, Magnarelli and Fikrig 2005)



▲ *Figure 62. ELISA plate (green color indicates positive antibody reactions).*

Figure 63. Dr. Louis A. Magnarelli reporting on serologic tests in humans at a Lyme disease meeting in 1992. ▶

and cattle (Magnarelli et al. 2004a). Improvements of serologic tests for domestic animals, finding co-infections with other tick-transmitted pathogens (*Ehrlichia* and *Anaplasma)*, and evaluation of recombinant antigens were subsequently reported (Fikrig et al. 1993, Magnarelli et al. 2000b, Magnarelli et al. 2001c, Magnarelli et al. 2004b, Magnarelli et al. 2005, Magnarelli and Fikrig 2005). Another study focused on detection of *Borrelia burgdorferi* in urine of animals by an ELISA to improve diagnosis of infections (Magnarelli and Anderson 1994, Magnarelli et al. 1994b).

Magnarelli et al. (2007) also reported the detection of antibodies to the organism that causes tularemia, *Francisella tularensis*, in cats that lived in Connecticut and New York State (Magnarelli et al. 2007). Still in another related study, the human and veterinary pathogen *Leptospira interrogans,* which is not transmitted by ticks or insects, was isolated from the skin of a dog (Anderson et al. 1993).

Serologic tests for* Borrelia burgdorferi *in humans

Magnarelli et al. (1984c, 1984e) published on methods for one of the first tests to detect antibodies to *Borrelia burgdorferi* in humans by ELISA and IFA, and, while both procedures confirmed Lyme disease, they concluded that ELISA was likely to be the preferred test (**Figure 62**). Improvement of the ELISA and IFA tests remained a focus of Magnarelli for the next 20 some years (**Figure 63**).

Subsequent serologic studies with human sera reported cross reactions with other human pathogens, documented early and persistent antibodies, and provided improvements for the test (Magnarelli and Anderson 1987, Magnarelli et al. 1987b). These studies detected IgM and IgG antibodies to *Borrelia burgdorferi*, but because of cross-reactivity among *Borrelia* and *Treponema*, clinical data and use of other serologic tests were likely needed sometimes to separate a diagnosis of Lyme disease from other infections (Magnarelli 1988b, Magnarelli and Anderson 1988a, Magnarelli et al. 1990e, Magnarelli and Anderson 1991). Assay sensitivity of Ig, IgM, and IgG antibodies was relatively low when serum samples were taken within three weeks of onset of erythema migrans, but during neuritis or arthritis, IgG antibody levels were usually elevated, and serologic verification of disease was more easily achieved (Magnarelli 1988b).

Fractions of the spirochete were then tested, and those with molecular masses of 34, 39, 59, and 68 kilodaltons had comparable sensitivity but greater specificity than tests with whole-cell spirochetes. Based on these studies, it appeared that serological diagnosis of Lyme disease might be improved by using subunit antigens (Magnarelli et al. 1989). A recombinant flagellar protein, p41-G, was used to confirm disease during early stages of illness (Magnarelli et al. 1992a). A recombinant outer surface protein C was later shown to help confirm *Borrelia burgdorferi* infections (Magnarelli et al. 1996). The use of class-specific ELISA with purified recombinant antigens and Western blot analyses confirmed earlier studies that used recombinant antigens and led to the conclusion that immunoblotting is advised as an adjunct procedure when relatively low antibody titers were obtained by ELISA (Magnarelli et al. 2000a, Magnarelli et al. 2002b). Different strains of *Borrelia burgdorferi* and species of *Borrelia* from different parts of the world were found to react similarly to serum samples from persons with Lyme disease (Magnarelli et al. 1994a).

Serologic studies for *Borrelia burgdorferi* and isolation of *Babesia microti* from humans in southeastern Connecticut indicated that patients were likely coinfected with both organisms (Anderson et al. 1991). Subsequently, Magnarelli et al. (1995d) provided serologic evidence of human exposure to multiple tick-associated pathogens and suggested that whenever the clinical

Figure 64. Congresswoman Rosa DeLauro visiting the serology laboratory of Dr. Louis Magnarelli. From l to r, Dr. Magnarelli, Rosa DeLauro, Tia Blevins, Lesha Peyton, July, 1997.

picture of disease was unclear, additional laboratory testing with multiple tick-borne pathogens be done.

Louis A. Magnarelli published a number of review articles pertaining to the quality and methods of various serologic tests that were being performed in hospital, public, and private laboratories for Lyme disease. These writings emphasized that serological tests for Lyme disease were useful and remained the most practical means of laboratory diagnosis, but quality control needed to be improved (Magnarelli 1989b, c, d, 1990b, 1991, 1995).

Beginning in 1984, the Experiment Station staff began analyzing human serum samples for antibodies to *Borrelia burgdorferi*. More than 6,000 serum samples were performed for the Connecticut State Department of Public Health without fee during that year. This experimental procedure was also used in three hospitals in Connecticut and a major research laboratory at the University of Minnesota. Experiment Station staff also provided reagents for an ELISA and expertise to personnel in clinical laboratories within Connecticut and nationally. For many years thereafter, Magnarelli provided needed services and reagents to hospitals throughout the country (**Figure 64**).

Collaborative studies with other scientific institutions

I have already reported on numerous collaborative studies with scientists elsewhere, but in addition, the Experiment Station was involved in many scientific experiments relating to Lyme disease and other diseases and often led by Professor Erol Fikrig or others at Yale University, physicians at the Connecticut State Department of Public Health, and elsewhere. These experiments pertained to necrotizing splenitis (Rank et al. 1989), laboratory-based surveillance of Lyme disease (Petersen et al. 1989b), isolation of *Borrelia burgdorferi* from patients (Nadelman et al. 1990), hantavirus (Wilson et al. 1995), Rift Valley fever (Linthicum et al. 2007) and tick immunity (Nazario et al. 1998). Extensive molecular studies were published on how *Ixodes scapularis* feeds and how *Borrelia burgdorferi* survives in and is transmitted between ticks and mammals. Important spirochete and tick proteins that contribute to the tick-mammal cycle were identified (Das et al. 2000, Fikrig et al. 2004, Li et al. 2007a, Li et al. 2007b, Narasimhan et al. 2002, Narasimhan et al. 2004, Narasimhan et al. 2007a, Narasimhan et al. 2007b, Pal et al. 2000, Pal et al. 2004a, Pal et al. 2004b, Pal et al. 2006, Ramamoorthi et al. 2005, Sukumaran et al. 2006). Collaborations continued with Dr. Utpal Pal after he relocated to the University of Maryland (Coleman et al. 2008, Pal et al. 2008, Promnares et al. 2009). Additionally, the effect of feeding duration on transmission of *Borrelia burgdorferi* and *Anaplasma phagocytophilum* was reported (des Vignes et al. 2001).

Concluding Remarks

Public health entomology at The Connecticut Agricultural Experiment Station began at a time when malaria caused human disease and death and hordes of salt marsh mosquitoes made life miserable in many shoreline communities. Effective mosquito control programs were developed and completed in the early part of the 20th century. Natural enemies of mosquitoes were identified and attempts were made to assess their use in integrated pest management programs. Blood and sugar feeding habits were documented. Previously unknown mosquito-associated viruses were later identified and studied, including West Nile virus, and surveillance programs for the most important viruses were established to help reduce risk of human disease. Similarly, when ticks and associated human diseases became a serious health problem in the latter part of the last century, the Experiment Station promptly responded by studying the ecology and control of ticks, the epidemiology of tick-associated pathogens, and developing serologic tests for humans and domestic and wild animals. These studies and various services to the public, such as tick identification and development of serology techniques, were done to reduce risk of citizen exposure to disease, and to confirm specific infections. The Experiment Station has promptly responded to a multitude of public health challenges in the past and will continue doing so as new challenges arise with evolving changes in rural and urban landscapes and living accommodations and the introduction of new invasive species of biting arthropods and human pathogens from abroad.

References

Anderson, J. F. 1966. Anomalous development of the cuticle of mosquitoes induced by griseofulvin. J Econ Entomol 59: 1476-1482.

Anderson, J. F. 1967a. Histopathology of intersexuality in mosquitoes. J Exper Zool 165: 475-496.

Anderson, J. F. 1967b. Sex determination in insects, pp. 76-102. *In* A. Allison [ed.], Biology of sex. Penguin Books, Inc., Baltimore.

Anderson, J. F. 1968a. Influence of photoperiod and temperature on the induction of diapause in *Aedes atropalpus* (Diptera: Culicidae). Entomol Exper Applic 11: 321-330.

Anderson, J. F. 1968b. Day length governs seasonal cycle of mosquitoes. Frontiers of Plant Science 20: 6-7.

Anderson, J. F. 1968c. Microsporidia parasitizing mosquitoes collected in Connecticut. J Invert Pathol 11: 440-455.

Anderson, J. F., and S. W. Hitchcock. 1968. Biology of *Chironomus atrella* in a tidal cove (Diptera: Chironomidae). Ann Entomol Soc Am 61: 1597-1603.

Anderson, J. F. 1969. Delta-winged combatants of the salt marsh. Frontiers of Plant Science 22: 2-3.

Anderson, J. F., and F. R. Kneen. 1969. The temporary impoundment of salt marshes for the control of coastal deer flies. Mosq News 29: 239-243.

Anderson, J. F., and S. L. Ringo. 1969. *Entomophthora aquatica* sp. n. infecting larvae and pupae of floodwater mosquitoes. J Invert Pathol 13: 386-393.

Anderson, J. F. 1970a. An iridescent virus infecting the mosquito, *Aedes stimulans* (Walker). J Invert Pathol 15: 219-224.

Anderson, J. F. 1970b. Induction and termination of embryonic diapause in the salt marsh mosquito, *Aedes sollicitans* (Diptera: Culicidae). Bull Conn Agric Exp Stn 711: 1-22.

Anderson, J. F. 1971. Autogeny and mating and their relationship to biting in the saltmarsh deer fly, *Chrysops atlanticus* (Diptera: Tabanidae). Ann Entomol Soc Am 64: 1421-1424.

Anderson, J. F. 1973a. Biting behavior of saltmarsh deer flies (Diptera: Tabanidae). Ann Entomol Soc Am 66: 21-23.

Anderson, J. F. 1973b. Insects (*Chrysops* flies) in Connecticut salt marshes, pp. 125-132, Wetlands Conference, Inst of Water Resources, University of Connecticut.

Anderson, J. F. 1975. Arthropod vectors of disease, pp. 1087-1116. *In* W. T. Hubbert, W. F. McCulloch and P. R. Schnurrenberger [eds.], Diseases transmitted from animals to man, 6 ed. C. C. Thomas, Springfield, Ill.

Anderson, J. F., and L. A. Magnarelli. 1978. *Cometoides pechumani* sp. n. (Protozoa: Eugregarinidae), a gregarine parasite of saltmarsh deer flies (Diptera:Tabanidae). J Invertebr Pathol 31: 324-328.

Anderson, J. F., and L. A. Magnarelli. 1979. *Entomophthora tabanivora*, a new pathogen in horseflies (Diptera: Tabanidae). J Invert Pathol 34: 263-266.

Anderson, J. F., L. A. Magnarelli, C. S. Donner, A. Spielman, and J. Piesman. 1979a. Canine *Babesia* new to North America. Science 204: 1431-1432.

Anderson, J. F., L. A. Magnarelli, and J. Kurz. 1979b. Intraerythrocytic parasites in rodent populations of Connecticut: *Babesia* and *Grahamella* species. J Parasitol 65: 599-604.

Anderson, J. F., and S. L. Anagnostakis. 1980. Validation of *Entomophthora aquatica*. Mycotaxon 10: 350.

Anderson, J. F., and L. A. Magnarelli. 1980. Vertebrate host relationships and distribution of ixodid ticks (Acari: Ixodidae) in Connecticut, USA. J Med Entomol 17: 314-323.

Anderson, J. F., L. A. Magnarelli, and A. J. Sulzer. 1980. Canine babesiosis: indirect fluorescent antibody test for a North American isolate of *Babesia gibsoni*. Am J Vet Res 41: 2102-2105.

Anderson, J. F., L. A. Magnarelli, W. Burgdorfer, E. A. Casper, and R. N. Philip. 1981a. Importation into the United States from Africa of *Rhipicephalus simus* on a boutonneuse fever patient. Am J Trop Med Hyg 30: 897-899.

Anderson, J. F., L. A. Magnarelli, and J. E. Keirans. 1981b. *Aponomma quadricavum* (Acari: Ixodidae) collected from an imported boa, *Epicrates striatus*, in Connecticut. J Med Entomol 18: 123-125.

Anderson, J. F., L. A. Magnarelli, and A. J. Sulzer. 1981c. Raccoon babesiosis in Connecticut, USA: *Babesia lotori* sp. n. J Parasitol 67: 417-425.

Anderson, J. F., and W. E. Furniss. 1983. Epidemic of urticaria associated with first-instar larvae of the gypsy moth (Lepidoptera: Lymantriidae). J Med Entomol 20: 146-150.

Anderson, J. F., and L. A. Magnarelli. 1983. Spirochetes in *Ixodes dammini* and *Babesia microti* on Prudence Island, Rhode Island. J Infect Dis 148: 1124.

Anderson, J. F., L. A. Magnarelli, W. Burgdorfer, and A. G. Barbour. 1983. Spirochetes in *Ixodes dammini* and mammals from Connecticut. Am J Trop Med Hyg 32: 818-824.

Anderson, J. F., R. W. Lyons, and K. A. Welch. 1984a. Caterpillar infestations in a diabetic patient. J Infect Dis 150: 964.

Anderson, J. F., and L. A. Magnarelli. 1984a. Avian and mammalian hosts for spirochete-infected ticks and insects in a Lyme disease focus in Connecticut. Yale J Biol Med 57: 627-641.

Anderson, J. F., and L. A. Magnarelli. 1984b. Hospital-acquired myiasis. Asepsis 6: 15-16.

Anderson, J. F., L. A. Magnarelli, and J. E. Keirans. 1984b. Ixodid and argasid ticks in Connecticut, U.S.A.: *Aponomma latum*, *Amblyomma dissimile*, *Haemaphysalis leachi* group, and *Ornithodoros kelleyi* (Acari: Ixodidae, Argasidae). Internat J Acarol 10: 149-151.

Anderson, J. F. 1985a. Epidemiologie de la maladie de Lmye dans le Connecticut (U. S. A.). Bull Soc Fran Parasitol 1: 53-60.

Anderson, J. F. 1985b. The control of horse flies and deer flies (Diptera: Tabanidae). Myia 3: 547-598.

Anderson, J. F. 1985c. House fly control. New Hamp Poul Health Conf Proceed: 9-11.

Anderson, J. F., R. C. Johnson, L. A. Magnarelli, and F. W. Hyde. 1985. Identification of endemic foci of Lyme disease: isolation of *Borrelia burgdorferi* from feral rodents and ticks (*Dermacentor variabilis*). J Clin Microbiol 22: 36-38.

Anderson, J. F., J. M. Doby, A. Coutarmanac'h, F. W. Hyde, and R. C. Johnson. 1986a. Differences antigeniques entre des souchesde *Borrelia burgdorferi* isolees de'*Ixodes ricinu*s en Bretagne. Med Malad Infect 16: 171-175.

Anderson, J. F., R. C. Johnson, L. A. Magnarelli, and F. W. Hyde. 1986b. Culturing *Borrelia burgdorferi* from spleen and kidney tissues of wild-caught white-footed mice, *Peromyscus leucopus*. Zentralbl Bakteriol Mikrobiol Hyg [A] 263: 34-39.

Anderson, J. F., R. C. Johnson, L. A. Magnarelli, and F. W. Hyde. 1986c. Involvement of birds in the epidemiology of the Lyme disease agent *Borrelia burgdorferi*. Infect Immun 51: 394-396.

Anderson, J. F., R. C. Johnson, L. A. Magnarelli, F. W. Hyde, and J. E. Myers. 1986d. *Peromyscus leucopus* and *Microtus pennsylvanicus* simultaneously infected with *Borrelia burgdorferi* and *Babesia microti*. J Clin Microbiol 23: 135-137.

Anderson, J. F., L. A. Magnarelli, R. N. Philip, and W. Burgdorfer. 1986e. *Rickettsia rickettsii* and *Rickettsia montana* from ixodid ticks in Connecticut. Am J Trop Med Hyg 35: 187-191.

Anderson, J. F., A. Spandorf, L. A. Magnarelli, and W. Glowa. 1986f. Control of house flies in commercial poultry houses in Connecticut. Poultry Science 65: 837-844.

Anderson, J. F., P. H. Duray, and L. A. Magnarelli. 1987a. Prevalence of *Borrelia burgdorferi* in white-footed mice and *Ixodes dammini* at Fort McCoy, Wis. J Clin Microbiol 25: 1495-1497.

Anderson, J. F., R. C. Johnson, and L. A. Magnarelli. 1987b. Seasonal prevalence of *Borrelia burgdorferi* in natural populations of white-footed mice, *Peromyscus leucopus*. J Clin Microbiol 25: 1564-1566.

Anderson, J. F., R. C. Johnson, L. A. Magnarelli, F. W. Hyde, and T. G. Andreadis. 1987c. New infectious spirochete isolated from short-tailed shrews and white-footed mice. J Clin Microbiol 25: 1490-1494.

Anderson, J. F., R. C. Johnson, L. A. Magnarelli, F. W. Hyde, and J. E. Myers. 1987d. Prevalence of *Borrelia burgdorferi* and *Babesia microti* in mice on islands inhabited by white-tailed deer. Appl Environ Microbiol 53: 892-894.

Anderson, J. F., L. A. Magnarelli, and J. B. McAninch. 1987e. *Ixodes dammini* and *Borrelia burgdorferi* in northern New England and upstate New York. J Parasitol 73: 419-421.

Anderson, J. F. 1988. Mammalian and avian reservoirs for *Borrelia burgdorferi*. Ann N Y Acad Sci 539: 180-191.

Anderson, J. F., L. A. Magnarelli, and J. B. McAninch. 1988. New *Borrelia burgdorferi* antigenic variant isolated from *Ixodes dammini* from upstate New York. J Clin Microbiol 26: 2209-2212.

Anderson, J. F. 1989a. Epizootiology of *Borrelia* in *Ixodes* tick vectors and reservoir hosts. Rev Infect Dis 11 Suppl 6: S1451-1459.

Anderson, J. F. 1989b. Isolation and cryopreservation of the Lyme disease spirochete *Borrelia burgdorferi*. U S Federation for Culture Collections 19: 1-4.

Anderson, J. F. 1989c. Ecology of Lyme disease. Conn Med 53: 343-346.

Anderson, J. F. 1989d. Preventing Lyme disease. Rheu Dis Clin North Am 15: 757-766.

Anderson, J. F., L. A. Magnarelli, R. B. LeFebvre, T. G. Andreadis, J. B. McAninch, G. C. Perng, and R. C. Johnson. 1989. Antigenically variable *Borrelia burgdorferi* isolated from cottontail rabbits and *Ixodes dentatus* in rural and urban areas. J Clin Microbiol 27: 13-20.

Anderson, J. F., S. W. Barthold, and L. A. Magnarelli. 1990a. Infectious but nonpathogenic isolate of *Borrelia burgdorferi*. J Clin Microbiol 28: 2693-2699.

Anderson, J. F., P. H. Duray, and L. A. Magnarelli. 1990b. *Borrelia burgdorferi* and *Ixodes dammini* prevalent in the greater Philadelphia area. J Infect Dis 161: 811-812.

Anderson, J. F., L. A. Magnarelli, and K. C. Stafford III. 1990c. Bird-feeding ticks transstadially transmit *Borrelia burgdorferi* that infect Syrian hamsters. J Wildl Dis 26: 1-10.

Anderson, J. F. 1991. Epizootiology of Lyme borreliosis. Scand J Infect Dis Suppl 77: 23-34.

Anderson, J. F., E. D. Mintz, J. J. Gadbaw, and L. A. Magnarelli. 1991. *Babesia microti*, human babesiosis, and *Borrelia burgdorferi* in Connecticut. J Clin Microbiol 29: 2779-2783.

Anderson, J. F., and L. A. Magnarelli. 1992. Epizootiology of Lyme disease and methods of cultivating *Borrelia burgdorferi*. Ann N Y Acad Sci 653: 52-63.

Anderson, J. F., and L. A. Magnarelli. 1993a. Natural history of *Borrelia burgdorferi* in vectors and vertebrate hosts., pp. 11-24. *In* H. S. Ginsberg [ed.], Ecology and environmental management of Lyme disease. Rutgers Univ. Press, New Brunswick.

Anderson, J. F., and L. A. Magnarelli. 1993b. Zoonotic aspects of Lyme borreliosis. *In* R. C. Johnson [ed.], World Health Organization meeting on Lyme Borreliosis Control and Research Piestany, Slovak Republic.

Anderson, J. F., and L. A. Magnarelli. 1993c. Epizootiology of Lyme disease-causing borreliae. Clin Dermatol 11: 339-351.

Anderson, J. F., D. A. Miller, J. E. Post, R. C. Johnson, L. A. Magnarelli, and T. G. Andreadis. 1993. Isolation of *Leptospira interrogans* serovar *grippotyphosa* from the skin of a dog. J Am Vet Med Assoc 203: 1550-1551.

Anderson, J. F., R. A. Flavell, L. A. Magnarelli, S. W. Barthold, F. S. Kantor, R. Wallich, and E. Fikrig. 1994.

Variants of the prototype *Borrelia burgdorferi* B 31 strain isolated from *Ixodes scapularis*, pp. 23-26. *In* R. Cevenini, V. Sambri and M. Laplaca [eds.], VI International Conference on Lyme Borreliosis University of Bologna, Italy.

Anderson, J. F., and L. A. Magnarelli. 1994. Lyme disease: A tick-associated disease originally described in Europe, but named after a town in Connecticut. Amer Entomol 40: 217-227.

Anderson, J. F., R. A. Flavell, L. A. Magnarelli, S. W. Barthold, F. S. Kantor, R. Wallich, D. H. Persing, D. Mathiesen, and E. Fikrig. 1996. Novel *Borrelia burgdorferi* isolates from *Ixodes scapularis* and *Ixodes dentatus* ticks feeding on humans. J Clin Microbiol 34: 524-529.

Anderson, J. F., and L. A. Magnarelli. 1998. The trouble with ticks. Amer Nurseryman 188: 53-56.

Anderson, J. F., T. G. Andreadis, C. R. Vossbrinck, S. Tirrell, E. M. Wakem, R. A. French, A. E. Garmendia, and H. J. Van Kruiningen. 1999. Isolation of West Nile virus from mosquitoes, crows, and a Cooper's hawk in Connecticut. Science 286: 2331-2333.

Anderson, J. F., and L. A. Magnarelli. 1999. Epizootiology of *Borrelia burgdorferi* in the northeastern and northcentral United States. Acarology IX:Symposia: 385-389.

Anderson, J. F., C. R. Vossbrinck, T. G. Andreadis, A. Iton, W. H. Beckwith, 3rd, and D. R. Mayo. 2001a. Characterization of West Nile virus from five species of mosquitoes, nine species of birds, and one mammal. Ann N Y Acad Sci 951: 328-331.

Anderson, J. F., C. R. Vossbrinck, T. G. Andreadis, A. Iton, W. H. Beckwith, 3rd, and D. R. Mayo. 2001b. A phylogenetic approach to following West Nile virus in Connecticut. Proc Natl Acad Sci U S A 98: 12885-12889.

Anderson, J. F. 2002. The natural history of ticks. Med Clin North Am 86: 205-218.

Anderson, J. F., and J. J. Rahal. 2002. Efficacy of interferon alpha-2b and ribavirin against West Nile virus in vitro. Emerg Infect Dis 8: 107-108.

Anderson, J. F., A. J. Main, T. G. Andreadis, S. K. Wikel, and C. R. Vossbrinck. 2003. Transstadial transfer of West Nile virus by three species of ixodid ticks (Acari: Ixodidae). J Med Entomol 40: 528-533.

Anderson, J. F., T. G. Andreadis, A. J. Main, and D. L. Kline. 2004. Prevalence of West Nile virus in tree canopy-inhabiting *Culex pipiens* and associated mosquitoes. Am J Trop Med 71: 112-119.

Anderson, J. F., and L. A. Magnarelli. 2004. Babesiosis in Fairfield County, Connecticut. Emerg Infect Dis 10: 545-546.

Anderson, J. F., T. G. Andreadis, A. J. Main, F. J. Ferrandino, and C. R. Vossbrinck. 2006. West Nile virus from female and male mosquitoes (Diptera:Culicidae) in subterranean, ground, and canopy habitats in Connecticut. J Med Entomol 43: 1010-1019.

Anderson, J. F., and A. J. Main. 2006. Importance of vertical and horizontal transmission of West Nile virus by *Culex pipiens* in the northeastern United States. J Infect Dis 194: 1577-1579.

Anderson, J. F., A. J. Main, F. J. Ferrandino, and T. G. Andreadis. 2007. Nocturnal activity of mosquitoes (Diptera: Culicidae) in a West Nile virus focus in Connecticut. J Med Entomol 44: 1102-1108.

Anderson, J. F., and L. A. Magnarelli. 2008. Biology of ticks. Infect Dis Clin North Am 22: 195-215, v.

Anderson, J. F., A. J. Main, K. Delroux, and E. Fikrig. 2008. Extrinsic incubation periods for horizontal and vertical transmission of West Nile virus by *Culex pipiens pipiens* (Diptera: Culicidae). J Med Entomol 45: 445-451.

Anderson, J. F., F. J. Ferrandino, S. McKnight, J. Nolen, and J. Miller. 2009. A carbon dioxide, heat and chemical lure trap for the bedbug, *Cimex lectularius*. Med Vet Entomol 23: 99-105.

Andreadis, T. G. 1981. A new cytoplasmic polyhedrosis virus from the salt-marsh mosquito, *Aedes cantator* (Diptera: Culicidae). J Invert Pathol 37: 160-167.

Andreadis, T. G. 1982. Life cycles and pathology of some microsporidian pathogens of mosquitoes, pp. 387-392, Intl Colloq Invertbr Pathol, Brighton.

Andreadis, T. G. 1983a. An epizootic *Amblyospora* sp. (Microspora: Amblyosporidae) in field populations of the mosquito, *Aedes cantator*. J Invertebr Pathol 42: 427-430.

Andreadis, T. G. 1983b. Life cycle and epizootiology of *Amblyospora sp.* (Microspora: Amblyosporidae) in the mosquito, *Aedes cantator*. J Protozool 30: 509-518.

Andreadis, T. G., and L. A. Magnarelli. 1983. *Erynia* (=*Entomopthora*) *aquatica* in a salt-marsh mosquito, *Aedes cantator*. J Invertebr Pathol 42: 277-279.

Andreadis, T. G., and L. A. Magnarelli. 1984. New variants of the *Coelomomyces psorophorae* "complex" (Chytridiomycetes: Blastocladiales) from the salt-marsh mosquitoes *Aedes cantator* and *Aedes sollicitans* (Diptera: Culicidae). J Med Entomol 21: 379-383.

Andreadis, T. G. 1985a. Experimental transmission of a microsporidian pathogen from mosquitoes to an alternate copepod host. Proc Natl Acad Sci U S A 82: 5574-5577.

Andreadis, T. G. 1985b. Microsporidian parasites regulate mosquito populations. Frontiers of Plant Science 37: 6-8.

Andreadis, T. G. 1985c. Life cycle, epizootiology and horizontal transmision of *Amblyospora* (Microspora: Amblyosporidae) in a univoltine mosquito, *Aedes stimulans.* J Invert Pathol 46: 31-46.

Andreadis, T. G. 1986a. New state records for *Aedes communis* and *Aedes punctor* in Connecticut. J Am Mosq Control Assoc 2: 378-379.

Andreadis, T. G. 1986b. Characterization of a cytoplasmic polyhedrosis virus affecting the mosquito *Culex restuans*. J Invert Pathol 47: 194-202.

Andreadis, T. G. 1986c. Life cycle and epizootiological investigations of *Amblyospora* (Microsporida) in the mosquito *Aedes cantator* and in the intermediate copepod host, pp. 344. *In* R. A. Samson, Vlak, J. M., Peters, D. [ed.], IVth Intl Cooloq Invertebr Pathol, Veldhoven, Netherlands.

Andreadis, T. G. 1987. Transmission, pp. 159-176. *In* J. R. Fuxa and Y. Tanada [eds.], Epizootiology of insect diseases. John Wiley and Sons, New York, New York.

Andreadis, T. G. 1988a. Comparative susceptibility of the

copepod, *Acanthocyclops vernalis* to a microsporidian parasite, *Amblyospora connecticus* from the mosquito, *Aedes cantator*. J Invert Pathol 52: 73-77.

Andreadis, T. G. 1988b. *Amblyospora connecticus* sp. nov. (Microsporida: Amblyosporidae): horizontal transmission studies in the mosquito, *Aedes cantator* and formal description. J Invert Pathol 52: 90-101.

Andreadis, T. G. 1988c. A survey of mosquitoes breeding in used tire stockpiles in Connecticut. J Am Mosq Control Assoc 4: 256-260.

Andreadis, T. G. 1989a. Infection of a field population of *Aedes cantator* with a polymorphic microsporidium, *Amblyospora connecticus* via release of the intermediate copepod host, *Acanthocyclops vernalis*. J Am Mosq Control Assoc 5: 81-85.

Andreadis, T. G. 1989b. Host specificity of *Amblyospora connecticus* (Microsporida: Amblyosporidae), a polymorphic microsporidian parasite of *Aedes cantator* (Diptera: Culicidae). J Med Entomol 26: 140-145.

Andreadis, T. G. 1990a. Epizootiology of *Amblyospora connecticus* (Microsporida) in field populations of the saltmarsh mosquito, *Aedes cantator*, and the cyclopoid copepod, *Acanthocyclops vernalis*. J Protozool 37: 174-182.

Andreadis, T. G. 1990b. Natural ecology and epizootiology of *Amblyospora connecticus* (Microsporida) in coastal salt marsh habitats of *Aedes cantator* (Diptera: Culicidae) and Copepoda: Cyclopidae., pp. 61-65, Vth Intl Cooloq Invertebr Pathol, Adelaide, Australia.

Andreadis, T. G. 1990c. Observations on installment egg hatching in the brown saltmarsh mosquito, *Aedes cantator*. J Am Mosq Control Assoc 6: 727-729.

Andreadis, T. G. 1990d. Polymorphic microsporidia of mosquitoes: potential for biological control., pp. 175-188. *In* R. Baker and P. Dunn [eds.], New directions in biological control UCLA symposia on molecular and cellular biology, new series. Alan R. Liss, New York.

Andreadis, T. G. 1991. Experimental observations on meiospore longevity in *Amblyospora connecticus* (Microsporida). J Invert Pathol 62: 458-460.

Andreadis, T. G., P. M. Capotosto, R. E. Shope, and S. J. Tirrell. 1992. Arbovirus surveillance in Connecticut 1991-1992. Proc Ann Meeting Northeastern Mosq Control Assoc 38: 6.

Andreadis, T. G., and M. A. Gere. 1992. Laboratory evaluation of *Acanthocyclops vernalis* and *Diacyclops bicuspidatus thomasi* (Copepoda: Cyclopidae) as predators of *Aedes canadensis* and *Aedes stimulans* (Diptera: Culicidae). J Med Entomol 29: 974-979.

Andreadis, T. G., and K. A. Welch. 1992. Controlling yellowjackets and wasps at the Connecticut Tennis Center. Frontiers of Plant Science 45: 5-6.

Andreadis, T. G. 1993a. Concurrent epizootics of *Amblyospora* spp. (Microsporida) in two northern *Aedes* mosquitoes. J Invert Pathol 62: 316-317.

Andreadis, T. G. 1993b. Epidemiology of eastern equine encephalitis in Connecticut. Fla Mosq Control Assoc 64: 97-103.

Andreadis, T. G. 1994a. Preliminary studies on the life cycle and epizootiology of *Hyalinocysta chapmani*, a microsporidian parasite of the mosquito, *Culiseta melanura* pp. 194-195, VIth Intl Colloq Invertebr Pathol, Montpellier, France.

Andreadis, T. G. 1994b. Ultrastructural characterization of meiospores of six new species of *Amblyospora* (Microsporida: Amblyosporidae) from northern *Aedes* (Diptera: Culicidae) mosquitoes. J Euk Microbiol 41: 147-154.

Andreadis, T. G. 1994c. Host range tests with *Edhazardia aedis* (Microsporida: Culicosporidae) against northern Nearctic mosquitoes. J Invertebr Pathol 64: 46-51.

Andreadis, T. G., P. M. Capotosto, R. E. Shope, and S. J. Tirrell. 1994. Mosquito and arbovirus surveillance in Connecticut 1991-1992. J Am Mosq Control Assoc 10: 556-564.

Andreadis, T. G., and L. E. Munstermann. 1997. Intraspecific variation in key morphological characters of *Culiseta melanura* (Diptera:Culicidae). J Am Mosq Control Assoc 13: 127-133.

Andreadis, T. G. 1998. Mosquitoes and eastern equine encephalitis in Connecticut. Frontiers of Plant Science 50: 4-6.

Andreadis, T. G., and J. F. Anderson. 1998. Mosquito arbovirus surveillance in Connecticut, 1998. Proc Ann Meeting Northeastern Mosq Control Assoc 44: 14-20.

Andreadis, T. G., J. F. Anderson, and S. J. Tirrell-Peck. 1998. Multiple isolations of eastern equine encephalitis and highlands J viruses from mosquitoes (Diptera: Culicidae) during a 1996 epizootic in southeastern Connecticut. J Med Entomol 35: 296-302.

Andreadis, T. G. 1999. Epizootiology of *Amblyospora stimuli* (Microsporidiida: Amblyosporidae) infections in field populations of a univoltine mosquito, *Aedes stimulans* (Diptera: Culicidae), inhabiting a temporary vernal pool. J Invertebr Pathol 74: 198-205.

Andreadis, T. G., J. F. Anderson, L. E. Munstermann, R. J. Wolfe, and D. A. Florin. 2001a. Discovery, distribution, and abundance of the newly introduced mosquito *Ochlerotatus japonicus* (Diptera: Culicidae) in Connecticut, USA. J Med Entomol 38: 774-779.

Andreadis, T. G., J. F. Anderson, and C. R. Vossbrinck. 2001b. Mosquito surveillance for West Nile virus in Connecticut, 2000: isolation from *Culex pipiens*, *Cx. restuans*, *Cx. salinarius*, and *Culiseta melanura*. Emerg Infect Dis 7: 670-674.

Andreadis, T. G. 2002. Epizootiology of *Hyalinocysta chapmani* (Microsporidia: Thelohaniidae) infections in field populations of *Culiseta melanura* (Diptera: Culicidae) and *Orthocyclops modestus* (Copepoda: Cyclopidae): a three-year investigation. J Invertebr Pathol 81: 114-121.

Andreadis, T. G., and C. R. Vossbrinck. 2002. Life cycle, ultrastructure and molecular phylogeny of *Hyalinocysta chapmani* (Microsporidia: Thelohaniidae), a parasite of *Culiseta melanura* (Diptera: Culicidae) and *Orthocyclops modestus* (Copepoda: Cyclopidae). J Eukaryot Microbiol 49: 350-364.

Andreadis, T. G. 2003. A checklist of the mosquitoes of Connecticut with new state records. J Am Mosq Control Assoc 19: 79-81.

Andreadis, T. G., J. J. Becnel, and S. E. White. 2003. Infectivity and pathogenicity of a novel baculovirus, CuniNPV from *Culex nigripalpus* (Diptera: Culicidae) for thirteen species and four genera of mosquitoes. J Med Entomol 40: 512-517.

Andreadis, T. G., J. F. Anderson, C. R. Vossbrinck, and A. J. Main. 2004. Epidemiology of West Nile virus in Connecticut: a five-year analysis of mosquito data 1999-2003. Vector Borne Zoonotic Dis 4: 360-378.

Andreadis, T. G. 2005. Evolutionary strategies and adaptations for survival between mosquito-parasitic microsporidia and their intermediate copepod hosts: a comparative examination of *Amblyospora connecticus* and *Hyalinocysta chapmani* (Microsporidia: Amblyosporidae). Folia Parasitol (Praha) 52: 23-35.

Andreadis, T. G., M. C. Thomas, and J. J. Shepard. 2005. Identification guide to the mosquitoes of Connecticut. Bull Conn Agric Exp Stn 966: 1-173.

Andreadis, T. G. 2007. Microsporidian parasites of mosquitoes. J Am Mosq Control Assoc 23: 3-29.

Andreadis, T. G., and P. M. Armstrong. 2007. A two-year evaluation of elevated canopy trapping for *Culex* mosquitoes and West Nile virus in an operational surveillance program in the northeastern United States. J Am Mosq Control Assoc 23: 137-148.

Andreadis, T. G., J. F. Anderson, P. M. Armstrong, and A. J. Main. 2008. Isolations of Jamestown Canyon virus (Bunyaviridae: Orthobunyavirus) from field-collected mosquitoes (Diptera: Culicidae) in Connecticut, USA: a ten-year analysis, 1997-2006. Vector Borne Zoonotic Dis 8: 175-188.

Andreadis, T. G. 2009. Failure of *Aedes albopictus* to overwinter following introduction and seasonal establishment at a tire recycling plant in the northeastern USA. J Am Mosq Control Assoc 25: 25-31.

Andreadis, T. G., and R. J. Wolfe. 2010. Evidence for reduction of native mosquitoes with increased expansion of invasive *Ochlerotatus japonicus japonicus* (Diptera: Culicidae) in the northeastern United States. J Med Entomol 47: 43-49.

Anonymous. 1902. Havana purged of fever-Major Gorgas regards "yellow jack" as a back number-the anti-mosquito plan's success, New York Times, New York.

Anonymous. 1994. Yale viral lab to move to Texas. New York Times 185: 57.

Anonymous. 2009. State of Connecticut Mosquito Management Program www.caes.state.ct.us

Armstrong, P. M., T. G. Andreadis, J. F. Anderson, and A. J. Main. 2005. Isolations of Potosi virus from mosquitoes (Diptera: Culicidae) collected in Connecticut. J Med Entomol 42: 875-881.

Armstrong, P. M., and T. G. Andreadis. 2006. A new genetic variant of La Crosse virus (Bunyaviridae) isolated from New England. Am J Trop Med Hyg 75: 491-496.

Armstrong, P. M., and T. G. Andreadis. 2007. Genetic relationships of Jamestown Canyon virus strains infecting mosquitoes collected in Connecticut. Am J Trop Med Hyg 77: 1157-1162.

Armstrong, P. M., T. G. Andreadis, J. F. Anderson, J. W. Stull, and C. N. Mores. 2008. Tracking eastern equine encephalitis virus perpetuation in the northeastern United States by phylogenetic analysis. Am J Trop Med Hyg 79: 291-296.

Arnold, H. 1753. Letter to Benedict Arnold, August 13, 1753. Historical Magazine, and Notes and Queries concerning the Antiquities, History, and Biography of America. (January, 1860) 4(1): page 18.

Atwater, W. O. 1904. Reminiscences of thirty years of agricultural science in Connecticut, pp. 216-233, Connecticut Board of Agriculture Proceedings, 1903.

Avitable, J. 2009. Horses to the West Indies. New London County Historical Society Newsletter 1,5,6.

Bai, F., T. Town, D. Pradhan, J. Cox, Ashish, M. Ledizet, J. F. Anderson, R. A. Flavell, J. K. Krueger, R. A. Koski, and E. Fikrig. 2007. Antiviral peptides targeting the West Nile virus envelope protein. J Virol 81: 2047-2055.

Baker, M. D., C. R. Vossbrinck, J. J. Becnel, and T. G. Andreadis. 1998. Phylogeny of *Amblyospora* (Microsporidia: Amblyosporidae) and related genera based on small subunit ribosomal DNA data: A possible example of host parasite cospeciation. J Invertebr Pathol 71: 199-206.

Bakken, J. S., J. S. Dumler, S. M. Chen, M. R. Eckman, L. L. Van Etta, and D. H. Walker. 1994. Human granulocytic ehrlichiosis in the upper Midwest United States. A new species emerging? JAMA 272: 212-218.

Bakken, J. S., and S. Dumler. 2008. Human granulocytic anaplasmosis. Infect Dis Clin North Am 22: 433-448.

Baranton, G., D. Postic, I. Saint Girons, P. Boerlin, J. C. Piffaretti, M. Assous, and P. A. Grimont. 1992. Delineation of *Borrelia burgdorferi* sensu stricto, *Borrelia garinii* sp. nov., and group VS461 associated with Lyme borreliosis. Int J Syst Bacteriol 42: 378-383.

Barber, M. A. 1929. The history of malaria in the United States. Public Health Rep 44: 2575-2587.

Beard, R. L. 1960. Laboratory studies on the role of insecticides in the ecology of house fly populations. Proc Internatl Congr Entomol 11: 440-444.

Beard, R. L. 1964a. Pathogenic stinging of housefly pupae by *Nasonia vitripennes* (Walker). J Insect Pathol 6: 1-7.

Beard, R. L. 1964b. Parasites of muscoid flies. WHO Bulletin 31: 491-493.

Beard, R. L. 1965a. Competition between DDT resistant and susceptible houseflies. J Econ Entomol 58: 584.

Beard, R. L. 1965b. An *Aspergillus* toxin lethal to house fly maggots. J Invert Pathol 7: 522-523.

Beard, R. L. 1965c. Observations on house flies in high ozone environments. Ann Entomol Soc Amer 58: 404-405.

Beard, R. L. 1965d. Experiments on physiologic induction of insecticide resistance. Int Cong Entomol Proc 12: 496-497.

Beard, R. L. 1965e. Ovarian suppression by DDT and resistance in the house fly. Entomol Exper Applic 8: 193-204.

Beard, R. L., and G. Walton. 1969. Kojic acid as an insecticidal mycotoxin. J Invert Pathol 14: 53-59.

Beard, R. L., and D. C. Sands. 1973. Factors affecting degradation of poultry manure by flies. Environ Entomol 2: 801-806.

Becnel, J. J., and T. G. Andreadis. 1998. *Amblyospora salinaria* n. sp. (Microsporidia: Amblyosporidae), parasite of *Culex salinarius* (Diptera: Culicidae): its life cycle stages in an intermediate host. J Invertebr Pathol 71: 258-262.

Becnel, J. J., and T. G. Andreadis. 1999. Microsporidia in insects, pp. 447-501. *In* M. Witter and L. M. Weiss [eds.], The Microsporidia and Microsporidiosis. American Society of Microbiology Press.

Benach, J. L., D. J. White, W. Burgdorfer, T. Keelan, S. Guirgis, and R. H. Altieri. 1977. Changing patterns in the incidence of Rocky Mountain spotted fever on Long Island (1971-1976). Am J Epidemiol 106: 380-387.

Blagburn, B. L., J. A. Spencer, S. A. Billeter, N. L. Drazenovich, J. M. Butler, T. M. Land, C. C. Dykstra, K. C. Stafford III, M. B. Pough, S. A. Levy, and D. L. Bledsoe. 2004. Use of imidacloprid-permethrin to prevent transmission of *Anaplasma phagocytophilum* from naturally infected *Ixodes scapularis* ticks to dogs. Vet Ther 5: 212-217.

Bodenstein, D. 1945. A study of the relationship between organ and organic environment in the post embryonic development of the yellow fever mosquito. Bull Conn Agric Exp Stn 501: 100-114.

Bonafe, N., J. A. Rininger, R. G. Chubet, H. G. Foellmer, S. Fader, J. F. Anderson, S. L. Bushmich, K. Anthony, M. Ledizet, E. Fikrig, R. A. Koski, and P. Kaplan. 2009. A recombinant West Nile virus envelope protein vaccine candidate produced in *Spodoptera frugiperda* expresSF+ cells. Vaccine 27: 213-222.

Botsford, R. C. 1933. Mosquito control in Connecticut, 1933. Bull Conn Agric Exp Stn 360: 442-443.

Botsford, R. C. 1934. Present status of salt marsh mosquito ditching in Connecticut. Bull Conn Agric Exp Stn 368: 208-209.

Botsford, R. C. 1935. Present status of mosquito control work in Connecticut. Bull Conn Agric Exp Stn 383: 292-301.

Botsford, R. C. 1936. Present status of mosquito control work in Connecticut. Bull Conn Agric Exp Stn 396: 396-399.

Botsford, R. C. 1937. Present status of mosquito control work in Connecticut. Bull Conn Agric Exp Stn 408: 250-252.

Botsford, R. C. 1938. Present status of mosquito control work in Connecticut, 1938. Bull Conn Agric Exp Stn 428: 58-64.

Botsford, R. C. 1939. Mosquito control work in Connecticut, 1939. Bull Conn Agric Exp Stn 434: 251-254.

Botsford, R. C. 1940. Mosquito control in Connecticut, 1940. Bull Conn Agric Exp Stn 445: 322-324.

Botsford, R. C. 1941. Mosquito control. Bull Conn Agric Exp Stn 461: 485-486.

Botsford, R. C. 1946. Mosquito control in 1945. Bull Conn Agric Exp Stn 501: 35-36.

Boyd, M. F. 1941. An historical sketch of the prevalence of malaria in North America. Am J Trop Med Hyg 21: 223-244.

Brandt, C. 1994. The Man in the Mirror: A Life of Benedict Arnold. Random House, New York.

Brei, B., J. S. Brownstein, J. E. George, J. M. Pound, J. A. Miller, T. J. Daniels, R. C. Falco, K. C. Stafford III, T. L. Schulze, T. N. Mather, J. F. Carroll, and D. Fish. 2009. Evaluation of the United States Department of Agriculture Northeast Area-wide Tick Control Project by meta-analysis. Vector Borne Zoonotic Dis 9: 423-430.

Britton, W. E., and H. L. Viereck. 1904. Report on mosquito investigations. Report of the State Entomologist of Connecticut 4: 253-310.

Britton, W. E. 1912. The mosquito plague of the Connecticut coast region and how to control it. Bull Conn Agric Exp Stn 173: 1-14.

Britton, W. E. 1914. Mosquito work in Connecticut in 1914. Report of the State Entomologist of Connecticut 14: 181-183.

Britton, W. E. 1915. Mosquito conditions in Connecticut in 1915. Report of the State Entomologist of Connecticut 15: 140-144.

Britton, W. E. 1916. Anti-mosquito work in Connectricut in 1916. Report of the State Entomologist of Connecticut 16: 126-137.

Britton, W. E. 1923. Mosquitoes and human welfare. Report of the State Entomologist of Connecticut 23: 294-303.

Brown, H., M. Duik-Wasser, T. Andreadis, and D. Fish. 2008. Remotely-sensed vegetation indices identify mosquito clusters of West Nile virus vectors in an urban landscape in the northeastern United States. Vector Borne Zoonotic Dis 8: 197-206.

Bunnell, J. E., L. A. Magnarelli, and J. S. Dumler. 1999. Infection of laboratory mice with the human granulocytic ehrlichiosis agent does not induce antibodies to diagnostically significant *Borrelia burgdorferi* antigens. J Clin Microbiol 37: 2077-2079.

Burgdorfer, W., and M. G. G. Varma. 1967. Trans-stadial and transovarial development of disease agents in arthropods. Ann Rev Entomol 12: 347-376.

Burgdorfer, W., A. G. Barbour, S. F. Hayes, J. L. Benach, E. Grunwaldt, and J. P. Davis. 1982. Lyme disease-a tick-borne spirochetosis? Science 216: 1317-1319.

Burgdorfer, W., J. F. Anderson, L. Gern, R. S. Lane, J. Piesman, and A. Spielman. 1991. Relationship of *Borrelia burgdorferi* to its arthropod vectors. Scand J Infect Dis Suppl 77: 35-40.

Calisher, C. H., and J. L. Sever. 1995. Are North American Bunyamwera serogroup viruses etiologic agents of human congenital defects of the central nervous system? Emerg Infect Dis 1: 147-151.

Carter, H. R. 1931. Yellow fever an epidemiological and historical study of its place of origin. The Williams & Wilkins Company, Baltimore.

Caulkins, F. M. 1895. History of New London, Connecticut. Day Publishing Company, New London, Connecticut.

Chamberlain, C. W. 1881. Malaria in Connecticut. Public Health: Papers and Reports 7: 174-185.

Chapin, C. V. 1884. The origin and progress of the malarial fever now prevalent in New England, Kellogg Printing Co., Providence, R.I.

Coleman, A. S., X. Yang, M. Kumar, X. Zhang, K. Promnares, D. Shroder, M. R. Kenedy, J. F. Anderson, D. R. Akins, and U. Pal. 2008. *Borrelia burgdorferi* complement regulator-acquiring surface protein 2 does not contribute to complement resistance or host infectivity. PLoS One 3: 3010e.

Conrad, P. A., J. W. Thomford, A. Marsh, S. R. Telford, 3rd, J. F. Anderson, A. Spielman, E. A. Sabin, I. Yamane, and D. H. Persing. 1992. Ribosomal DNA probe for differentiation of *Babesia microti* and *B. gibsoni* isolates. J Clin Microbiol 30: 1210-1215.

Cook, G. C. 1993. Some early British contributions to tropical disease. J Infection 27: 325-333.

Das, S., N. Marcantonio, K. Deponte, S. R. Telford, 3rd, J. F. Anderson, F. S. Kantor, and E. Fikrig. 2000. SALP16, a gene induced in *Ixodes scapularis* salivary glands during tick feeding. Am J Trop Med Hyg 62: 99-105.

de Kruif, P. 1950. Microbe hunters. Pocket Book, Inc., New York.

Defosse, D. L., R. C. Johnson, B. J. Paster, F. E. Dewhirst, and G. J. Fraser. 1995. *Brevinema andersonii* gen. nov., sp. nov., an infectious spirochete isolated from the short-tailed shrew (*Blarina brevicauda*) and the white-footed mouse (*Peromyscus leucopus*). Int J Syst Bacteriol 45: 78-84.

des Vignes, F., J. Piesman, R. Heffernan, T. L. Schulze, K. C. Stafford III, and D. Fish. 2001. Effect of tick removal on transmission of *Borrelia burgdorferi* and *Ehrlichia phagocytophila* by *Ixodes scapularis* nymphs. J Infect Dis 183: 773-778.

Diuk-Wasser, M. A., H. E. Brown, T. G. Andreadis, and D. Fish. 2006. Modeling the spatial distribution of mosquito vectors for West Nile virus in Connecticut, USA. Vector Borne Zoonotic Dis 6: 283-295.

Doby, J. M., J. F. Anderson, A. Coutarmanac'h, L. A. Magnarelli, and A. Martin. 1987. Lyme disease in Canada with possible transmission by an insect. Zentralbl Bakteriol Mikrobiol Hyg A 263: 488-490.

Dolan, M. C., G. O. Maupin, B. S. Schneider, C. Denatale, N. Hamon, C. Cole, N. S. Zeidner, and K. C. Stafford III. 2004. Control of immature *Ixodes scapularis* (Acari: Ixodidae) on rodent reservoirs of *Borrelia burgdorferi* in a residential community of southeastern Connecticut. J Med Entomol 41: 1043-1054.

Edwards, J. F. 1994. Cache Valley virus. Vet Clin North Am Food Anim Pract 10: 515-524.

Eidson, M., N. Komar, F. Sorhage, R. Nelson, T. Talbot, F. Mostashari, R. McLean, and the West Nile Virus Avian Mortality Surveillance Group, including T. G. Andreadis, J. F. Anderson, and C. R. Vossbrinck 2001. Crow deaths as a sentinel surveillance system for West Nile virus in the northeastern U. S., 1999. Emerg Infect Dis 7: 615-620.

Fikrig, E., L. A. Magnarelli, M. Chen, J. F. Anderson, and R. A. Flavell. 1993. Serologic analysis of dogs, horses, and cottontail rabbits for antibodies to an antigenic flagellar epitope of *Borrelia burgdorferi*. J Clin Microbiol 31: 2451-2455.

Fikrig, E., U. Pal, M. Chen, J. F. Anderson, and R. A. Flavell. 2004. OspB antibody prevents *Borrelia burgdorferi* colonization of *Ixodes scapularis*. Infect Immun 72: 1755-1759.

Finlay, C. 1881. El mosquito hipoteticamente considerado como agente de transmision de la fiebre amarilla. An r Acad de cien med de la Habana 18: 147-169.

Fonseca, D. M., S. Campbell, W. J. Crans, M. Mogi, I. Miyagi, T. Toma, M. Bullians, T. G. Andreadis, R. L. Berry, B. Pagac, M. R. Sardelis, and R. C. Wilkerson. 2001. *Aedes* (Finlaya) *japonicus* (Diptera: Culicidae), a newly recognized mosquito in the United States: analyses of genetic variation in the United States and putative source populations. J Med Entomol 38: 135-146.

Fothergill, L. D., J. H. Dingle, S. Farber, and M. L. Connerley. 1938. Human encephalitis caused by the virus of the eastern variety of equine encephalomyelitis. New Engl J Med 219: 411.

Friend, R. B. 1939 Wilton Everett Britton, pp. 215-221, 63rd Report of the Connecticut Agricultural Experiment Station, New Haven.

Friend, R. B. 1946a. Spraying with a helicopter. Report of the State Entomologist of Connecticut 45: 37-40; 47.

Friend, R. B. 1946b. New methods for dispersing insecticides. Report of the State Entomologist of Connecticut 45: 13-14.

Gadbaw, J. J., J. F. Anderson, M. L. Cartter, and J. L. Hadler. 1989. Babesiosis-Connecticut. CDC Morbid Mortal Weekly Rep 38: 649-650.

Gallivan, G. J., I. K. Barker, H. Artsob, L. A. Magnarelli, J. T. Robinson, and D. R. Voigt. 1998. Serologic survey for antibodies to *Borrelia burgdorferi* in white-tailed deer in Ontario. J Wildl Dis 34: 411-414.

Garmendia, A. E., H. J. Van Kruiningen, R. A. French, J. F. Anderson, T. G. Andreadis, A. Kumar, and A. B. West. 2000. Recovery and identification of West Nile virus from a hawk in winter. J Clin Microbiol 38: 3110-3111.

Ginsberg, H. S., and K. C. Stafford III. 2005. Management of ticks and tick-borne diseases, pp. 65-86. *In* J. L. Goodman, D. T. Dennis and D. E. Sonenshine [eds.], Tick-borne diseases of humans. ASM Press, Washington, D.C. .

Gorgas, W. C. 1904. A few general directions with regard to destroying mosquitoes, particularly the yellow fever mosquito. Government Printing Office, Washington.

Gough, P. 2000. Discovery of West Nile virus in Connecticut and what was learned during the first year. Frontiers of Plant Science 52: 1-4.

Gould, L. H., J. Sui, H. Foellmer, T. Oliphant, T. Wang, M. Ledizet, A. Murakami, K. Noonan, C. Lambeth, K. Kar, J. F. Anderson, A. M. de Silva, M. S. Diamond, R. A. Koski, W. A. Marasco, and E. Fikrig. 2005. Protective and therapeutic capacity of human single-chain Fv-Fc fusion proteins against West Nile virus. J Virol 79: 14606-14613.

Graves, C. B. 1920. Epidemic disease in early Connecticut times. Proc. Conn. Med. Soc.:67-95.

Graves, C. B. 1922. Early medicine and medical men, pp.

363-400. *In* B. T. Marshall [ed.], A modern history of New London County Connecticut. Lewis Historical Publishing Co., New York, New York.

Grimstad, P. R. 1988. California group virus disease, pp. 99-136. *In* T. P. Monath [ed.], The Arboviruses: Epidemiology and Ecology. CRC Press, Boca Raton, FL.

Hadler, J., R. Nelson, T. McCarthy, T. Andreadis, M. J. Lis, R. French, W. Beckwith, D. Mayo, G. Archambault, and M. Cartter. 2001. West Nile virus surveillance in Connecticut in 2000: an intense epizootic without high risk for severe human disease. Emerg Infect Dis 7: 636-642.

Hard, S. 1966. Erythema chronicum migrans (Afzelii) associated with a mosquito bite. Acta Derm Venerol (Stockholm) 46: 473-476.

Hayes, C. G. 1989. West Nile fever, pp. 59-88. *In* T. P. Monath [ed.], The arboviruses: epidemiology and ecology. CRC, Boca Raton, FL.

Healy, G. R., A. Speilman, and N. Gleason. 1976. Human babesiosis: reservoir in infection on Nantucket Island. Science 192: 479-480.

Hiscock, I. V. 1942. The background of public health in Connecticut., pp. 137-150. *In* H. Thoms [ed.], The heritage of Connecticut Medicine. Whaples-Bullis Co., New Haven.

Hitchcock, S. W., and J. F. Anderson. 1966. 15 billion midges-more or less. Frontiers of Plant Science 19: 6-7.

Hitchcock, S. W., and J. F. Anderson. 1968. Field-plot tests with insecticides for control of *Chironomus atrella*. J Econ Entomol 61: 16-19.

Hoadley, F. H. 1900. A review of the history of the epidemic of yellow fever in New Haven, Connecticut in the year 1794. New Haven County Historical Society 6: 223-263.

Hoen, A. G., L. G. Rollend, M. A. Papero, J. F. Carroll, T. J. Daniels, T. N. Mather, T. L. Schulze, K. C. Stafford III, and D. Fish. 2009. Effects of tick control by acaricide self-treatment of white-tailed deer on host-seeking tick infection prevalence and entomologic risk for *Ixodes scapularis*-borne pathogens. Vector Borne Zoonotic Dis 9: 431-438.

Horsfall, J. G. 1992. The pioneer experiment station 1875 to 1975 a history. Antoca Press, Lexington, Kentucky.

Howitt, B. 1938. Recovery of the virus of equine encephalomyelitis from the brain of a child. Science 88: 455-456.

Huang, S., G. Molaei, and T. G. Andreadis. 2008. Genetic insights into the population structure of *Culex pipiens* (Diptera: Culicidae) in the Northeastern United States by using microsatellite analysis. Am J Trop Med Hyg 79: 518-527.

Huang, S., G. L. Hamer, G. Molaei, E. D. Walker, T. L. Goldberg, U. D. Kitron, and T. G. Andreadis. 2009. Genetic variation associated with mammalian feeding in *Culex pipiens* from a West Nile virus epidemic region in Chicago, Illinois. Vector Borne Zoonotic Dis 9: 637-642.

Hubalek, Z., J. F. Anderson, J. Halouzka, and V. Hajek. 1996. *Borreliae* in immature *Ixodes ricinus* (Acari:Ixodidae) ticks parasitizing birds in the Czech Republic. J Med Entomol 33: 766-771.

Hubalek, Z., and J. Halouzka. 1999. West Nile fever-a reemerging mosquito-borne viral disease in Europe. *Emerg Infect Dis* 5: 643-650.

IJdo, J., Y. Zhang, E. Hodzic, L. A. Magnarelli, M. L. Wilson, S. R. Telford, 3rd, S. W. Barthold, and E. Fikrig. 1997. The early humoral response in human granulocytic ehrlichiosis. J Infect Dis 176: 687-692.

IJdo, J. W., W. Sun, Y. Zhang, L. A. Magnarelli, and E. Fikrig. 1998. Cloning of the gene encoding the 44-kilodalton antigen of the agent of human granulocytic ehrlichiosis and characterization of the humoral response. Infect Immun 66: 3264-3269.

IJdo, J., C. Wu, L. A. Magnarelli, and E. Fikrig. 1999. Serodiagnosis of human granulocytic ehrlichiosis by a recombinant HGE-44-based enzyme-linked immunosorbent assay. J Clin Microbiol 37: 3540-3544.

IJdo, J., J. I. Meek, M. L. Cartter, L. A. Magnarelli, C. Wu, S. W. Tenuta, E. Fikrig, and R. W. Ryder. 2000a. The emergence of another tickborne infection in the 12-town area around Lyme, Connecticut: human granulocytic ehrlichiosis. J Infect Dis 181: 1388-1393.

IJdo, J. W., C. Wu, L. A. Magnarelli, K. C. Stafford III, J. F. Anderson, and E. Fikrig. 2000b. Detection of *Ehrlichia chaffeensis* DNA in *Amblyomma americanum* ticks in Connecticut and Rhode Island. J Clin Microbiol 38: 4655-4656.

Jaynes, H. A., L. Parente, and R. C. Wallis. 1962. Potential encephalitis vectors in Hamden, Conn. Mosquito News 22: 357-360.

Johnson, R. C., G. P. Schmid, F. W. Hyde, A. G. Steigerwald, and D. J. Brenner. 1984. *Borrelia burgdorferi* sp. nov.: Etiologic agent of Lyme disease. Internat J System Bact 34: 496-497.

Jungherr, E. L., and R. C. Wallis. 1958. Investigation of eastern equine encephalomyelitis. I. General aspects. Am J Hyg 67: 1-3.

Keefe, T. J., C. J. Holland, P. E. Salyer, and M. Ristic. 1982. Distribution of *Ehrlichia canis* among military working dogs in the world and selected civilian dogs in the United States. J Am Vet Med Assoc 181: 236-238.

Kerr, J. A. 1951. The clinical aspects and diagnosis of yellow fever, pp. 385-426. *In* G. K. Strode [ed.], Yellow fever. McGraw-Hill Book Company, New York.

Knowles, R. C., D. W. Anderson, W. D. Shipley, R. H. Whittlock, B. D. Perry, and J. P. Davidson. 1983. Acute equine diarrhea syndrome (AEDS): a preliminary report. Proc Am Assoc Equine Pract 29: 353-357.

Kong, K. F., X. Wang, J. F. Anderson, E. Fikrig, and R. R. Montgomery. 2008. West Nile virus attenuates activation of primary human macrophages. Viral Immunol 21: 78-82.

Kurtti, T. J., U. G. Munderloh, T. G. Andreadis, L. A. Magnarelli, and T. N. Mather. 1996. Tick cell culture isolation of an intracellular prokaryote from the tick *Ixodes scapularis*. J Invertebr Pathol 67: 318-321.

Labensky, A. 1942. Samuel Holden Parsons Lee and yellow fever in New London, pp. 114-120. *In* H. Thoms [ed.],

The heritage of Connecticut medicine. Whaples-Bullis Co., New Haven.

Lanciotti, R. S., J. T. Roehrig, V. Deubel, J. Smith, M. Parker, K. Steele, B. Crise, K. E. Volpe, M. B. Crabtree, J. H. Scherret, R. A. Hall, J. S. MacKenzie, C. B. Cropp, B. Panigrahy, E. Ostlund, B. Schmitt, M. Malkinson, C. Banet, J. Weissman, N. Komar, H. M. Savage, W. Stone, T. McNamara, and D. J. Gubler. 1999. Origin of the West Nile virus responsible for an outbreak of encephalitis in the northeastern United States. Science (Wash DC) 286: 2333-2337.

Lang, C. A. 1956. The influence of mating on egg production by *Aedes aegypt*i, L. . Amer J Trop Med Hyg 5: 916-920.

Lang, C. A., and R. C. Wallis. 1956. An artificial feeding procedure for *Aedes aegypti*, L. using sucrose as a stimulant. Amer J Trop Med Hyg 5: 915-920.

Laveran, A. 1907. Nobel lecture. Nobelprizeorg.

Ledizet, M., K. Kar, H. G. Foellmer, T. Wang, S. L. Bushmich, J. F. Anderson, E. Fikrig, and R. A. Koski. 2005. A recombinant envelope protein vaccine against West Nile virus. Vaccine 23: 3915-3924.

Levy, S. A., and L. A. Magnarelli. 1992. Relationship between development of antibodies to *Borrelia burgdorferi* in dogs and the subsequent development of limb/joint borreliosis. J Am Vet Med Assoc 200: 344-347.

Li, X., G. Neelakanta, X. Liu, D. S. Beck, F. S. Kantor, D. Fish, J. F. Anderson, and E. Fikrig. 2007a. Role of outer surface protein D in the *Borrelia burgdorferi* life cycle. Infect Immun 75: 4237-4244.

Li, X., U. Pal, N. Ramamoorthi, X. Liu, D. C. Desrosiers, C. H. Eggers, J. F. Anderson, J. D. Radolf, and E. Fikrig. 2007b. The Lyme disease agent *Borrelia burgdorferi* requires BB0690, a Dps homologue, to persist within ticks. Mol Microbiol 63: 694-710.

Linthicum, K. J., A. Anyamba, S. C. Britch, J.-P. Chretien, R. L. Erickson, J. Small, C. J. Tucker, K. E. Bennett, R. T. Mayer, E. T. Schmidtmann, T. G. Andreadis, J. F. Anderson, W. C. Wilson, J. E. Freier, A. M. James, R. S. Miller, B. S. Drolet, S. N. Miller, C. A. Tedrow, C. L. Bailey, D. A. Strickman, D. R. Barnard, G. G. Clark, and L. Zou. 2007. A Rift Valley fever risk surveillance system for Africa using remotely sensed data: potential for use on other continents. Vet Italiana 43: 663-674.

Lucarotti, C. J., and T. G. Andreadis. 1995. Reproductive strategies and adaptations for survival among obligatory microsporidian and fungal parasites of mosquitoes: a comparative analysis of *Amblyospora* and *Coelomomyces*. J Am Mosq Control Assoc 11: 111-121.

Maeda, K., N. Markowitz, R. C. Hawley, M. Ristic, D. Cox, and J. E. McDade. 1987. Human infection with *Ehrlichia canis*, a leukocytic rickettsia. N Engl J Med 316: 853-856.

Magnarelli, L. A. 1977a. Nectar feeding by female mosquitoes and its relationship to follicular development and parity. J Med Entomol 14: 527-530.

Magnarelli, L. A. 1977b. Nectar feeding by *Aedes sollicitans* and its relation to gonotrophic activity. Environ Entomol 6: 237-242.

Magnarelli, L. A. 1977c. Host feeding patterns of Connecticut mosquitoes (Diptera: Culicidae). Am J Trop Med Hyg 26: 547-552.

Magnarelli, L. A., and J. F. Anderson. 1977. Follicular development in the salt marsh Tabanidae (Diptera) and incidence of nectar feeding with relation to gonotrophic activity. Ann Entomol Soc Am 70: 529-533.

Magnarelli, L. A. 1978a. Bionomics of the salt-marsh mosquito, *Aedes cantator* (Diptera: Culicidae). Environ Entomol 7: 512-517.

Magnarelli, L. A. 1978b. Blood-feeding and gonotrophic dissociation in *Anopheles punctipennis* (Diptera: Culicidae) prior to hibernation in Connecticut. J Med Entomol 15: 278-281.

Magnarelli, L. A. 1978c. Presumed *Dirofilaria immitis* infections in natural mosquito populations of Connecticut. J Med Entomol 15: 84-85.

Magnarelli, L. A. 1978d. Nectar-feeding by female mosquitoes and its relation to follicular development and parity. J Med Entomol 14: 527-530.

Magnarelli, L. A., and J. F. Anderson. 1978a. Searching for tick-borne diseases. Frontiers of Plant Science 30: 7-8.

Magnarelli, L. A., and J. F. Anderson. 1978b. Distribution and development of immature salt marsh Tabanidae (Diptera). J Med Entomol 14: 573-578.

Magnarelli, L. A. 1979a. Diurnal nectar-feeding of *Aedes cantator* and *Aedes sollicitans* (Diptera: Culicidae). Environ Entomol 8: 949-955.

Magnarelli, L. A. 1979b. Feeding behavior of mosquitoes (Diptera: Culicidae) on man, raccoons, and white-footed mice. Ann Entomol Soc Amer 72: 162-166.

Magnarelli, L. A., and J. F. Anderson. 1979a. Oviposition, fecundity, and fertility of the saltmarsh deer fly, *Chrysops fuliginosus* (Diptera: Tabanidae). J Med Entomol 15: 176-179.

Magnarelli, L. A., and J. F. Anderson. 1979b. Oogenesis and oviposition in *Chrysops atlanticus* (Diptera: Tabanidae). Ann Entomol Soc Amer 72: 350-352.

Magnarelli, L. A., J. F. Anderson, and W. Burgdorfer. 1979a. Rocky Mountain spotted fever in Connecticut: human cases, spotted-fever group rickettsiae in ticks, and antibodies in mammals. Am J Epidemiol 110: 148-155.

Magnarelli, L. A., J. F. Anderson, and J. H. Thorne. 1979b. Diurnal nectar-feeding of salt marsh Tabanidae (Diptera). Environ Entomol 8: 544-548.

Magnarelli, L. A. 1980. Bionomics of *Psorophora ferox* (Diptera: Culicidae): seasonal occurrence and acquisition of sugars. J Med Entomol 17: 328-332.

Magnarelli, L. A., and J. F. Anderson. 1980a. Blood and sugars are needed to nourish deer flies and horse flies. Frontiers of Plant Science 32: 7-8.

Magnarelli, L. A., and J. F. Anderson. 1980b. Feeding behavior of Tabanidae (Diptera) on cattle and serologic analyses of partial blood meals. Environ Entomol 9: 664-667.

Magnarelli, L. A., and J. F. Anderson. 1980c. Parasitism of *Tabanus nigrovittatus* immatures (Diptera: Tabanidae) by *Trichopria* sp. (Hymenoptera: Diapriidae). J Med Entomol 17: 481-482.

Magnarelli, L. A., and J. G. Stoffolano Jr. 1980. Blood feeding, oogenesis, and oviposition by *Tabanus nigrovittatus* in the laboratory. Ann Entomol Soc Am 73: 14-17.

Magnarelli, L. A. 1981. Parity, follicular development, and sugar feeding in *Culicoides melleus* and *Culicoides hollensis*. Environ Entomol 10: 807-811.

Magnarelli, L. A., and J. F. Anderson. 1981. Sugar-feeding by female tabanids (Diptera:Tabanidae) and its relation to gonotrophic activity. J Med Entomol 18: 429-433.

Magnarelli, L. A., J. F. Anderson, and W. Burgdorfer. 1981a. Geographical distribution of human cases of Rocky Mountain spotted fever, infected ticks, and seropositive mammals in Connecticut, pp. 559-568. *In* W. Burgdorfer and R. L. Anacker [eds.], Rickettsia and rickettsial diseases. Academic Press, New York.

Magnarelli, L. A., J. F. Anderson, R. N. Philip, W. Burgdorfer, and E. A. Casper. 1981b. Endemicity of spotted fever group rickettsiae in Connecticut. Am J Trop Med Hyg 30: 715-721.

Magnarelli, L. A., and T. G. Andreadis. 1981. Human cases of furuncular, traumatic, and nasal myiasis in Connecticut. Am J Trop Med Hyg 30: 894-896.

Magnarelli, L. A., J. F. Anderson, R. N. Philip, and W. Burgdorfer. 1982a. Antibodies to spotted fever-group rickettsiae in dogs and prevalence of infected ticks in southern Connecticut. Am J Vet Res 43: 656-659.

Magnarelli, L. A., D. J. Leprince, J. F. Burger, and J. F. Butler. 1982b. Oviposition behavior and fecundity in *Chrysops cincticornis* (Diptera: Tabanidae). J Med Entomol 19: 597-600.

Magnarelli, L. A. 1983a. Nectar sugars and caloric reserves in natural populations of *Aedes canadensis* and *Aedes stimulans* (Diptera: Culicidae). Environ Entomol 12: 1482-1486.

Magnarelli, L. A. 1983b. Resorption of retained eggs and follicular degeneration in mosquitoes (Diptera: Culicidae). J Med Entomol 20: 106-107.

Magnarelli, L. A., J. F. Anderson, R. N. Philip, W. Burgdorfer, and W. A. Chappell. 1983. Rickettsiae-infected ticks (Acari: Ixodidae) and seropositive mammals at a focus for Rocky Mountain spotted fever in Connecticut, USA. J Med Entomol 20: 151-156.

Magnarelli, L. A. 1984. Hovering and swarming behavior of males of *Hybomitra lasiophthalma* and *Hybomitra aurilimba* (Diptera: Tabanidae). Myia 3: 475-484.

Magnarelli, L. A., and J. F. Anderson. 1984. Infected *Ixodes* ticks found where Lyme disease occurs. Frontiers of Plant Science 36: 6-7.

Magnarelli, L. A., and T. G. Andreadis. 1984. Caloric reserves in *Aedes cantator* (Diptera: Culicidae). J Med Entomol 21: 263-267.

Magnarelli, L. A., and J. F. Burger. 1984. Caloric reserves in natural populations of a black fly, *Simulium decorum* (Diptera: Simuliidae), and a deer fly, *Chrysops ater* (Diptera: Tabanidae). Can J Zool 62: 2589-2593.

Magnarelli, L. A., J. F. Anderson, W. Burgdorfer, and W. A. Chappell. 1984a. Parasitism by *Ixodes dammini* (Acari: Ixodidae) and antibodies to spirochetes in mammals at Lyme disease foci in Connecticut, USA. J Med Entomol 21: 52-57.

Magnarelli, L. A., J. F. Anderson, W. Burgdorfer, R. N. Philip, and W. A. Chappell. 1984b. Antibodies to *Rickettsia rickettsii* in *Peromyscus leucopus* from a focus of Rocky Mountain spotted fever in Connecticut. Can J Microbiol 30: 491-494.

Magnarelli, L. A., J. F. Anderson, and W. A. Chappell. 1984c. Geographic distribution of humans, raccoons, and white-footed mice with antibodies to Lyme disease spirochetes in Connecticut. Yale J Biol Med 57: 619-626.

Magnarelli, L. A., J. F. Anderson, and W. A. Chappell. 1984d. Antibodies to spirochetes in white-tailed deer and prevalence of infected ticks from foci of Lyme disease in Connecticut. J Wildl Dis 20: 21-26.

Magnarelli, L. A., J. M. Meegan, J. F. Anderson, and W. A. Chappell. 1984e. Comparison of an indirect fluorescent-antibody test with an enzyme-linked immunosorbent assay for serological studies of Lyme disease. J Clin Microbiol 20: 181-184.

Magnarelli, L. A., G. B. Modi, and R. B. Tesh. 1984f. Follicular development and parity in phlebotomine sand flies (Diptera: Psychodidae). J Med Entomol 21: 681-689.

Magnarelli, L. A. 1985a. Blood feeding and oviposition by tabanids (Diptera) in the laboratory. J Med Entomol 22: 600-603.

Magnarelli, L. A. 1985b. Caloric reserves in salt marsh deer flies, *Chrysops fuliginosus* (Diptera: Tabanidae). Ann Entomol Soc Amer 78: 594-599.

Magnarelli, L. A., J. F. Anderson, W. Burgdorfer, R. N. Philip, and W. A. Chappell. 1985a. Spotted fever group rickettsiae in immature and adult ticks (Acari: Ixodidae) from a focus of Rocky Mountain spotted fever in Connecticut. Can J Microbiol 31: 1131-1135.

Magnarelli, L. A., J. F. Anderson, A. F. Kaufmann, L. L. Lieberman, and G. D. Whitney. 1985b. Borreliosis in dogs from southern Connecticut. J Am Vet Med Assoc 186: 955-959.

Magnarelli, L. A. 1986. Energy reserves in natural populations of *Aedes triseriatus* (Diptera: Culicidae). Ann Entomol Soc Amer 79: 829-832.

Magnarelli, L. A., J. F. Anderson, C. S. Apperson, D. Fish, R. C. Johnson, and W. A. Chappell. 1986a. Spirochetes in ticks and antibodies to *Borrelia burgdorferi* in white-tailed deer from Connecticut, New York State, and North Carolina. J Wildl Dis 22: 178-188.

Magnarelli, L. A., J. F. Anderson, and A. G. Barbour. 1986b. The etiologic agent of Lyme disease in deer flies, horse flies, and mosquitoes. J Infect Dis 154: 355-358.

Magnarelli, L. A., and J. F. Anderson. 1987. Early detection and persistence of antibodies to *Borrelia burgdorferi* in persons with Lyme disease. Zentralbl Bakteriol Mikrobiol Hyg [A] 263: 392-399.

Magnarelli, L. A., J. F. Anderson, and D. Fish. 1987a. Transovarial transmission of *Borrelia burgdorferi* in *Ixodes dammini* (Acari:Ixodidae). J Infect Dis 156: 234-236.

Magnarelli, L. A., J. F. Anderson, and R. C. Johnson. 1987b. Cross-reactivity in serological tests for Lyme disease and other spirochetal infections. J Infect Dis 156: 183-188.

Magnarelli, L. A., J. F. Anderson, A. B. Schreier, and C. M. Ficke. 1987c. Clinical and serologic studies of canine borreliosis. J Am Vet Med Assoc 191: 1089-1094.

Magnarelli, L. A., and T. G. Andreadis. 1987. Energy reserves in *Aedes canadensis*, *Aedes stimulans*, *Aedes provocans* (Diptera: Culicidae), and *Mochlonyx cinctipes* (Diptera: Chaoboridae) in Connecticut. J Med Entomol 24: 315-318.

Magnarelli, L. A., J. E. Freier, and J. F. Anderson. 1987d. Experimental infections of mosquitoes with *Borrelia burgdorferi*, the etiologic agent of Lyme disease. J Infect Dis 156: 694-695.

Magnarelli, L. A. 1988a. Parity, follicular development, and sugar feeding in *Atylotus bicolor* (Diptera: Tabanidae). J NY Ent Soc 95: 487-490.

Magnarelli, L. A. 1988b. Serologic diagnosis of Lyme disease. Ann N Y Acad Sci 539: 154-161.

Magnarelli, L. A., and J. F. Anderson. 1988a. Enzyme-linked immunosorbent assays for the detection of class-specific immunoglobulins to *Borrelia burgdorferi*. Am J Epidemiol 127: 818-825.

Magnarelli, L. A., and J. F. Anderson. 1988b. Ticks and biting insects infected with the etiologic agent of Lyme disease, *Borrelia burgdorferi*. J Clin Microbiol 26: 1482-1486.

Magnarelli, L. A., J. F. Anderson, K. E. Hyland, D. Fish, and J. B. McAninch. 1988a. Serologic analyses of *Peromyscus leucopus*, a rodent reservoir for *Borrelia burgdorferi*, in northeastern United States. J Clin Microbiol 26: 1138-1141.

Magnarelli, L. A., J. F. Anderson, E. Shaw, J. E. Post, and F. C. Palka. 1988b. Borreliosis in equids in northeastern United States. Am J Vet Res 49: 359-362.

Magnarelli, L. A., and G. B. Modi. 1988. Caloric determinations of phlebotomine sand flies (Diptera: Psychodidae). J Med Entomol 25: 127-130.

Magnarelli, L. A. 1989a. Lyme disease: an increasing public health problem. J Clin Microbiol Newsletter 11: 81-84.

Magnarelli, L. A. 1989b. Quality of Lyme disease tests. JAMA 262: 3464-3465.

Magnarelli, L. A. 1989c. Laboratory diagnosis of Lyme disease. Rheum Dis Clin North Am 15: 735-745.

Magnarelli, L. A. 1989d. Laboratory analyses for Lyme disease. Conn Med 53: 331-334.

Magnarelli, L. A., and J. F. Anderson. 1989a. Infected ticks feeding on persons in areas endemic for Lyme disease and Rocky Mountain spotted fever. J Infect Dis 160: 729-730.

Magnarelli, L. A., and J. F. Anderson. 1989b. Class-specific and polyvalent enzyme-linked immunosorbent assays for detection of antibodies to *Borrelia burgdorferi* in equids. J Am Vet Med Assoc 195: 1365-1368.

Magnarelli, L. A., J. F. Anderson, and A. G. Barbour. 1989. Enzyme-linked immunosorbent assays for Lyme disease: reactivity of subunits of *Borrelia burgdorferi*. J Infect Dis 159: 43-49.

Magnarelli, L. A. 1990a. Total available carbohydrates in *Aedes stimulans* (Diptera: Culicidae). Can J Zool 68: 603-606.

Magnarelli, L. A. 1990b. Serologic testing for Lyme disease. Postgrad Med 87: 149-150, 153, 156.

Magnarelli, L. A., J. F. Anderson, H. R. Levine, and S. A. Levy. 1990a. Tick parasitism and antibodies to *Borrelia burgdorferi* in cats. J Am Vet Med Assoc 197: 63-66.

Magnarelli, L. A., J. F. Anderson, and J. B. McAninch. 1990b. Serologic analyses of cottontail rabbits for antibodies to *Borrelia burgdorferi*. J Clin Microbiol 28: 890-893.

Magnarelli, L. A., J. F. Anderson, and A. B. Schreier. 1990c. Persistence of antibodies to *Borrelia burgdorferi* in dogs of New York and Connecticut. J Am Vet Med Assoc 196: 1064-1068.

Magnarelli, L. A., H. J. Litwin, C. J. Holland, J. F. Anderson, and M. Ristic. 1990d. Canine ehrlichiosis in Connecticut. J Clin Microbiol 28: 366-367.

Magnarelli, L. A., J. N. Miller, J. F. Anderson, and G. R. Riviere. 1990e. Cross-reactivity of nonspecific treponemal antibody in serologic tests for Lyme disease. J Clin Microbiol 28: 1276-1279.

Magnarelli, L. A. 1991. New understanding of the epidemiology of Lyme disease, pp. 225-227. In A. Vaheri, R. C. Tilton and A. Balows [eds.], Rapid methods and automation in microbiology and immunology. Springer-Verlag, Berlin-Heidelberg.

Magnarelli, L. A., and J. F. Anderson. 1991. Adsorption and biotin-streptavidin amplification in serologic tests for diagnosis of Lyme borreliosis. J Clin Microbiol 29: 1761-1764.

Magnarelli, L. A., T. G. Andreadis, K. C. Stafford III, and C. J. Holland. 1991a. Rickettsiae and *Borrelia burgdorferi* in ixodid ticks. J Clin Microbiol 29: 2798-2804.

Magnarelli, L. A., J. H. Oliver, Jr., H. J. Hutcheson, and J. F. Anderson. 1991b. Antibodies to *Borrelia burgdorferi* in deer and raccoons. J Wildl Dis 27: 562-568.

Magnarelli, L. A., and R. K. Swihart. 1991. Spotted fever group rickettsiae or *Borrelia burgdorferi* in *Ixodes cookei* (Ixodidae) in Connecticut. J Clin Microbiol 29: 1520-1522.

Magnarelli, L. A., E. Fikrig, R. Berland, J. F. Anderson, and R. A. Flavell. 1992a. Comparison of whole-cell antibodies and an antigenic flagellar epitope of *Borrelia burgdorferi* in serologic tests for diagnosis of Lyme borreliosis. J Clin Microbiol 30: 3158-3162.

Magnarelli, L. A., J. H. Oliver, Jr., H. J. Hutcheson, J. L. Boone, and J. F. Anderson. 1992b. Antibodies to *Borrelia burgdorferi* in rodents in the eastern and southern United States. J Clin Microbiol 30: 1449-1452.

Magnarelli, L. A., K. C. Stafford III., and V. C. Bladen. 1992c. *Borrelia burgdorferi* and *Ixodes dammini* (Acari: Ixodidae) feeding on birds in Lyme, Connecticut, U.S.A. Can J Zool 70: 2322-2325.

Magnarelli, L. A., and J. F. Anderson. 1993. Serologic evidence of canine and equine ehrlichiosis in northeastern United States. J Clin Microbiol 31: 2857-2860.

Magnarelli, L. A., J. F. Anderson, and M. L. Cartter. 1993.

Geographic distribution of white-tailed deer with ticks and antibodies to *Borrelia burgdorferi* in Connecticut. Yale J Biol Med 66: 19-26.

Magnarelli, L. A., and J. F. Anderson. 1994. Detection of *Borrelia burgdorferi* in urine of mammals, pp. 195-198. *In* R. Cevenini, V. Sambri and M. Laplaca [eds.], VI International Conference on Lyme borreliosis, University of Bologna, Italy.

Magnarelli, L. A., J. F. Anderson, R. C. Johnson, R. B. Nadelman, and G. P. Wormser. 1994a. Comparison of different strains of *Borrelia burgdorferi* sensu lato used as antigens in enzyme-linked immunosorbent assays. J Clin Microbiol 32: 1154-1158.

Magnarelli, L. A., J. F. Anderson, and K. C. Stafford III. 1994b. Detection of *Borrelia burgdorferi* in urine of *Peromyscus leucopus* by inhibition enzyme-linked immunosorbent assay. J Clin Microbiol 32: 777-782.

Magnarelli, L. A. 1995. Current status of laboratory diagnosis for Lyme disease. Am J Med 98: 10S-12S; discussion 12S-14S.

Magnarelli, L. A., J. F. Anderson, R. A. Flavell, and E. Fikrig. 1995a. Reactivity of white-footed mouse and raccoon sera to whole cell and recombinant antigens of *Borrelia burgdorferi*. J Wildl Dis 31: 339-344.

Magnarelli, L. A., J. F. Anderson, and R. C. Johnson. 1995b. Analyses of mammalian sera in enzyme-linked immunosorbent assays with different strains of *Borrelia burgdorferi* sensu lato. J Wildl Dis 31: 159-165.

Magnarelli, L. A., A. Denicola, K. C. Stafford III, and J. F. Anderson. 1995c. *Borrelia burgdorferi* in an urban environment: white-tailed deer with infected ticks and antibodies. J Clin Microbiol 33: 541-544.

Magnarelli, L. A., J. S. Dumler, J. F. Anderson, R. C. Johnson, and E. Fikrig. 1995d. Coexistence of antibodies to tick-borne pathogens of babesiosis, ehrlichiosis, and Lyme borreliosis in human sera. J Clin Microbiol 33: 3054-3057.

Magnarelli, L. A., K. C. Stafford III, T. N. Mather, M. T. Yeh, K. D. Horn, and J. S. Dumler. 1995e. Hemocytic rickettsia-like organisms in ticks: serologic reactivity with antisera to ehrlichiae and detection of DNA of agent of human granulocytic ehrlichiosis by PCR. J Clin Microbiol 33: 2710-2714.

Magnarelli, L. A., E. Fikrig, S. J. Padula, J. F. Anderson, and R. A. Flavell. 1996. Use of recombinant antigens of *Borrelia burgdorferi* in serologic tests for diagnosis of Lyme borreliosis. J Clin Microbiol 34: 237-240.

Magnarelli, L. A. 1997. Why are ticks and tick-borne infections increasing? Conn Woodlands 62: 22-24.

Magnarelli, L. A., J. F. Anderson, K. C. Stafford III, and J. S. Dumler. 1997a. Antibodies to multiple tick-borne pathogens of babesiosis, ehrlichiosis, and Lyme borreliosis in white-footed mice. J Wildl Dis 33: 466-473.

Magnarelli, L. A., R. A. Flavell, S. J. Padula, J. F. Anderson, and E. Fikrig. 1997b. Serologic diagnosis of canine and equine borreliosis: use of recombinant antigens in enzyme-linked immunosorbent assays. J Clin Microbiol 35: 169-173.

Magnarelli, L. A., J. W. IJdo, J. F. Anderson, J. E. Madigan, J. S. Dumler, and E. Fikrig. 1997c. Antibodies to *Ehrlichia equi* in dogs from the northeastern United States. J Am Vet Med Assoc 211: 1134-1137.

Magnarelli, L. A., J. W. IJdo, J. F. Anderson, S. J. Padula, R. A. Flavell, and E. Fikrig. 1998a. Human exposure to a granulocytic *Ehrlichia* and other tick-borne agents in Connecticut. J Clin Microbiol 36: 2823-2827.

Magnarelli, L. A., J. W. IJdo, J. S. Dumler, R. Heimer, and E. Fikrig. 1998b. Reactivity of human sera to different strains of granulocytic ehrlichiae in immunodiagnostic assays. J Infect Dis 178: 1835-1838.

Magnarelli, L. A., J. W. IJdo, K. C. Stafford III, and E. Fikrig. 1999a. Infections of granulocytic ehrlichiae and *Borrelia burgdorferi* in white-tailed deer in Connecticut. J Wildl Dis 35: 266-274.

Magnarelli, L. A., K. C. Stafford III, J. W. IJdo, E. Fikrig, J. H. Oliver, Jr., H. J. Hutcheson, and J. L. Boone. 1999b. Antibodies to granulocytic ehrlichiae in white-footed and cotton mice in eastern United States. J Wildl Dis 35: 259-265.

Magnarelli, L. A., A. E. Van Andel, J. W. IJdo, R. Heimer, and E. Fikrig. 1999c. Serologic testing of horses for granulocytic ehrlichiosis, using indirect fluorescent antibody staining and immunoblot analysis. Am J Vet Res 60: 631-635.

Magnarelli, L. A., J. W. IJdo, S. J. Padula, R. A. Flavell, and E. Fikrig. 2000a. Serologic diagnosis of Lyme borreliosis by using enzyme-linked immunosorbent assays with recombinant antigens. J Clin Microbiol 38: 1735-1739.

Magnarelli, L. A., J. W. IJdo, A. E. Van Andel, C. Wu, S. J. Padula, and E. Fikrig. 2000b. Serologic confirmation of *Ehrlichia equi* and *Borrelia burgdorferi* infections in horses from the northeastern United States. J Am Vet Med Assoc 217: 1045-1050.

Magnarelli, L. A., J. W. IJdo, A. E. Van Andel, C. Wu, and E. Fikrig. 2001a. Evaluation of a polyvalent enzyme-linked immunosorbent assay incorporating a recombinant p44 antigen for diagnosis of granulocytic ehrlichiosis in dogs and horses. Am J Vet Res 62: 29-32.

Magnarelli, L. A., J. W. IJdo, A. E. Van Andel, C. Wu, J. H. Oliver, Jr., and E. Fikrig. 2001b. Reactivity of serum samples of dogs and horses tested by use of class-specific recombinant-based enzyme-linked immunosorbent assays for detection of granulocytic ehrlichiosis. Am J Vet Res 62: 1365-1369.

Magnarelli, L. A., S. A. Levy, J. W. IJdo, C. Wu, S. J. Padula, and E. Fikrig. 2001c. Reactivity of dog sera to whole-cell or recombinant antigens of *Borrelia burgdorferi* by ELISA and immunoblot analysis. J Med Microbiol 50: 889-895.

Magnarelli, L. A., J. W. IJdo, B. A. Sherman, S. L. Bushmich, S. A. Levy, and E. Fikrig. 2002a. Antibodies to granulocytic ehrlichiae in cattle from Connecticut. J Med Microbiol 51: 326-331.

Magnarelli, L. A., M. Lawrenz, S. J. Norris, and E. Fikrig. 2002b. Comparative reactivity of human sera to recom-

binant VlsE and other *Borrelia burgdorferi* antigens in class-specific enzyme-linked immunosorbent assays for Lyme borreliosis. J Med Microbiol 51: 649-655.

Magnarelli, L. A., S. L. Bushmich, B. A. Sherman, and E. Fikrig. 2004a. A comparison of serologic tests for the detection of serum antibodies to whole-cell and recombinant *Borrelia burgdorferi* antigens in cattle. Can Vet J 45: 667-673.

Magnarelli, L. A., J. W. IJdo, U. Ramakrishnan, D. W. Henderson, K. C. Stafford III, and E. Fikrig. 2004b. Use of recombinant antigens of *Borrelia burgdorferi* and *Anaplasma phagocytophilum* in enzyme-linked immunosorbent assays to detect antibodies in white-tailed deer. J Wildl Dis 40: 249-258.

Magnarelli, L. A., S. L. Bushmich, J. W. IJdo, and E. Fikrig. 2005. Seroprevalence of antibodies against *Borrelia burgdorferi* and *Anaplasma phagocytophilum* in cats. Am J Vet Res 66: 1895-1899.

Magnarelli, L. A., and E. Fikrig. 2005. Detection of antibodies to *Borrelia burgdorferi* in naturally infected horses in the USA by enzyme-linked immunosorbent assay using whole-cell and recombinant antigens. Res Vet Sci 79: 99-103.

Magnarelli, L. A., K. C. Stafford III, J. W. IJdo, and E. Fikrig. 2006. Antibodies to whole-cell or recombinant antigens of *Borrelia burgdorferi*, *Anaplasma phagocytophilum*, and *Babesia microti* in white-footed mice. J Wildl Dis 42: 732-738.

Magnarelli, L. A., S. Levy, and R. Koski. 2007. Detection of antibodies to *Francisella tularensis* in cats. Res Vet Sci 82: 22-26.

Magnarelli, L. A., S. L. Bushmich, J. F. Anderson, M. Ledizet, and R. A. Koski. 2008. Serum antibodies to West Nile virus in naturally exposed and vaccinated horses. J Med Microbiol 57: 1087-1093.

Magnarelli, L. A. 2009. Global importance of ticks and associated infectious disease agents. Clinical Microbiology Newsletter 31: 33-37.

Main, A. J., S. E. Brown, R. C. Wallis, and J. Elston. 1979a. Arbovirus surveillance in Connecticut. II. California serogroup. Mosq News 39: 552-559.

Main, A. J., S. W. Hildreth, R. C. Wallis, and J. Elston. 1979b. Arbovirus surveillance in Connecticut. III. Flanders virus. Mosq News 39: 560-565.

Main, A. J., A. L. Smith, and R. C. Wallis. 1979c. Arbovirus surveillance in Connecticut. I. Group A. viruses. Mosq News 39: 544-551.

Main, A. J. 1981. Arbovirus surveillance in Connecticut IV. Bunyamwera group. Mosq News 41: 490-494.

Marconi, R. T., D. Liveris, and I. Schwartz. 1995. Identification of novel insertion elements, restriction fragment length polymorphism patterns, and discontinuous 23S rRNA in Lyme disease spirochetes: phylogenetic analyses of rRNA genes and their intergenic spacers in *Borrelia japonica* sp. nov. and genomic group 21038 (*Borrelia andersonii* sp. nov.) isolates. J Clin Microbiol 33: 2427-2434.

Massung, R. F., M. J. Mauel, J. H. Owens, N. Allan, J. W. Courtney, K. C. Stafford III, and T. N. Mather. 2002. Genetic variants of *Ehrlichia phagocytophila*, Rhode Island and Connecticut. Emerg Infect Dis 8: 467-472.

Mast, W. E., and W. M. J. Burrows. 1976. Erythema chronicum migrans in the United States. JAMA 236: 859-860.

Matheson, R. 1945. Guide to the insects of Connecticut. Part VI. The Diptera or true flies of Connecticut. Second Fascicle. Family Culicidae, the mosquitoes. Bull Conn Geol Nat Hist Survey 68: 1-48.

Mathiesen, D. A., J. H. Oliver, Jr., C. P. Kolbert, E. D. Tullson, B. J. Johnson, G. L. Campbell, P. D. Mitchell, K. D. Reed, S. R. Telford, 3rd, J. F. Anderson, R. S. Lane, and D. H. Persing. 1997. Genetic heterogeneity of *Borrelia burgdorferi* in the United States. J Infect Dis 175: 98-107.

Mayo, D., N. Karabatsos, F. J. Scarano, T. Brennan, D. Buck, T. Fiorentino, J. Mennone, and S. Tran. 2001. Jamestown Canyon virus: seroprevalence in Connecticut. Emerg Infect Dis 7: 911-912.

Micieli, M. V., J. J. Garcia, and T. G. Andreadis. 2001. Epizootiological studies of *Amblyospora albifasciat*i (Microsporidiida: Amblyosporidae) in natural populations of *Aedes albifasciatus* (Diptera: Culicidae) and *Mesocyclops annulatus* (Copepoda: Cyclopidae) in a transient floodwater habitat. J Invertebr Pathol 77: 68-74.

Micieli, M. V., J. J. Garcia, and T. G. Andreadis. 2009. Factors affecting horizontal transmission of the microsporidium *Amblyospora albifasciati* to its intermediate copepod host *Mesocyclops annulatus*. J Invertebr Pathol 101: 228-233.

Mintz, E. D., J. F. Anderson, R. G. Cable, and J. L. Hadler. 1991. Transfusion-transmitted babesiosis: a case report from a new endemic area. Transfusion 31: 365-368.

Molaei, G., and T. G. Andreadis. 2006. Identification of avian- and mammalian-derived bloodmeals in *Aedes vexans* and *Culiseta melanura* (Diptera: Culicidae) and its implication for West Nile virus transmission in Connecticut, U.S.A. J Med Entomol 43: 1088-1093.

Molaei, G., T. G. Andreadis, P. M. Armstrong, J. F. Anderson, and C. R. Vossbrinck. 2006a. Host feeding patterns of *Culex* mosquitoes and West Nile virus transmission, northeastern United States. Emerg Infect Dis 12: 468-474.

Molaei, G., J. Oliver, T. G. Andreadis, P. M. Armstrong, and J. J. Howard. 2006b. Molecular identification of blood-meal sources in *Culiseta melanura* and *Culiseta morsitans* from an endemic focus of eastern equine encephalitis virus in New York. Am J Trop Med Hyg 75: 1140-1147.

Molaei, G., T. G. Andreadis, P. M. Armstrong, R. Bueno, Jr., J. A. Dennett, S. V. Real, C. Sargent, A. Bala, Y. Randle, H. Guzman, A. Travassos da Rosa, T. Wuithiranyagool, and R. B. Tesh. 2007. Host feeding pattern of *Culex quinquefasciatus* (Diptera: Culicidae) and its role in transmission of West Nile virus in Harris County, Texas. Am J Trop Med Hyg 77: 73-81.

Molaei, G., T. G. Andreadis, P. M. Armstrong, and M. Diuk-Wasser. 2008. Host-feeding patterns of potential

mosquito vectors in Connecticut, U.S.A.: molecular analysis of bloodmeals from 23 species of *Aedes*, *Anopheles*, *Culex*, *Coquillettidia*, *Psorophora*, and *Uranotaenia*. J Med Entomol 45: 1143-1151.

Molaei, G., A. Farajollahi, P. M. Armstrong, J. Oliver, J. J. Howard, and T. G. Andreadis. 2009a. Identification of bloodmeals in *Anopheles quadrimaculatus* and *Anopheles punctipennis* from eastern equine encephalitis virus foci in northeastern U.S.A. Med Vet Entomol 23: 350-356.

Molaei, G., A. Farajollahi, J. J. Scott, R. Gaugler, and T. G. Andreadis. 2009b. Human bloodfeeding by the recently introduced mosquito, *Aedes japonicus japonicus*, and public health implications. J Am Mosq Control Assoc 25: 210-214.

Morrison, A., and T. G. Andreadis. 1992. Larval population dynamics in a community of nearctic *Aedes* inhabiting a temporary vernal pool. J Am Mosq Control Assoc 8: 52-57.

Nadelman, R. B., C. S. Pavia, L. A. Magnarelli, and G. P. Wormser. 1990. Isolation of *Borrelia burgdorferi* from the blood of seven patients with Lyme disease. Am J Med 88: 21-26.

Narasimhan, S., F. Santiago, R. A. Koski, B. Brei, J. F. Anderson, D. Fish, and E. Fikrig. 2002. Examination of the *Borrelia burgdorferi* transcriptome in *Ixodes scapularis* during feeding. J Bacteriol 184: 3122-3125.

Narasimhan, S., R. R. Montgomery, K. DePonte, C. Tschudi, N. Marcantonio, J. F. Anderson, J. R. Sauer, M. Cappello, F. S. Kantor, and E. Fikrig. 2004. Disruption of *Ixodes scapularis* anticoagulation by using RNA interference. Proc Natl Acad Sci U S A 101: 1141-1146.

Narasimhan, S., K. Deponte, N. Marcantonio, X. Liang, T. E. Royce, K. F. Nelson, C. J. Booth, B. Koski, J. F. Anderson, F. Kantor, and E. Fikrig. 2007a. Immunity against *Ixodes scapularis* salivary proteins expressed within 24 hours of attachment thwarts tick feeding and impairs *Borrelia* transmission. PLoS ONE 2: e451.

Narasimhan, S., B. Sukumaran, U. Bozdogan, V. Thomas, X. Liang, K. DePonte, N. Marcantonio, R. A. Koski, J. F. Anderson, F. Kantor, and E. Fikrig. 2007b. A tick antioxidant facilitates the Lyme disease agent's successful migration from the mammalian host to the arthropod vector. Cell Host Microbe 2: 7-18.

Nazario, S., S. Das, A. M. de Silva, K. Deponte, N. Marcantonio, J. F. Anderson, D. Fish, E. Fikrig, and F. S. Kantor. 1998. Prevention of *Borrelia burgdorferi* transmission in guinea pigs by tick immunity. Am J Trop Med Hyg 58: 780-785.

Nelson, J. A., J. K. Bouseman, U. Kitron, S. M. Callister, B. Harrison, M. J. Bankowski, M. E. Peeples, B. J. Newton, and J. F. Anderson. 1991. Isolation and characterization of *Borrelia burgdorferi* from Illinois *Ixodes dammini*. J Clin Microbiol 29: 1732-1734.

Nelson, R., B. A. Brennan, and D. Mayo. 2002. Surveillance for arbovirus infections. Conn Epidemiol 22: 5-8.

Nicholson, W. L., J. A. Comer, J. W. Sumner, C. Gingrich-Baker, R. T. Coughlin, L. A. Magnarelli, J. G. Olson, and J. E. Childs. 1997. An indirect immunofluorescence assay using a cell culture-derived antigen for detection of antibodies to the agent of human granulocytic ehrlichiosis. J Clin Microbiol 35: 1510-1516.

O'Neill, S. L., P. Kittayapong, H. R. Braig, T. G. Andreadis, J. P. Gonzalez, and R. B. Tesh. 1995. Insect densoviruses may be widespread in mosquito cell lines. J Gen Virol 76 (Pt 8): 2067-2074.

O'Neill, S. L., M. M. Pettigrew, S. P. Sinkins, H. R. Braig, T. G. Andreadis, and R. B. Tesh. 1997. In vitro cultivation of *Wolbachia pipientis* in an *Aedes albopictus* cell line. Insect Mol Biol 6: 33-39.

Oliver, J. H., Jr., L. A. Magnarelli, H. J. Hutcheson, and J. F. Anderson. 1999. Ticks and antibodies to *Borrelia burgdorferi* from mammals at Cape Hatteras, NC and Assateague Island, MD and VA. J Med Entomol 36: 578-587.

Pal, U., A. M. de Silva, R. R. Montgomery, D. Fish, J. Anguita, J. F. Anderson, Y. Lobet, and E. Fikrig. 2000. Attachment of *Borrelia burgdorferi* within *Ixodes scapularis* mediated by outer surface protein A. J Clin Invest 106: 561-569.

Pal, U., X. Li, T. Wang, R. R. Montgomery, N. Ramamoorthi, A. M. Desilva, F. Bao, X. Yang, M. Pypaert, D. Pradhan, F. S. Kantor, S. Telford, J. F. Anderson, and E. Fikrig. 2004a. TROSPA, an *Ixodes scapularis* receptor for *Borrelia burgdorferi*. Cell 119: 457-468.

Pal, U., X. Yang, M. Chen, L. K. Bockenstedt, J. F. Anderson, R. A. Flavell, M. V. Norgard, and E. Fikrig. 2004b. OspC facilitates *Borrelia burgdorferi* invasion of *Ixodes scapularis* salivary glands. J Clin Invest 113: 220-230.

Pal, U., J. F. Anderson, and E. Fikrig. 2006. *Borrelia burgdorferi* and *Ixodes scapularis*: exploring the pathogen-vector interface., pp. 345-353. *In* F. C. Cabello, D. Hulinska and H. P. Godfrey [eds.], Life and behavioural sciences: Molecular biology of spirochetes. NATO Science Series.

Pal, U., J. Dai, X. Li, G. Neelakanta, P. Luo, M. Kumar, P. Wang, X. Yang, J. F. Anderson, and E. Fikrig. 2008. A differential role for BB0365 in the persistence of *Borrelia burgdorferi* in mice and ticks. J Infect Dis 197: 148-155.

Persing, D. H., S. R. Telford, A. S. Spielman, and S. W. Barthold. 1990. Detection of *Borrelia burgdorferi* infection in *Ixodes dammini* ticks with the polymerase chain reaction. J Clin Microbiol 28: 566-572.

Petersen, L. R., L. A. Sawyer, D. B. Fishbein, P. W. Kelley, R. J. Thomas, L. A. Magnarelli, M. Redus, and J. E. Dawson. 1989a. An outbreak of ehrlichiosis in members of an Army Reserve unit exposed to ticks. J Infect Dis 159: 562-568.

Petersen, L. R., A. H. Sweeney, P. J. Checko, L. A. Magnarelli, P. A. Mshar, R. A. Gunn, and J. L. Hadler. 1989b. Epidemiological and clinical features of 1,149 persons with Lyme disease identified by laboratory-based surveillance in Connecticut. Yale J Biol Med 62: 253-262.

Piesman, J., T. N. Mather, S. R. Telford, 3rd, and A. Spielman. 1986. Concurrent *Borrelia burgdorferi* and *Babesia microti* infection in nymphal *Ixodes dammini*. J Clin Microbiol 24: 446-447.

Popov, V. L., V. C. Han, S. M. Chen, J. S. Dumler, H. M. Feng, T. G. Andreadis, R. B. Tesh, and D. H. Walker. 1998. Ultrastructural differentiation of the genogroups in the genus *Ehrlichia*. J Med Microbiol 47: 235-251.

Pound, J. M., J. A. Miller, J. E. George, D. Fish, J. F. Carroll, T. L. Schulze, T. J. Daniels, R. C. Falco, K. C. Stafford III, and T. N. Mather. 2009. The United States Department of Agriculture's Northeast Area-wide Tick Control Project: summary and conclusions. Vector Borne Zoonotic Dis 9: 439-448.

Promnares, K., M. Kumar, D. Y. Shroder, X. Zhang, J. F. Anderson, and U. Pal. 2009. *Borrelia burgdorferi* small lipoprotein Lp6.6 is a member of multiple protein complexes in the outer membrane and facilitates pathogen transmission from ticks to mice. Molec Microbiol 74: 112-125.

Rahal, J. J., J. Anderson, C. Rosenberg, T. Reagan, and L. L. Thompson. 2004. Effect of interferon-alpha2b therapy on St. Louis viral meningoencephalitis: clinical and laboratory results of a pilot study. J Infect Dis 190: 1084-1087.

Ramamoorthi, N., S. Narasimhan, U. Pal, F. Bao, X. F. Yang, D. Fish, J. Anguita, M. V. Norgard, F. S. Kantor, J. F. Anderson, R. A. Koski, and E. Fikrig. 2005. The Lyme disease agent exploits a tick protein to infect the mammalian host. Nature 436: 573-577.

Rank, E. L., S. M. Dias, J. Hasson, P. H. Duray, R. C. Johnson, L. A. Magnarelli, and R. D. Fister. 1989. Human necrotizing splenitis caused by *Borrelia burgdorferi*. Am J Clin Pathol 91: 493-498.

Raoult, D., and D. H. Walker. 1990. *Rickettsia rickettsii* and other spotted fever group rickettsiae (Rocky Mountain spotted fever and other spotted fevers). *In* G. L. Mandell, R. G. Douglas Jr. and J. E. Bennett [eds.], Principles and practice of infectious diseases, 3 ed. Churchill Livingstone, New York.

Reed, W., J. Carroll, A. Agramonte, and J. W. Lazear. 1900. Etiology of yellow fever; prelimiary note. Philadelphia Med J 6: 790-796.

Reed, W., and J. Carroll. 1902. Etiology of yellow fever; supplemental note. Am Med 3: 301-305.

Roher, D. P., J. F. Anderson, and S. W. Nielsen. 1985. Experimental babesiosis in coyotes and coydogs. Am J Vet Res 46: 256-262.

Ross, R. 1902. Researches on malaria. http://nobelprize-org/nobel_prizes/medicine/laureates/1902/ross-lecturepdf.

Rozsa, R. 1995. Human impacts on tidal wetlands: history and regulations, pp. 42-50. *In* G. D. Dreyer and W. A. Niering [eds.], Tidal marshes of Long Island Sound: ecology, history and restoration. Connecticut College Arboretum, New London, CT.

Satriano, S. F., R. E. Luginbuhl, R. C. Wallis, E. L. Jungherr, and L. A. Williamson. 1958. Investigation of eastern equine encephalomyelitis. IV. Susceptibility and transmission studies with virus of pheasant origin. Am J Hyg 67: 21-34.

Schaible, U. E., R. Wallich, M. D. Kramer, L. Gern, J. F. Anderson, C. Museteanu, and M. M. Simon. 1993. Immune sera to individual *Borrelia burgdorferi* isolates or recombinant OspA thereof protect SCID mice against infection with homologous strains but only partially or not at all against those of different OspA/OspB genotype. Vaccine 11: 1049-1054.

Sexton, D. J., P. E. Rollin, E. B. Breitschwerdt, G. R. Corey, S. A. Myers, M. R. Dumais, M. D. Bowen, C. S. Goldsmith, S. R. Zaki, S. T. Nichol, C. J. Peters, and T. G. Ksiazek. 1997. Life-threatening Cache Valley virus infection. N Engl J Med 336: 547-549.

Sheldahl, J. A. 1974. A simple conversion of a back-pack mistblower into an efficient power aspirator. Mosq News 34: 166-169.

Shepard, J. J., T. G. Andreadis, and C. R. Vossbrinck. 2006. Molecular phylogeny and evolutionary relationships among mosquitoes (Diptera: Culicidae) from the northeastern United States based on small subunit ribosomal DNA (18S rDNA) sequences. J Med Entomol 43: 443-454.

Simakova, A. V., C. R. Vossbrinck, and T. G. Andreadis. 2008. Molecular and ultrastructural characterization of *Andreanna caspii* n. gen., n. sp. (Microsporida: Amblyosporidae), a parasite of *Ochlerotatus caspius* (Diptera: Culicidae). J Invertebr Pathol 99: 302-311.

Smith, J. B. 1902. Report of the mosquito investigations, pp. 511-558, Report of the Entomological Department of the New Jersey Agricultural Experiment Station.

Smith, B. M. 1985. The cover. JAMA 253: 2517.

Smith, T., and F. L. Kilborne. 1893. Investigations into the nature, causation, and prevention of Texas or southern cattle fever. U S Dept Agric Bur Anim Ind Bull 1: 1-301.

Spencer, J. A., J. M. Butler, K. C. Stafford III, M. B. Pough, S. A. Levy, D. L. Bledsoe, and B. L. Blagburn. 2003. Evaluation of permethrin and imidacloprid for prevention of *Borrelia burgdorferi* transmission from blacklegged ticks (*Ixodes scapularis*) to *Borrelia burgdorferi*-free dogs. Parasitol Res 90 Suppl 3: S106-107.

Spielman, A. 1976. Human babesiosis on Nantucket Island: transmission by nymphal *Ixodes* ticks. Am J Trop Med Hyg 25: 784-787.

Sprance, H. E., A. J. Main, and R. C. Wallis. 1978. Jamestown Canyon virus in Connecticut. Mosq News 38: 392-395.

Stafford III, K. C. 1989. Lyme disease prevention: personal protection and prospects for tick control. Conn Med 53: 347-351.

Stafford III, K. C. 1991a. Effectiveness of host-targeted permethrin in the control of *Ixodes dammini* (Acari: Ixodidae). J Med Entomol 28: 611-617.

Stafford III, K. C. 1991b. Effectiveness of carbaryl applications for the control of *Ixodes dammini* (Acari: Ixodidae) nymphs in an endemic residential area. J Med Entomol 28: 32-36.

Stafford III, K. C. 1992a. Oviposition and larval dispersal of *Ixodes dammini* (Acari: Ixodidae). J Med Entomol 29: 129-132.

Stafford III, K. C. 1992b. Third-year evaluation of host-targeted permethrin for the control of *Ixodes dammini*

(Acari: Ixodidae) in southeastern Connecticut. J Med Entomol 29: 717-720.

Stafford III, K. C. 1993. Reduced abundance of *Ixodes scapularis* (Acari: Ixodidae) with exclusion of deer by electric fencing. J Med Entomol 30: 986-996.

Stafford III, K. C., and L. A. Magnarelli. 1993. Spatial and temporal patterns of *Ixodes scapularis* (Acari: Ixodidae) in southeastern Connecticut. J Med Entomol 30: 762-771.

Stafford III, K. C. 1994. Survival of immature *Ixodes scapularis* (Acari: Ixodidae) at different relative humidities. J Med Entomol 31: 310-314.

Stafford III, K. C., V. C. Bladen, and L. A. Magnarelli. 1995. Ticks (Acari: Ixodidae) infesting wild birds (Aves) and white-footed mice in Lyme, CT. J Med Entomol 32: 453-466.

Stafford III, K. C., A. J. Denicola, and L. A. Magnarelli. 1996. Presence of *Ixodiphagus hookeri* (Hymenoptera: Encyrtidae) in two Connecticut populations of *Ixodes scapularis* (Acari: Ixodidae). J Med Entomol 33: 183-188.

Stafford III, K. C. 1997. Pesticide use by licensed applicators for the control of *Ixodes scapularis* (Acari: Ixodidae) in Connecticut. J Med Entomol 34: 552-558.

Stafford III, K. C., M. L. Cartter, L. A. Magnarelli, S. H. Ertel, and P. A. Mshar. 1998a. Temporal correlations between tick abundance and prevalence of ticks infected with *Borrelia burgdorferi* and increasing incidence of Lyme disease. J Clin Microbiol 36: 1240-1244.

Stafford III, K. C., J. S. Ward, and L. A. Magnarelli. 1998b. Impact of controlled burns on the abundance of *Ixodes scapularis* (Acari: Ixodidae). J Med Entomol 35: 510-513.

Stafford III, K. C., R. F. Massung, L. A. Magnarelli, J. W. IJdo, and J. F. Anderson. 1999. Infection with agents of human granulocytic ehrlichiosis, Lyme disease, and babesiosis in wild white-footed mice (*Peromyscus leucopus)* in Connecticut. J Clin Microbiol 37: 2887-2892.

Stafford III, K. C., and U. Kitron. 2002. Environmental management for Lyme borreliosis control, pp. 301-334. *In* J. Gray [ed.], Lyme borreliosis: biology and control. CABI Publishing, Oxon, UK.

Stafford III, K. C., A. J. Denicola, and H. J. Kilpatrick. 2003. Reduced abundance of *Ixodes scapularis* (Acari: Ixodidae) and the tick parasitoid *Ixodiphagus hookeri* (Hymenoptera: Encyrtidae) with reduction of white-tailed deer. J Med Entomol 40: 642-652.

Stafford III, K. C. 2007. Tick management handbook: an integrated guide for homeowners, pest control operators, and public health officials on the prevention of tick-associated disease. Bull Conn Agric Exp Stn 1010: 1-77.

Stafford III, K. C. 2008. Fly management handbook a guide to biology, dispersal, and management of the house fly and related flies for farmers, municipalities, and public health officials. Bull Conn Agric Exp Stn 1013: 1-40.

Stafford III, K. C., A. J. Denicola, J. M. Pound, J. A. Miller, and J. E. George. 2009. Topical treatment of white-tailed deer with an acaricide for the control of *Ixodes scapularis* (Acari: Ixodidae) in a Connecticut Lyme borreliosis hyperendemic Community. Vector Borne Zoonotic Dis 9: 371-379.

Stanek, G., H. Flamm, V. Groh, A. Hirschl, W. Kristoferitsch, R. Neumann, E. Schmutzhard, and G. Wewalka. 1987. Epidemiology of *Borrelia* infections in Austria, pp. 442-449. *In* G. Stanek, H. Flamm, A. G. Barbour and W. Burgdorfer [eds.], Lyme borreliosis Proceedings of the second international symposium on Lyme disease and related disorders, Vienna 1985. Gustav Fischer Verlag, Stuttgart.

Steere, A. C., S. E. Malawista, D. R. Snydman, R. E. Shope, W. A. Andiman, M. R. Ross, and F. M. Steele. 1977. Lyme arthritis: an epidemic of oligoarticular arthritis in children and adults in three Connecticut communities. Arthritis Rheum 20: 7-17.

Steere, A. C. 2001. Lyme disease. N Engl J Med 345: 115-125.

Sternberg, G. M. 1908. Yellow fever: history and geographic distribution, pp. 715-722. *In* T. L. Stedman [ed.], Appendix to the reference handbook of the medical sciences. William Wood and Company, New York, New York.

Sukumaran, B., S. Narasimhan, J. F. Anderson, K. Deponte, N. Marcantonio, M. N. Krishnan, D. Fish, S. R. Telford, F. S. Kantor, and E. Fikrig. 2006. An *Ixodes scapularis* protein required for survival of *Anaplasma phagocytophilum* in tick salivary glands. J Exp Med 203: 1507-1517.

Tesh, R. B., and T. G. Andreadis. 1992. Infectivity and pathogenesis of iridescent virus type 22 in various insect hosts. Arch Virol 126: 57-65.

Theiler, M., and W. G. Downs. 1973. The arthropod-borne viruses of vertebrates-An account of The Rockefeller Foundation virus program 1951-1970. University Press, New Haven, CT.

Town, T., F. Bai, T. Wang, A. T. Kaplan, F. Qian, R. R. Montgomery, J. F. Anderson, R. A. Flavell, and E. Fikrig. 2009. Toll-like receptor 7 mitigates lethal West Nile encephalitis via interleukin 23-dependent immune cell infiltration and homing. Immunity 30: 242-253.

Trask, J. W. 1916. Malaria as a public health and economic problem in the United States. Am J Pub Health 6: 1290-1297.

Tuininga, A. R., J. L. Miller, S. U. Morath, T. J. Daniels, R. C. Falco, M. Marchese, S. Sahabi, D. Rosa, and K. C. Stafford III. 2009. Isolation of entomopathogenic fungi from soils and *Ixodes scapularis* (Acari: Ixodidae) ticks: prevalence and methods. J Med Entomol 46: 557-565.

Tully, W. 1823a. History of the peculiar fever, that occurred at Middletown, Connecticut, during the months of June and July, 1820, pp. 291-356. *In* T. Miner and W. Tully [eds.], Essays on fevers, and other medical subjects. E. & H. Clark, Middletown, Connecticut.

Tully, W. 1823b. Yellow-fever in Chatham, in 1796, and its origin, pp. 357-364. *In* T. Miner and W. Tully [eds.], Essays on fevers, and other medical subjects. E. & H. Clark, Middletown, CT.

Tully, W. 1823c. Cases of yellow-fever in Middletown,

1820., pp. 365-403. *In* T. Miner and W. Tully [eds.], Essays on fevers, and other medical subjects. E. & H. Clark, Middletown.

Turell, M. J., D. J. Dohm, M. R. Sardelis, M. L. Oguinn, T. G. Andreadis, and J. A. Blow. 2005. An update on the potential of North American mosquitoes (Diptera: Culicidae) to transmit West Nile virus. J Med Entomol 42: 57-62.

Turner, N. 1932. Tests of mosquito light traps and larvicides in 1932. Report of the State Entomologist of Connecticut 32: 441-445.

Turner, N. 1974. Entomology in Connecticut: 1901-1950, pp. 19-58. *In* R. L. Beard [ed.], 25th anniversary memoirs Connecticut Entomology Society. The Connecticut Entomological Society, New Haven.

Tuttle, A. D., T. G. Andreadis, S. Frasca, Jr., and J. L. Dunn. 2005. Eastern equine encephalitis in a flock of African penguins maintained at an aquarium. J Am Vet Med Assoc 226: 2059-2062, 2003.

Tyzzer, E. E., A. W. Sellards, and B. L. Bennett. 1938. The occurrence in nature of equine encephalomyelitis in the ring-necked pheasant. Science 83: 505-506.

Van Andel, A. E., L. A. Magnarelli, R. Heimer, and M. L. Wilson. 1998. Development and duration of antibody response against *Ehrlichia equi* in horses. J Am Vet Med Assoc 212: 1910-1914.

Vannier, E., B. E. Gewurz, and P. J. Krause. 2008. Human babesiosis. Infect Dis Clin North Am 22: 469-488.

Vossbrinck, C. R., T. G. Andreadis, and B. A. Debrunner-Vossbrinck. 1998. Verification of intermediate hosts in the life cycles of microsporidia by small subunit rDNA sequencing. J Eukaryot Microbiol 45: 290-292.

Vossbrinck, C. R., T. G. Andreadis, J. Vavra, and J. J. Becnel. 2004. Molecular phylogeny and evolution of mosquito parasitic *Microsporidia* (Microsporidia: Amblyosporidae). J Eukaryot Microbiol 51: 88-95.

Walden, B. H. 1907. Notes on fumigating buildings. Report of the State Entomologist of Connecticut 6: 291-294.

Walden, B. H. 1910. Fumigating buildings with hydrocyanic acid gas. Report of the State Entomologist of Connecticut 9: 365-367.

Walden, B. H. 1917. Mosquito work in Connecticut during 1917. Report of the State Entomologist of Connecticut 17: 345-356.

Wallis, R. C. 1953. Notes on the biology of *Culiseta melanura* (Coquillett). Mosq News 14: 33-34.

Wallis, R. C. 1955. Oviposition activity of three species of *Anopheles*. Amer J Trop Med Hyg 4: 557-563.

Wallis, R. C. 1956. Ovipostion activity of mosquitoes in the laboratory (Diptera:Culicidae). Proc Tenth Intnl Congress Entomol 3: 797-798.

Wallis, R. C., and C. A. Lang. 1956. Egg formation and oviposition in blood-fed *Aedes aegypti*. Mosq News 16: 283-286.

Wallis, R. C. 1957. Host feeding of *Culiseta morsitans*. Proc Entomol Soc Wash 59: 199-200.

Wallis, R. C., and R. J. DeBishop. 1957. Death-stress oviposition by *Aedes canadensis*. J Econ Entomol 50: 112.

Wallis, R. C., E. L. Jungherr, R. E. Luginbuhl, C. F. Helmboldt, S. F. Satriano, L. A. Williamson, and A. L. Lamson. 1958a. Investigation of eastern equine encephalomyelitis. V. Entomologic and ecologic field studies. Am J Hyg 67: 35-45.

Wallis, R. C., R. M. Taylor, R. W. McCollum, and J. T. Riodan. 1958b. Study of hibernating mosquitoes in eastern equine encephalomyelitis endemic areas in Connecticut. Mosq News 18: 1-4.

Wallis, R. C. 1959a. *Culiseta melanura* (Coquillett) and eastern equine encephalitis in Connecticut. Mosq News 19: 157-158.

Wallis, R. C. 1959b. Diapause and body fat formation by *Culex restuans* Theobald (Diptera: Culicidae). Proc Entomol Soc Wash 61: 219-222.

Wallis, R. C. 1960. Mosquitoes in Connecticut. Bull Conn Agri Exp Stn 632: 1-30.

Wallis, R. C., R. M. Taylor, and J. R. Henderson. 1960. Isolation of eastern equine encephalomyelitis virus from *Aedes vexans* in Connecticut. Proc Soc Exp Biol Med 103: 442-444.

Wallis, R. C. 1961. The effect of phenylthiourea and 4-chlororesorcinol on *Aedes aegypti* larvae. Mosq News 21: 187-189.

Wallis, R. C. 1962a. Chicken egg chlorio-allantoic membrane for mosquito feeding. Mosq News 22: 305-306.

Wallis, R. C. 1962b. Common Connecticut flies. Bull Conn Agric Exp Stn 650: 1-23.

Wallis, R. C. 1962c. Overwintering *Culiseta melanura* larvae. Proc Entomol Soc Wash 64: 119-122.

Wallis, R. C., and A. J. Main. 1974. Eastern equine encephalitis in Connecticut progress and problems, pp. 117-144. In R. L. Beard [ed.], 25th anniversary memoirs Connecticut Entomology Society. The Connecticut Entomological Society New Haven.

Wang, T., J. F. Anderson, L. A. Magnarelli, S. Bushmich, S. Wong, R. A. Koski, and E. Fikrig. 2001a. West Nile virus envelope protein: role in diagnosis and immunity. Ann N Y Acad Sci 951: 325-327.

Wang, T., J. F. Anderson, L. A. Magnarelli, S. J. Wong, R. A. Koski, and E. Fikrig. 2001b. Immunization of mice against West Nile virus with recombinant envelope protein. J Immunol 167: 5273-5277.

Wang, T., L. A. Magnarelli, J. F. Anderson, L. H. Gould, S. L. Bushmich, S. J. Wong, and E. Fikrig. 2002. A recombinant envelope protein-based enzyme-linked immunosorbent assay for West Nile virus serodiagnosis. Vector Borne Zoonotic Dis 2: 105-109.

Wang, T., E. Scully, Z. Yin, J. H. Kim, S. Wang, J. Yan, M. Mamula, J. F. Anderson, J. Craft, and E. Fikrig. 2003. IFN-gamma-producing gamma delta T cells help control murine West Nile virus infection. J Immunol 171: 2524-2531.

Wang, T., T. Town, L. Alexopoulou, J. F. Anderson, E. Fikrig, and R. A. Flavell. 2004. Toll-like receptor 3 mediates West Nile virus entry into the brain causing lethal encephalitis. Nat Med 10: 1366-1373.

Wang, T., Y. Gao, E. Scully, C. T. Davis, J. F. Anderson, T. Welte, M. Ledizet, R. Koski, J. A. Madri, A. Barrett, Z.

Yin, J. Craft, and E. Fikrig. 2006. Gamma delta T cells facilitate adaptive immunity against West Nile virus infection in mice. J Immunol 177: 1825-1832.

Wang, S., T. Welte, M. McGargill, T. Town, J. Thompson, J. F. Anderson, R. A. Flavell, E. Fikrig, S. M. Hedrick, and T. Wang. 2008. Drak2 contributes to West Nile virus entry into the brain and lethal encephalitis. J Immunol 181: 2084-2091.

Warren, A. J. 1951. Landmarks in the conquest of yellow fever, pp. 1-37. *In* G. K. Strode [ed.], Yellow Fever. McGraw-Hill, New York.

Watts, D. M., S. Pantuwatana, G. R. DeFoliart, T. M. Tuill, and W. H. Thompson. 1973. Transovarial transmission of La Crosse virus (California encephalitis group) in the mosquito, *Aedes triseriatus*. Science 182: 1140-1141.

Webster, N. 1799. A brief history of epidemic and pestilential diseases; with the principal phenomena of the physical world, which preceded and accompany them, and observations deduced from the facts stated. Vol. I. Hudson & Goodwin, Hartford.

Welte, T., J. Lamb, J. F. Anderson, W. K. Born, R. L. O'Brien, and T. Wang. 2008. Role of two distinct gammadelta T cell subsets during West Nile virus infection. FEMS Immunol Med Microbiol 53: 275-283.

Western, K. A., G. D. Benson, N. N. Gleason, G. R. Healy, and M. G. Schultz. 1970. Babesiosis in a Massachusetts resident. N Engl J Med 283: 854-856.

White, D. J. 2001. West Nile virus detection, surveillance,and control. Ann N Y Acad Sci 951: i.-374.

Whitman, L., R. C. Wallis, and E. A. Leventhal. 1968. Isolation of California group arbovirus from *Aedes abserratus* (Felt and Young) in Simsbury, Connecticut. Am J Trop Med Hyg 17: 449-450.

Williams, S. C., J. S. Ward, T. E. Worthley, and K. C. Stafford III. 2009. Managing Japanese barberry (Ranunculales: Berberidaceae) infestations reduces blacklegged tick (Acari: Ixodidae) abundance and infection prevalence with *Borrelia burgdorferi* (Spirochaetales: Spirochaetaceae). Environ Entomol 38: 977-984.

Wilske, B., J. F. Anderson, G. Baranton, A. G. Barbour, K. Hovind-Hougen, R. C. Johnson, and V. Preac-Mursic. 1991. Taxonomy of *Borrelia* spp. Scand J Infect Dis Suppl 77: 108-129.

Wilson, M. L., R. B. Tesh, D. Fish, M. A. Gerber, L. A. Magnarelli, H. M. Feder, Jr., and E. D. Shapiro. 1995. Evidence of hantavirus infection in rodents and human beings from Connecticut and New York, USA. Lancet 345: 738.

Work, T. H. 1975. Introduction to arthropod-borne viruses, pp. 922-928. *In* W. T. Hubbert, W. F. McCulloch and P. R. Schnurrenberger [eds.], Diseases transmitted from animals to man, 6 ed. Charles C. Thomas, Springfield, Illinois.

Wyler, D. J. 1990. Plasmodium species (malaria), pp. 2056-2066. In G. L. Mandell, R. G. Douglas Jr. and J. E. Bennett [eds.], Principles and practice of infectious diseases, 3 ed. Churchill Livingstone, New York.

Zamparo, J. M., T. G. Andreadis, R. E. Shope, and S. J. Tirrell. 1997. Serologic evidence of Jamestown Canyon virus infection in white-tailed deer populations from Connecticut. J Wildlife Diseases 33: 623-627.

Zhang, Y. Q., D. Mathiesen, C. P. Kolbert, J. F. Anderson, R. T. Schoen, E. Fikrig, and D. H. Persing. 1997. *Borrelia burgdorferi* enzyme-linked immunosorbent assay for discrimination of OspA vaccination from spirochete infection. J Clin Microbiol 35: 233-238.

Zingg, B. C., J. F. Anderson, R. C. Johnson, and R. B. LeFebvre. 1993. Comparative analysis of genetic variability among *Borrelia burgdorferi* isolates from Europe and the United States by restriction enzyme analysis, gene restriction fragment length polymorphism, and pulsed-field gel electrophoresis. J Clin Microbiol 31: 3115-3122.

Credits/Sources of Figures and Photographs

Cover: Top row (l to r)

Unfed Culex pipiens, *Experiment Station, Michael C. Thomas*
Electron micrograph of West Nile virus, Experiment Station, Dr. Theodore G. Andreadis
Dermacentor variabilis *adult, Dr. Durland Fish, Yale University*
Fed Aedes triseriatus, *Experiment Station, Michael C. Thomas*
Ixodes scapularis *adult, Dr. Durland Fish, Yale University*

Bottom row (l to r)

Rickettsia rickettsii, *Rocky Mountain Laboratories, NIAID, NIH*
Cimex lectularius, *Experiment Station, Michael P. Vasil*
Ixodes scapularis *nymph, Experiment Station, Dr. John F. Anderson*
Electron micrograph of Borrelia burgdorferi, *Experiment Station, Dr. Theodore G. Andreadis*
Anaplasma phagocytophilum, *Dr. Jacob W. IJdo, Yale University*

Figure 1: Experiment Station, archives
Figure 2: Experiment Station, archives
Figure 3: Experiment Station, archives
Figure 4: Experiment Station, archives
Figure 5: Experiment Station, archives
Figure 6: Experiment Station, archives
Figure 7: James W. Campbell, New Haven Museum.
Figure 8: Connecticut Colony Map-http://www.ctbiography.com/maps/
Arnold-http://en.wikipedia.org/wiki/Benedict_Arnold
Figure 9: Jane Bradley, Creative Advertising & Publishing Services
Figure 10:
Mosquito (Andreadis et al. 2005)
Malaria parasites: http://www.malaria.org.za/Malaria_Risk/General_Information/Parasite.jpg
Mill: www.thinkstock.com, royalty-free
Oliver Pond: http://members.fortunecity.com/dforbus/up.htm
Figure 11: All portraits on http://commons.wikimedia.org/wiki
Figure 12: David Miles, Andrew Rogalski and Terrie Wheeler, Gorgas Memorial Library,
Walter Reed Army Institute of Research
Figure 13:
Gorgas: http://www.hsl.virginia.edu/historical/medical_history/yellow_fever/new_strategies.cfm
Panama canal: http://commons.wikimedia.org/wiki/File:Kroonland_in_Panama_Canal,_1915.jpg
Figure 14: Experiment Station, archives
Figure 15: Experiment Station, archives
Figure 16: Experiment Station, archives
Figure 17: Redrawn by Philip Murawski, based on (top map):
http://www.koshland-science-museum.org/exhib_infectious/malaria_vector_control_05.jsp
(bottom map): http://www.celtnet.org.uk/medicine/malaria.php
Figure 18: Experiment Station, archives
Figure 19: Experiment Station, archives
Figure 20: Both photographs: Experiment Station, archives
Figure 21: Experiment Station, archives
Figure 22: Experiment Station, Paul Gough
Figure 23: Experiment Station, Paul Gough
Figure 24: Experiment Station, Paul Gough
Figure 25: Experiment Station, Dr.Theodore G. Andreadis
Figure 26:
Upper right, Experiment Station, Vickie M. Bomba-Lewandoski
Center row (3 photographs): Experiment Station, John F. Anderson
Bottom row: Experiment Station (l to r)
Vickie M. Bomba-Lewandoski, John F. Anderson, John F. Anderson, Philip M. Armstrong

Figure 27: *Experiment Station, Paul Gough*
Figure 28: The Day, *The Day Publishing Company, New London, Connecticut*
Figure 29: *Experiment Station, John F. Anderson*
Figure 30: *Experiment Station, Philip M. Armstrong*
Figure 31: *Experiment Station, John F. Anderson*
Figure 32: *Experiment Station, Congresswoman Rosa DeLauro*
Figure 33: *Experiment Station (clockwise from upper left)): John F. Anderson, Vickie M. Lewandoski, John F. Anderson, Vickie M. Lewandoski*
Figure 34: *Experiment Station, Dr. John F. Anderson*
Figure 35: *Experiment Station, Dr. John F. Anderson*
Figure 36:

Adult mosquitoes: Experiment Station, Michael C. Thomas
Electron micrograph of virus: Experiment Station, Dr. Theodore G. Andreadis
Mosquito eggs: www.msmosquito.com/newsroom.html
Photos: www.thinkstock.com, royalty-free

Figure 37: *Experiment Station, Michael C. Thomas*
Figure 38: *Experiment Station, Michael C. Thomas*
Figure 39: *Experiment Station, Vickie M. Bomba-Lewandoski*
Figure 40: *Experiment Station, Vickie M. Bomba-Lewandoski*
Figure 41: *Experiment Station, archives*
Figure 42: *Experiment Station, archives*
Figure 43: *Experiment Station, archives*
Figure 44: *Experiment Station, Dr. John F. Anderson*
Figure 45: *Jim Miller, Yale Termite and Pest Elimination Corp.*
Figure 46: *Experiment Station, John F. Anderson*
Figure 47: *Experiment Station, Michael C. Thomas*
Figure 48: *Experiment Station:*
Bed bug photographs: Michael P. Vasil
Life-cycle design: Bonnie L. Hamid
Figure 49: *Experiment Station, Paul Gough*
Figure 50: *Rocky Mountain Laboratories, NIAID, NIH*
Figure 51: *Dr. Durland Fish, Yale University*
Figure 52: *Experiment Station, archives*
Figure 53: *Experiment Station, Kirby C. Stafford III*
Figure 54: *Connecticut Television Network*
Figure 55: *Experiment Station, Michael C. Thomas*
Figure 56:

Upper left, Rocky Mountain Laboratories, NIAID, NIH
Upper center, Rocky Mountain Laboratories, NIAID, NIH
Upper right, Experiment Station, Paul Gough
Lower right, Experiment Station, Paul Gough

Figure 57: *Experiment Station, Paul Gough*
Figure 58:

Upper left photo, Experiment Station, John F. Anderson
Upper center photo, Archives of Dermatology (1984) 120: 1017-1021 Figure 1.
Copyright © (1984) American Medical Association. All rights reserved.
Upper right photo, Experiment Station, Paul Gough
Lower left photo, Experiment Station, Dr. Theodore G. Andreadis
Center mouse photo, Experiment Station, Dr. Kirby C. Stafford
Center bird photo, James Occi, Cranford, New Jersey
Lower right, Experiment Station, Dr. John F. Anderson

Figure 59: *Experiment Station, Paul Gough*
Figure 60: *Experiment Station, John F. Anderson*
Figure 61: *Experiment Station, Michael C. Thomas*
Figure 62: *Experiment Station, Paul Gough*
Figure 63: *Experiment Station, Louis M. Magnarelli*
Figure 64: *Experiment Station, Paul Gough*

About the Author

John F. Anderson was born in 1936 in Fargo, North Dakota, and spent his childhood in both North Dakota and South Dakota. He graduated from North Dakota State University in 1957 and received a Master's degree in entomology in 1959. After completing Reserve Officers Training Corps, he was commissioned as a Second Lieutenant in the United States Army Reserves in 1957. He was on active duty in the Army Medical Service Corps at Fort Sam Houston, Texas. He then served in the 5000th Research and Development Unit in Urbana, Illinois, and the United States Army Reserve 340th General Hospital in New Haven, Connecticut. He was honorably discharged as a Captain in 1967. He completed his PhD in entomology from the University of Illinois in 1963 and studied tropical medicine in Central America in 1962 as an Inter-American Fellow at Louisiana State University. After completing a National Science Foundation Postdoctoral Fellowship at the University of Illinois, he was hired in 1964 as an Assistant Scientist in the Department of Entomology at The Connecticut Agricultural Experiment Station. He was Chief Entomologist and State Entomologist from 1969-1987, Director from 1987-2004, and Distinguished Scientist from 2004-2009. He retired in 2009. He is a lecturer at Yale University. He has been married to his wife Marilynn for 52 years, and they have three adult children.

The Connecticut Agricultural Experiment Station

About The Connecticut Agricultural Experiment Station

The Connecticut Agricultural Experiment Station (CAES) prohibits discrimination in all of its programs and activities on the basis of race, color, ancestry, national origin, sex, religious creed, age, political beliefs, sexual orientation, criminal conviction record, genetic information, learning disability, present or past history of mental disorder, mental retardation or physical disability including but not limited to blindness, or marital or family status. To file a complaint of discrimination, write Director, The Connecticut Agricultural Experiment Station, P.O. Box 1106, New Haven, CT 06504, or call (203) 974-8440. CAES is an affirmative action/equal opportunity provider and employer. Persons with disabilities who require alternate means of communication of program information should contact the Chief of Services at (203) 974-8442 (voice); (203) 974-8502 (FAX); or Michael.Last@ct.gov (E-mail).

The Connecticut Agricultural Experiment Station
123 Huntington Street ■ New Haven, CT 06511-2016
Phone (203) 974-8500 ■ Statewide Toll-Free (877) 855-2237
www.ct.gov/CAES