A TICKING TIME BOMB: THE EMYL, CONNECTICUT, STORY

Robert Seiple

1. Executive Summary

A Ticking Time Bomb: The Emyl, Connecticut, Story is an inquiry-based simulation developed to engage and enlighten students through problem solving in a real-world application involving public health, applied biology, and epidemiology.

Target Audience	9th–12th grades, general to Advanced Placement
Nature of the Material	Unit for inclusion in biology and/or environmental sciences courses; could be used as either kick-off or capstone material
Prerequisites	No specific previous course work required, but familiarity with basic science concepts, skills, and attitudes is necessary
Time Required for Full Implementation	7–8 class periods of approximately 1 hour each

A TICKING TIME BOMB: THE EMYL, CONNECTICUT, STORY

Epidemiology concerns itself with the patterns of occurrence of disease in human populations. This simulation is based on the actual detection and eventual discovery of the underlying causes of the outbreak of what has become known as Lyme disease. Students are presented with the case history of a small town that has been impacted by an outbreak of illnesses of unknown origin. Students must assess the situation and use problem-solving skills to unravel the causes of the outbreak and eventually propose an effective short-term solution to stop its spread. The steps, decisions, and outcomes, though hidden from participants, mirror the history of "Lyme arthritis" from its recognition as a single, isolated illness to its eventual discovery, treatment, and understanding as a broader public health concern.

The simulation is versatile in that it can be adapted for various age groups (junior high to senior high), abilities, and instructional time frames. Additionally, the model may be used in a variety of instructional disciplines such as biology, environmental science, or even health. The simulation has elements of epidemiology, pathology, and field biology.

In addition to helping students better understand the history and causes of the spread of Lyme disease from its earliest detection to the present day, the simulation is an excellent means of introducing or reinforcing skills involving the scientific process, critical thinking, collaborative problem solving, cause and effect, and evaluation of bioethical issues. The simulation is an excellent tool for instruction of environmental science, since many aspects of epidemiology have strong interconnections with the environment. Individual and group assessments insure accountability for the knowledge, skills, and attitudes that students develop. Assessments are both written and performance based. Despite these rigors, students maintain high motivation throughout the simulation mainly through its attractive mystery-solving format that allows for each group to discover the answer for themselves in a unique pathway based on the choices and decisions made.

2. Learning Goals

Upon the completion of the simulation, students will

- Understand the causes of Lyme disease, including its connection with people's modification of the environment; grasp the way it is propagated; and comprehend the severity of its effect on society
- Appreciate the intricacy and interconnectedness of seemingly different life forms
- Realize the broader challenge of developing effective management strategies for public health while respecting nature and minimizing people's impact
- Learn the vital role that medical epidemiologists, pathologists, public health workers, and field biologists perform in society
- Have learned and exercised skills of questioning and developing explanations, related facts, found and evaluated evidence, exercised critical thinking, and applied the scientific method to a "real-world" problem

Demonstration of this acquired knowledge and skill is accomplished through a series of written communiqués to an unseen supervisor, and culminates in a written summary and management plan for handling the outbreak. Further demonstration of formative knowledge and skills takes place throughout the simulation as documented observed actions and behaviors ("observables") of individuals and groups.

3. Requirements

Time Requirements	7–8 class periods of approximately 1 hour	
Facilities Requirements	Classroom is sufficient for conducting entire simulation	Access to hallways or other space (e.g., commons, gym, outdoors) for group discussions desirable
Equipment Requirements	Organizer for hanging file folders	Access to computers for editing of communiqués helpful but not critical
Books, including textbooks	None	Optional
Other Resources Required	51 hanging folders with tabs, color coded (4 colors) as follows: • 26 folders for initial epidemiological study results • 6 folders for health and sanitation study results • 13 folders for field biology study results • 6 folders for additional study results	
	Manila folders or large envelopes (one per team)	
	Student handouts	See appendixes

4. Content

Materials and Preparation

On day one of the simulation, describe the nature of the simulation and what will be expected of participants throughout. Organize the class into teams of two to four individuals each. Careful selection of the teams is vital since students will be assessed both individually and corporately in small teams.

Explain to students their role as a team of medical epidemiologists working at a hospital/research clinic. Once teams are established, they will work together throughout the remainder of the simulation. Emphasize that teams are not to share any evidence or findings or partake in discussions with other teams. (This protocol may be very different from what the students are used to; at the developer's school, students are encouraged to share evidence, discoveries, etc. during the rest of the course.)

Provide each group with a folder containing several vital documents (samples of which appear in Appendix A). These include

- A general introduction and case history of the community where a mysterious outbreak of illnesses is occurring
- A map of the community
- A letter from the team's medical supervisor ordering an investigation of the outbreak
- Interview notes describing the supervisor's recent encounter with a patient from the community who is suffering many mysterious symptoms
- A research log in which to record observations, inferences, questions, and actions taken
- Hospital stationary on which to communicate to their supervisor
- A copy of the simulation assessment rubric

At this initial session, allot time to read all the documents and record initial questions and inferences about what the patient and the community are experiencing. At this time, clearly communicate teacher expectations and explain that each group and individual will be assessed daily, using the sample assessment rubric. Make sure students understand that group and individual behavior assessments are made daily on the basis of their ability to focus and stay on task. Day one concludes (as do all subsequent days) with the ritual of submitting the folder and admonishing groups to keep information confidential.

Day two is spent reacquainting groups with what they know or suspect before each group receives a list of possible epidemiological studies they may perform. The study choices are limited to just the realm of epidemiology, so they are low budget and mostly statistically based (e.g., How many of the patients are male? Is there any geographical clustering of the patients?) None of the groups will be able to solve the mystery through these studies alone, and soon groups will exhaust the list and want to check the health and environment of the community.

This, however, is outside the realm of epidemiology. Thus teams must petition their supervisor with the first of several written communiqués to secure the help of health workers and field biologists. Well-written, logical letters to the supervisor are rewarded with funding to expand their research choices to include health and field biology studies. Unclear letters that display little more than hunches are sent back to the drawing board for revision. Usually at about day three or four, groups begin to hone in on insect vectors as the main culprit. At this point, groups generally come to discover a new species of bacteria in the midgut of the deer tick as the cause of the townspeople's symptoms. Around day five of the simulation, groups are doing additional studies of the relationship of deer, tick, and human populations. (Slower groups are penalized somewhat in that they may fail to get to these studies, which limits their complete knowledge of the mechanisms of transmission.)

By the close of day six, all groups are required to complete a written summary of the cause of the outbreak and a proposal for an effective yet ethical short-term management plan for the community. For the instructor, the evening of day six is spent assessing and scoring these documents using assessment rubrics (samples of which appear in section 5, "Assessment").

Day seven is spent discussing the teams' respective management plans, which reveals various nuances of the simulation and ultimately the true identity of the outbreak as Lyme disease. Students receive their individual and group assessments. Day eight is an optional day to put closure to the simulation and unit.

Day-by-Day Timeline

Day 1 (one hour): Form research teams, establish roles as epidemiologists—define what epidemiology involves. Distribute introduction, memo #1 from Doctor Steele, notes from Dr. Steele's interview with Mrs. Murray, Research Log sheets, town map, and medical center stationary. Allow brainstorming time (approximately 10 minutes). Distribute epidemiological study choices and team folder. Collect folders at session's end and remind the teams not to share information outside their respective teams.

Day 2 (one hour): Distribute folders containing all forms from day one. Research teams conduct initial epidemiological studies and record results, formulate hypotheses, etc. Some teams may submit a request for expanding research to the supervisor by day's end. Requests should be made on medical center stationary. Collect folders and caution about not sharing.

Day 3 (one hour): Distribute folders. Provide the supervisor's response letter (memo #2 from Dr. Steele in Appendix A) to those teams that requested further research. Teams continue to conduct epidemiological and/or health and sanitation (HD series)/field biology (FB series) studies. Focus shifts from the cause of the illnesses to what to do about it. Research culminates in the additional studies (ADL series). Collect and caution.

Day 4 (one hour): Distribute folders. Provide the supervisor's third letter (memo #3 from Dr. Steele in Appendix A). Teams reflect on their discoveries, develop short-term solution(s) to the problem, and construct a preliminary report. Collect and caution.

Day 5 (one hour): Distribute folders. Teams finalize their reports to the supervisor focusing on (a) the cause(s) of the outbreak, and (b) recommendation(s) of action to be taken. Collect and caution.

Day 6 (one hour): Conduct roundtable discussion of effective solutions to the situation with all the research teams (class). Distribute and/or discuss reflection questions (see Appendix B for sample). Collect and caution.

Day 7 (one hour): Reveal the identity of the community and disease. Discuss various nuances of the simulation and real-life drama that led to the discovery and treatment of Lyme disease. Discuss present research and issues. (Teachers may want to find and distribute articles on Lyme disease history and discovery.) Deliver individual and group assessments.

5. Assessment

Students are assessed both individually and as group members, according to the following rubrics.

A. Group Scoring Criteria: Diagnosis of the Problem

2 – Incorrect and incomplete

Examples: "Disease transmitted by tainted food, such as deer meat"
"Disease transmitted by the bite of a mosquito"
"Disease transmitted through contaminated wells"

4 – Incomplete (vague)

Examples: "Disease is caused by ticks" (no elaboration)
"Disease is caused by bacteria" (no elaboration)

6 – Nearly complete

Examples: "Disease from infected ticks" (no further elaboration)
"Disease from pets that had infected ticks" (no further elaboration)

8 – Nearly complete with some higher-level thoughts

Example: "Ticks bite infected host, get spirochete bacteria, then bite human or wildlife host such as a deer or mouse"

10 – Complete and accurate showing higher-level thought

Example: "Ticks lay eggs on the forest floor, hatch out and bite infected mice. Tick is dormant over the winter, bites another wildlife host (rodent or herbivore), molts into adult and bites and infects family pet or human host traveling in the wild or on the home property"

B. Group Scoring Criteria: Management Plan

2 – Poor

Example: "Don't know what can be done—just let nature take its course"

4 – Inadequate

Examples: "Eliminate mice" (impractical)
"Administer antibiotics to mice or deer" (impractical)
"Cut down or burn all the forests and wooded areas" (shortsighted)

6 – Fair

Example: Only one strong step, e.g.,"increase public awareness" or "use pesticides"

8 – Good

Example: Two strong steps: "increase public awareness" and "use pesticides"

10 – Excellent

Example: "Use multifaceted approach that includes appropriate technology (pesticides, rodent control, integrated pest or wildlife management) and social control (use of quarantined areas, public awareness, warnings posted, laws passed, etc.)"

C. Individual Assessment Rubric for Simulation

Assesment Rubric for ______________________________
(Student's Name)

Scoring

3 – Demonstrated excellent skills: observed consistently throughout simulation
2 – Demonstrated good skills: observed often throughout simulation
1 – Demonstrated adequate skills: observed occasionally throughout simulation
0 – Demonstrated poor skills: observed rarely or not at all throughout simulation

Group Participation

- ☐ Evidence of persistence/diligence
- ☐ Evidence of relating facts/data
- ☐ Evidence of collaboration in decision making
- ☐ Evidence of proper sharing of responsibilities
- ☐ Evidence of following directions/rules/proper protocol

Individual Participation

- ☐ Evidence of consistent curiosity/engagement
- ☐ Evidence of respect of others/other opinions
- ☐ Attendance (periods present multiplied by 3)
- ☐ Evidence of staying on task for extended period of time
- ☐ Evidence of independent work with little or no guidance/minimal direction
- ☐ Evidence of contribution to the group

Scoring for Written Expression

10 – Excellent skills: complete and insightful, showing higher-level thought, organized

8 – Good skills: nearly complete, showing some higher-level thought, organized

6 – Fair skills: nearly complete but lacking depth, detail; some naive explanations or inaccuracies; disorganized

4 – Fair/poor skills: lacking completeness and/or depth, explanations are disorganized and/or naive

2 – Poor skills: incomplete, gross lack of depth or detail, very basic or incorrect understanding, disorganized

☐ Evidence of proper and complete diagnosis of root causes of problem
☐ Evidence of insight in proposed solution(s)
☐ Evidence of clerical participation (recording, retrieving, organized logging)

Total (out of 70 possible): _____

Comments:

6. Alignment of Content and Standards

Alignment with the National Science Education Standards (NSES)

The simulation is consistent with the current National Science Education Standards as directed by the National Research Council. The standards call for "more than science as a process in which students learn skills such as observing, inferring, and experimenting." "Inquiry is central to science learning," according to the National Science Education Standards, which go on to specify that when engaging in inquiry, students describe objects and events, ask questions, construct explanations, test those explanations against current scientific knowledge, and communicate their ideas to others. Students perform all these actions as they move through the simulation, developing their understanding of the outbreak crisis and combining their new knowledge with thinking and reasoning skills.

The following table summarizes the alignment of the simulation's content with the NSES:

Summary Table
Simulation Correlation to the National Science Education Standards

Unifying Concepts and Processes

Students should develop understanding and abilities aligned with the following concepts and processes:

	Met through Simulation
Systems, order, and organization	√
Evidence, models, and explanation	√
Constancy, change, and measurement	√
Evolution and equilibrium	√
Form and function	√

Content Standards for Life Science Grades 9–12

Students will develop understanding of	Content within Simulation	
	Strong	Addressed
The cell		√
Molecular basis of heredity		√
Biological evolution	√	
Interdependence of organisms	√	
Matter, energy, and organization in living systems	√	
Behavior of organisms	√	

Science in Personal and Social Perspectives Grades 9–12

Students will develop understanding of

Personal and community health	√
Population growth	√
Natural resources	√
Environmental quality	√
Natural and human-induced hazards	√
Science and technology in local, national, and global challenges	√

For further elaboration on the NSES standards and the degree to which the simulation is aligned, please see Appendix B.

Alignment with State Standards (Ohio)

Although the Ohio Science Standards are still in draft form, the simulation conforms nicely to draft content standards as defined by the Joint Council of State Board of Education and the Ohio Board of Regents. Some of the content emphases for grades 9–12 include understanding inquiry processes, improving skills for doing investigations, and recognizing how science and technology are interdependent. The simulation exercises these skills through the problem solving that is required to unravel the mystery.

The state content standards place emphasis on developing an understanding of the living environment, including topics such as the interdependence of life, the nature of science, and the study of ethical practices and application of appropriate technology. Again, the simulation strongly incorporates these understandings and topics, particularly in the formation of management plans near the end of the simulation.

Finally, the state standards call for a coherent study of the environment that looks at people's role in the biosphere and how people have modified current ecosystems, which in turn modifies what people try to accomplish. This is the heart of the simulation, and for that matter, the indirect cause of the spread of Lyme disease in America, since it is directly coupled with people's land-development practices and our attempts to manage wildlife.

8. Appendix

Appendix A
Student Handouts

A Ticking Time Bomb

The Emyl, Connecticut, Story

Introduction

A time bomb is ticking in the small, tranquil town of Emyl, Connecticut. However, this time bomb is not a mechanical one. It is biological in nature. The historical town founded by settlers in the mid-1600s stands as a quiet oasis for its 6,500 permanent residents amid the increasingly populous eastern seacoast. Yet this quaint town is under siege by an outbreak of mysterious illnesses of unknown origin. The outbreak threatens to become an epidemic unless steps are taken to discover its cause and manage it.

As medical epidemiologists working at a reputable medical research clinic, you have been assigned to determine the origin of the illnesses and recommend appropriate actions before it becomes a regional, or a national, concern.

Emyl—Past and Present

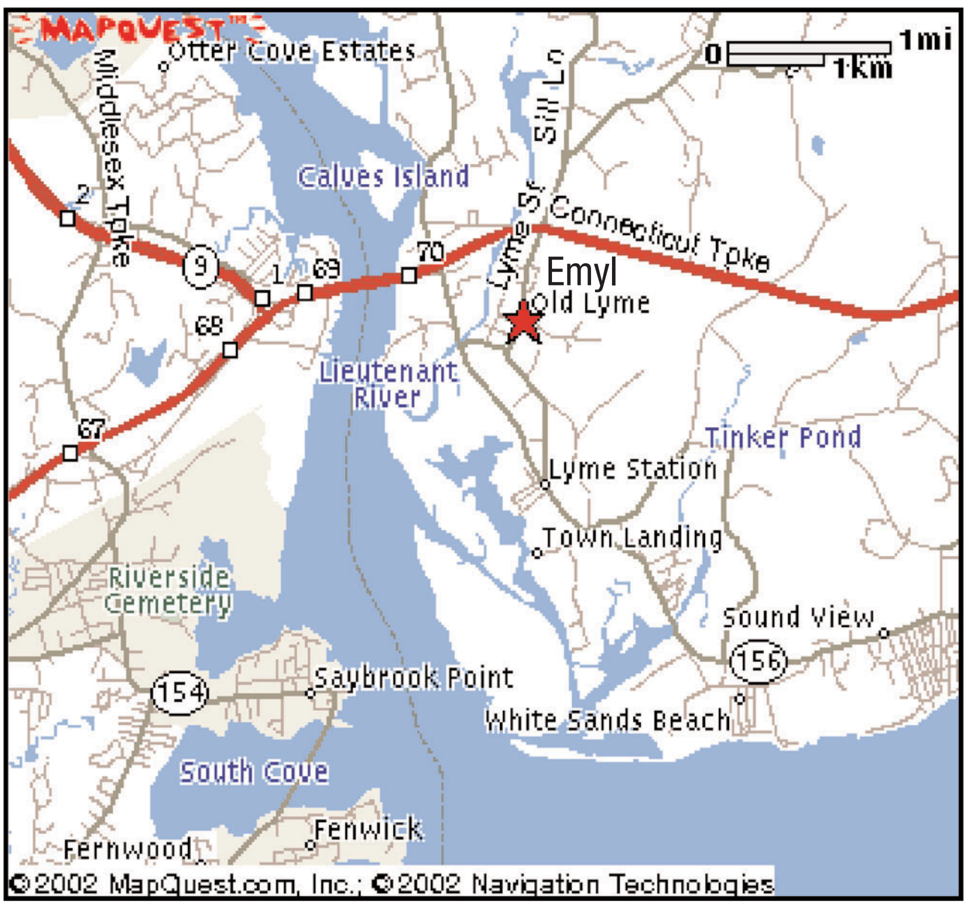
Emyl is a small, rural town with a winter population of 6,500, and a summer population of over 16,000. The town was settled in the mid-1600s by settlers who crossed the Connecticut River from the west. That initial heritage still holds strong 325 years later, as it is manifested in the community's art, architecture, and history. This peaceful colonial history is found everywhere.

Emyl was once a lucrative seaport and served as a hub for trade with the West Indies. The town was gradually cleared for pastureland for livestock by the 1800s. This livelihood shaped the landscape up until about 50 years ago when agricultural practices diminished and sheep and cow pastureland has since become wooded hills. Those seeking a natural refuge in which to raise a family or vacation during the summer months have gradually infiltrated the town. Ideally situated along the Connecticut River midway between New York and Boston, Emyl has become a bedroom community for people who earn a living in larger cities.

People most often attracted to Emyl love the beaches, woods, marshes, scenic riverfront, lakes, and gardens, and the community maintains a healthy respect for natural resources such as wetlands and watercourses. Strong regulations also exist to limit and carefully control growth. The largest employers are now the regional schools and the local A&P supermarket. Emyl is also home to a variety of small-to-medium-sized businesses. The town's per capita income is very impressive—ranking in the top 10% of the state.

But recently this seemingly perfect community has been tainted as news spreads of the growing number of the town's inhabitants who are suffering from a series of mysterious illnesses of unknown origin.

Emyl, Connecticut



Lyme Disease at a Glance

Pathology

Lyme disease is a complex illness with three definable stages:

1. **Initial** (7–10 days following infectious tick bite): Flu-like symptoms, followed by expanding circular rash surrounding bite

2. **Intermediate** (weeks or months after infection): Multiple rashes, cardiac or neurological abnormalities, arthritis in major joints

3. **Advanced** (years after infection): Attack on central nervous system, behavior changes and memory deficits

- The deer tick (*Ixodes dammini*) carries the disease, but the agent of Lyme disease is *Borrelia burgdorferi*, spirochete bacteria similar to those that cause syphilis.
- It essentially is an autoimmune disease. The bacteria trigger the body to produce antibodies that attack various organs of "self."
- The *reservoir host* (the most heavily infected organism in the environment) is the white-footed mouse (*Peromyscus leucopus*).

Spread

- The disease spreads according to the expansion of the range of the tick that carries it.
- It has the distinction of being the number one vectorborne disease in the U.S. today.

Life Cycle

- The life cycle is dependent upon the interaction of immature deer ticks and their primary host, the white-footed mouse.
- Female adult ticks lay eggs after successfully feeding in the autumn. These eggs hatch as larvae in midsummer, which feed upon an already infected mouse. They drop off and overwinter in an inactive state. During the spring, molting occurs until the larvae enter a nymph stage. The nymphs seek a host in spring/early summer and inoculate uninfected mice. The cycle is completed when nymphs that have been successful in finding a host molt to adult ticks in the fall.

- The adult ticks most frequently feed on the white-tailed deer. The deer's numbers are increasing because of the elimination of predators, and the deer is being pushed closer to human's habitat because of development practices.

History

- It is suspected that the disease was transported here from ticks originally in Europe, and the disease may have been reported as early as the 1920s. Other possible accounts could stretch well back into the 1700s, which suggests it is anything but a new disease.
- In the mid 1970s, an unusually high number of people in Old Lyme, Connecticut, developed headaches, rashes, and stiff joints. The children had unusually high rates of juvenile rheumatoid arthritis (35 cases in all).
- In 1976 Dr. Allen Steere coined the term "Lyme arthritis," which later became known as Lyme disease. The symptoms matched a situation in Europe in 1909 in patients bitten by *Ixodes ricinus* (sheep tick).
- In 1977 the vector was identified: *Ixodes dammini* (deer tick).
- In 1981 Dr. Jorge Benach and Dr. Willie Burgdorfer isolated the spirochete, *Borrelia burgdorferi*, from the gut of the deer tick.

Initial Epidemiology Studies

A. Orchestrate a town meeting for residents of Emyl and surrounding regions*

B. Investigate the timing in which patients became symptomatic

C. Investigate patient pet-ownership tendencies

D. Investigate patient geographic location within town/region

E. Investigate successful treatments of patients by physicians

F. Investigate patient relationships

G. Investigate patient recreational tendencies and occupational relationships

H. Investigate patient age/gender relationships

I. Access patient hospital-discharge records of recent weeks*

J. Compile patient allergy-testing results

K. Compile patient blood-testing results

L. Compile patient strep-culture test results

M. Compile knee-fluid test results for patients

N. Compile connective-tissue-disorder test results for patients

O. Compile rheumatic fever test results for patients

P. Compile mononucleosis test results for patients

Q. Compile hormone-imbalance test results for patients

R. Compile spinal tap test results for patients

S. Compile sexually-transmitted-disease test results for patients

T. Investigate patient rash-location tendencies

U. Investigate medical literature on similar symptoms*

V. Investigate patient home-water-source tendencies

W. Investigate patient food-source (shopping/dining) tendencies

*Follow-up studies available

Field Biology Studies (FB)

FB1) Investigate present and recent-past weather and climate trends for region

FB2) Survey local changes in vegetation and wildlife (flora and fauna changes)

FB3) Compile pet-ailment patterns from local veterinarians*

FB4) Study changes in wildlife populations of region*

FB5) Study changes in wildlife behavior and health*

FB6) Study changes in insect populations of region*

*Follow-up studies available

Health and Sanitation Studies (HD)

HD1) Investigate patient food choices and sample for possible toxin or pathogen

HD2) Test patient well water for toxin or pathogen

HD3) Test river and local streams for possible toxin or pathogen

HD4) Conduct air-quality study for the community and region

HD5) Test patient homes for toxic substances

HD6) Test ocean water for toxin or pathogen

Additional Studies (ADL)

ADL1) Study deer tick (*I. dammini*) life cycle and ecology*

ADL2) Test white-tailed deer for exposure (antibodies for) *B. burgdorferi* bacterium*

*Follow-up studies available

Initial Epidemiological Study Results

Study A Results

Over 400 attend the first-ever Emyl arthritis town meeting in a local gymnasium. Those represented cover a 100-mile radius. People note that a good number of children riding the bus had water on the knee. The number of children on crutches was noticed by many, especially at large gatherings such as sporting events. Complaints of foot swellings and episodes of rashes were noticed; they had been diagnosed as some sort of sun poisoning. Many reported they had been diagnosed with lupus and butterfly rashes. Some noticed they had twitching they never had before. Some reported they experienced Bell's palsy—a sudden onset of paralysis on one side of the face.

(Follow-up study on a case in a neighboring town available—study AA1)

Study AA1 Results

An eight-year-old girl who was hospitalized with a very swollen knee—believed to be due to osteomylitis—was put on antibiotics for several days. Tests were run to find the bacterial cause was inconclusive. The other knee then swelled, and the diagnosis was changed to juvenile rheumatoid arthritis (JRA), and the patient was sent home. The mother was skeptical that so many cases of JRA could be occurring in this rural region since JRA is relatively rare and is not contagious.

(Follow-up study on case involving family pets/animals available—study AA2)

Study AA2 Results

A woman from a rural section of Emyl reported that her cat had become lame and her dog stiffened with arthritis. Her horses had unusual ailments as well.

Study B Results

Rashes, fevers, aches, and joint swellings are most common from spring to late fall—with the most common month being April, followed by August. Joint swellings, headaches, twitches, numbness, and stiff necks were reported year round, however. Other symptoms included

Fatigue	Sore throat
Weight loss	Hoarseness
Sun sensitivity	Eye infections
Sensitivity to insect bite	Jaw problems

Study C Results

Nearly 75% of patients owned pets—cats were the most common pet, followed by dogs.

Study D Results

Overall, 4/1000 residents of Emyl seem to have this arthritic condition. Marked geographic clustering was observed, with many living near heavily wooded, sparsely settled areas. On some roads, 1 in 10 children have the illness. There is also a strong correlation to water (streams, bogs, etc.), although almost no one along the ocean shore or town center is afflicted.

Study E Results

Successful, long-term treatment has not been achieved. Most noteworthy successful treatment has been with the administering of antibiotics to alleviate fevers and rashes. These, however, often recur in patients later. Aspirin and anti-inflammatory drugs have had some limited success in reducing swelling, but only on a prolonged basis. Other prescribed medications have sporadic results.

Study F Results

It is noteworthy that six families have more than one affected member. This accounts for 25% of all patients. Outside of this, no direct family correlation exists between patients. Often victims have not so much as met.

Study G Results

No direct correlation exists. Patients work in the town, outside the town, indoors as well as out of doors. All have spent some time recreating in the past six months, but in no consistent ways—some garden, some boat, some hunt.

Study H Results

To date, 51 residents have Emyl arthritis: 39 children, 12 adults. Most of the adults are male; the children are evenly divided.

Study I Results

The majority of patients with similar symptoms are discharged from the hospital undiagnosed. The most common labels for the arthritic condition are rheumatoid arthritis, juvenile rheumatoid arthritis, or rheumatic fever.

(Follow-up study of patient John Doan available—study II)

Study II Results

Mr. Doan had been working with a group of biologists along the Connecticut shoreline on an ecological study when he was bitten by a tiny tick. He came to the county hospital to have it removed. Several days later he developed malaise, swollen glands, stiff jaw muscles, swelling and redness in knees, hips, shoulders, and elbows. The tick was identified as *Ixodes dammini* (deer tick) a close cousin to *Ixodes scapularis* (black-legged tick) of the southern states.

Study J Results

Only 1/3 of patients were tested for allergies. None of the tests revealed a change in the patients' allergic disposition.

Study K Results

Patients with fevers and rashes had, at the same time, circulating immune complexes in the serum of the blood, which indicates that the body is mounting an immune response to an infectious agent. Patients with fevers and rashes also had *cryoglobulins* (remnants of dead cells), whose presence indicates active infection. As symptoms improved, the cryoglobulins lessened or disappeared.

Study L Results

Seventy-five percent of patients had strep cultures done. All but one came back negative for strep.

Study M Results

Fluid analyses were done on 11 of the 51 patients. The fluid tested negative for known bacterial or viral infections.

Study N Results

Data on connective tissue disorders is as follows:

8 patients were tested for lupus (SLE)—all negative
13 patients were tested for rheumatoid arthritis—all negative but one
6 patients were tested for scleroderma—all negative

Study O Results

Nineteen patients were tested for rheumatic fever. All tested negative.

Study P Results

Fifteen patients were tested for mono. All came back negative.

Study Q Results

Five patients were tested for hormone imbalance. None were found to be out of the normal range.

Study R Results

Spinal taps were performed on four patients. One was found positive for viral meningitis and was hospitalized and treated.

Study S Results

All tests for STDs came back negative.

Study T Results

Seventy-five percent of patients have or had an expanding circular rash. Most common regions of the body were

1. Underarm/torso
2. Legs—lower, then upper
3. Abdomen near waistline

Most reported that the rashes occurred in the summer.

Study U Results

The circular (ECM) rash was first described in 1910 by Dr. Arvid Afzelius in Sweden. It was associated with a preceding sheep tick (*I. ricinus*) bite.

The first recorded description in U.S. medical literature was by R. J. Scrimenti in 1970. The victim was a 57-year-old male who was hunting grouse in north-central Wisconsin and had been bitten by an insect—believed to be a tick.

In 1975 two vacationing children developed expanding ring-like rashes. They were diagnosed as having erysipeloid (fish-handler's disease). Later they developed episodes of arthritis.

(Follow-up account from *New York Times* article on related medical case—study UU)

Study UU Results

A child from somewhere along the Connecticut shoreline was reported near death in a local hospital with severe fever and neurological problems. No definite diagnosis was made until an alert nurse found a tick embedded in the child's scalp. Once the tick was removed, the symptoms began to subside.

Study V Results

The majority of patients' homes have personal wells to supply their home water needs. A small percentage use city water, which is removed from the Connecticut River and processed before distribution.

Study W Results

There appears to be no pattern to patients' eating habits or any one common food supply. A variety of grocers and local markets bring in food from as far as the West Coast to as near as produce grown in the town.

Field Biology Study Results

Study FB1 Results

The coastal climate is historically warmer and more humid than inland areas of New England. Recent winters have seen above-normal snowfalls and above-average temperatures. Springs and summers have been drier than average over this same time period.

Study FB2 Results

No major shifts in vegetation have taken place in the recent past. Historically, the region was heavily wooded before being cleared for pastureland in the 1800s. By 1860 just 27% of the town was wooded.

In 1910, 45% of the town was woods, and by 1965, 63% was wooded, which shows a gradual reverting of the land to its original forest state. As a result of this trend, wildlife and insect populations as a whole are on the rise as food and habitat become more iabundant.

Study FB3 Results

Veterinarians are seeing an increase in lameness in pets, active infections, and mysterious illness—twitching and paralysis. Fleas and ticks are particularly a problem for pets this year and last.

(Follow-up study on testing insect vectors for known pathogens available—study FB3b)

Study FB3b Results

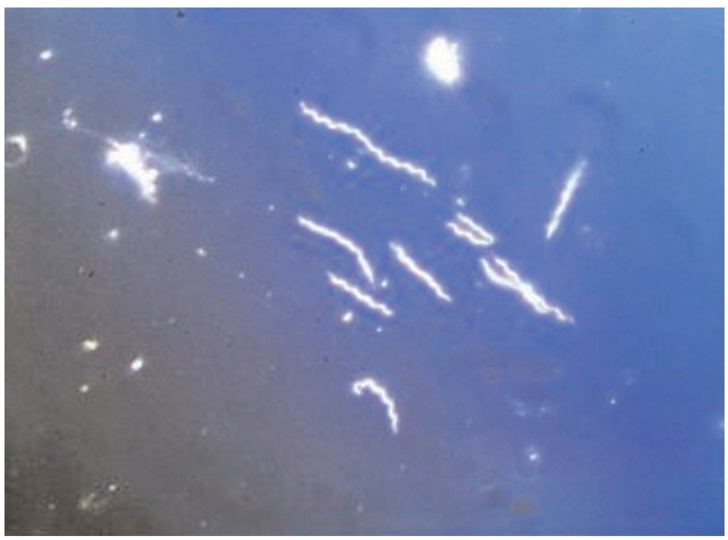
Testing of fleas, ticks, mosquitoes, and biting flies reveals them to be clear of any known pathogenic agents.

(Follow-up test on insect vectors for unidentified pathogen available—study FB3c)

Study FB3c Results

The study reveals a bacterial pathogen that has never been documented before! The pathogenic agent was isolated in the midgut of the deer tick, and on the basis of its traits appears to be a member of the genus *Borrelia*. This type of bacterium is known as a spirochete and is often associated with relapsing fever of its host. The discovery is the 21st species of the *Borrelia* genus and is given the species name *burgdorferi* after the scientist who first isolated it.

It is also noteworthy that the bacterium is similar to the one that causes syphilis—both are spirochetes.



Borrelia burgdorferi are helical-shaped bacteria about 10–25 _m long.
www.cdc.gov/ncidod/dvbid/lyme/bburgdorferi.htm

Notify your supervisor at once! Additional funding will be secured to expand your research to include additional studies, known as the ADL series.

Study FB4 Results

The wildlife populations are all growing with the increasing habitat of the region. Deer populations have grown dramatically in the past 10 years—doubling in that time. To date, hunting has not been successful in stabilizing their numbers, and it is becoming increasingly common to see deer browsing on lawns and around homes.

Historically, deer populations have risen in the past two centuries because of the elimination of their chief natural enemies, the wolf and the panther.

(Follow-up study of deer range available—study FB4b)

Study FB4b Results

The individual white-tailed deer (*Odocoileus virginianus*) generally has a home range of a few miles most of the year. The range expands when food availability decreases, herd numbers increase, or both. Deer are found to be extraordinarily abundant in abandoned fields and pastures, which then become covered with trees and brush.

Nationally, white-tailed deer range from northern New England to as far south as Virginia, and as far west as Illinois and the Lake Superior region.

Study FB5 Results

Several strange behaviors of wildlife have been documented recently:

- Rodents were observed on several occasions running in circles at odd times and places, sometimes in the middle of the road.
- An early fall drove many rodents (mice in particular) into homes in the community this year.
- The deer harvest was exceptionally large this year because of the large herd. The number of tick parasites on each deer rose dramatically over the past year.

(Follow-up study on testing insect vectors for known pathogens available—study FB5b)

Study FB5b Results

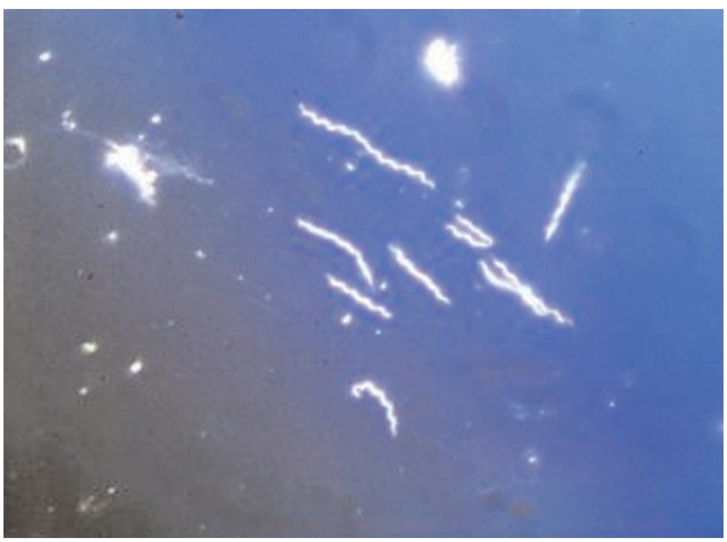
Testing of fleas, ticks, mosquitoes, and biting flies reveals them to be clear of any known pathogenic agents.

(Follow-up test on insect vectors for unidentified pathogen available—study FB5c)

Study FB5c Results

The study reveals a bacterial pathogen that has never been documented before! The pathogenic agent was isolated in the midgut of the deer tick, and on the basis of its traits appears to be a member of the genus *Borrelia*. This type of bacterium is known as a spirochete and is often associated with relapsing fever of its host. The discovery is the 21st species of the *Borrelia* genus and is given the species name *burgdorferi* after the scientist who first isolated it.

It is also noteworthy that the bacterium is similar to the one that causes syphilis—both are spirochetes.



Borrelia burgdorferi are helical-shaped bacteria about 10–25 _m long.
www.cdc.gov/ncidod/dvbid/lyme/bburgdorferi.htm

Notify your supervisor at once! Additional funding will be secured to expand your research to include additional studies, known as the ADL series.

Study FB6 Results

Insect numbers are on the rise due to snowy winters (snow insulates the ground) and hot, dry springs and summers. Mosquitoes, deer flies, fleas, and ticks are the most abundant.
(Follow-up study on testing insect vectors for known pathogens available—study FB6b)

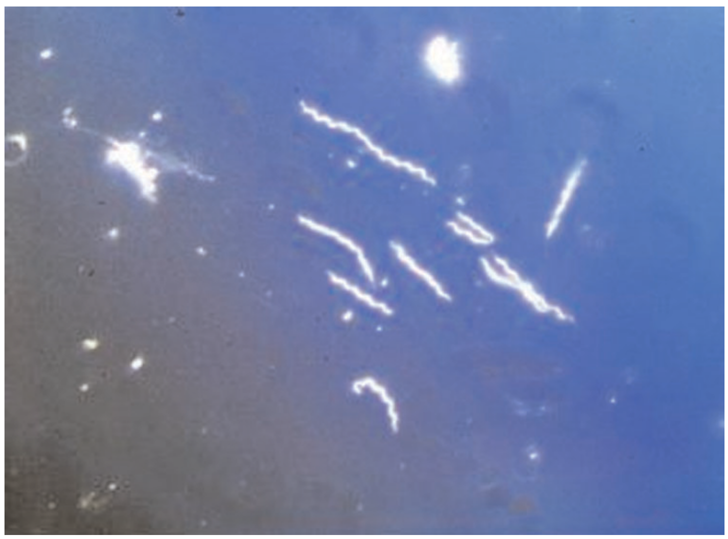
Study FB6b Results

Testing of fleas, ticks, mosquitoes, and biting flies reveals them to be clear of any known pathogenic agents.
(Follow-up test on insect vectors for unidentified pathogen available—study FB6c)

Study FB6c Results

The study reveals a bacterial pathogen that has never been documented before! The pathogenic agent was isolated in the midgut of the deer tick, and on the basis of its traits appears to be a member of the genus *Borrelia*. This type of bacterium is known as a spirochete and is often associated with relapsing fever of its host. The discovery is the 21st species of the *Borrelia* genus and is given the species name *burgdorferi* after the scientist who first isolated it.

It is also noteworthy that the bacterium is similar to the one that causes syphilis—both are spirochetes.



Borrelia burgdorferi are helical-shaped bacteria about 10–25 _m long.
www.cdc.gov/ncidod/dvbid/lyme/bburgdorferi.htm

Notify your supervisor at once! Additional funding will be secured to expand your research to include additional studies, known as the ADL series

Health and Sanitation Department Study Results

Study HD1 Results

The food sampled from both markets and preparation sites (restaurants) is found pure and free of known toxins or pathogenic organisms.

Study HD2 Results

Wells of each of the known patients were tested and found free of both toxins and pathogenic organisms.

Study HD3 Results

Water-quality tests were negative for toxins or pathogen; this is unchanged from previous results of monitoring conducted over the past several years around the community.

Study HD4 Results

The air quality has not deteriorated in the past several years. The air quality has actually improved over the past 20 years since a practice of burning marsh grasses each season was banned by the EPA two decades ago.

Study HD5 Results

Studies are inconclusive. No toxin was consistently present in all patient homes. The toxins present were often well within allowable limits.

Study HD6 Results

No detectable deterioration in ocean water quality has occurred in the past several months.

Additional Study Results

Study ADL1 Results

Tick life cycles are characterized by the frequency of feeding and the number of individual hosts that are required to complete the life cycle. Members of the genus *Ixodes* feed upon three different individual hosts, but not necessarily different host species. *Ixodid* ticks have four life stages: egg, larva, nymph, and adult. Larvae hatch from eggs on the forest floor in midsummer and feed on a host for a blood meal. Larvae then molt into nymphs and remain in the duff layer (leaf litter) through the winter. Host-seeking nymphs become active in late spring. After feeding, they fall to the ground and molt into adults. Adults seek out larger animals in the fall and winter, and then lay eggs on the forest floor.

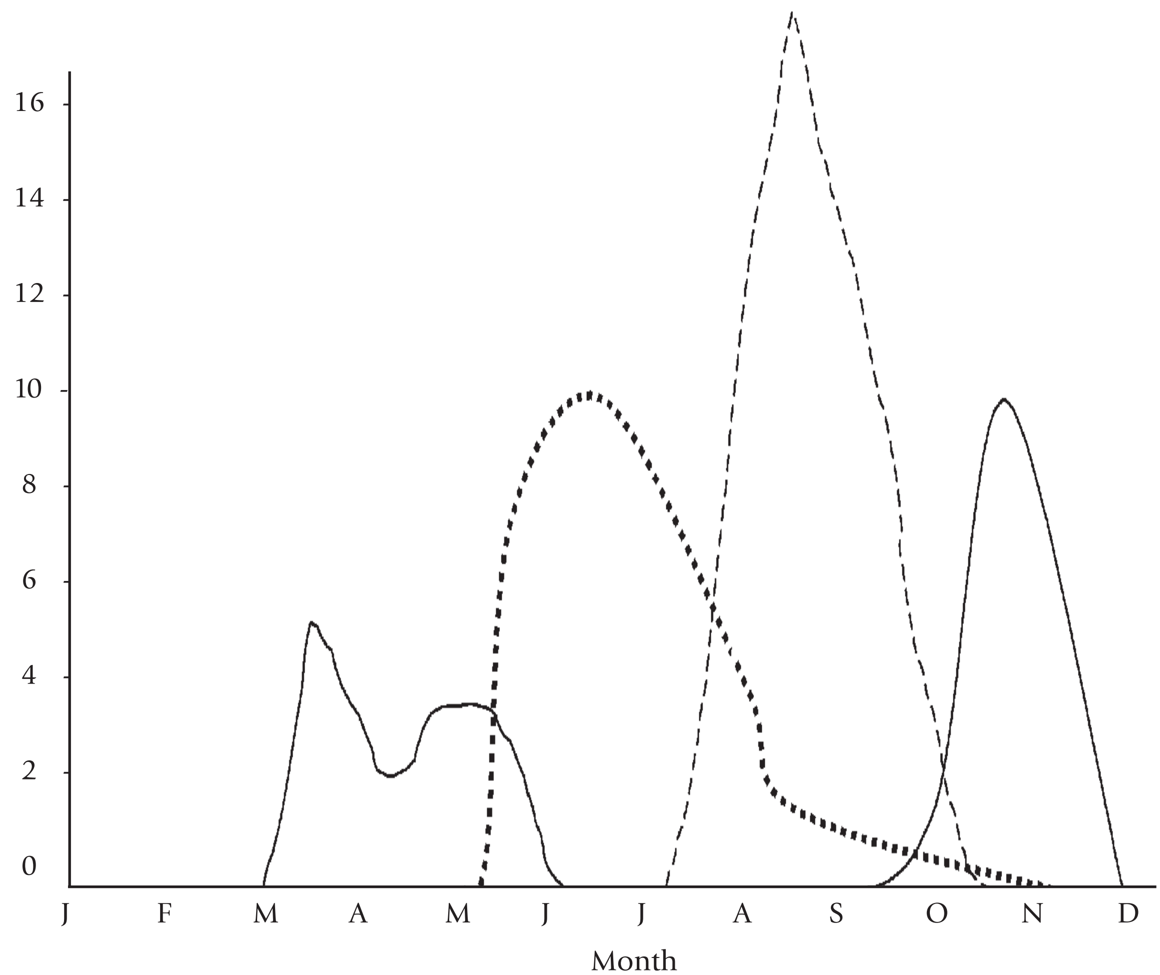
From left to right: The deer tick (*Ixodes scapularis*)
adult female, adult male, nymph, and larva
on a centimeter scale
www.cdc.gov/ncidod/dvbid/lyme/

(Follow-up study of deer tick seasonality available—study ADL1b)

Study ADL1b Results

Seasonal activity of the deer tick (*Ixodes dammini*) is dependent upon the developmental stage of the tick. The activity of each stage is represented in the graphic below:

Seasonal Activity of *Ixodes dammini*
(Courtesy of Thomas J. Daniels, New York Medical College)



(Follow-up study of host preference of adult, nymph, and larva available—study ADL1c)

Study ADL1c Results

Deer tick larvae and nymphs are rather immobile and seek a host that is in direct contact with the forest floor. Adults are more mobile—capable of climbing vegetation and dropping on a host. The most common host for each stage is summarized below:

Larvae and nymphs:	*White-footed mouse (*Peromyscus leucopus*) Raccoon (*Procyon lotor*) Meadow vole (*Microtus pennsylvanicus*) Short-tailed shrew (*Blarina brevicauda*) Eastern chipmunk (*Tamias striatus*)
Adults:	*White-tailed deer (*Odocoileus virginianus*) Domestic dogs and cats Humans

*Preferred host

(Follow-up study of deer tick mortality in the wild available—study ADL1d)

Study ADL1d Results

Engorged adult deer ticks can lay up to 3,000 eggs. This can lead to potentially 4.5 million offspring in just two generations. The great majority does not survive to adulthood. Factors that contribute to tick mortality include

Winter
Fungi
Bacteria
Viruses
Predatory ants
Wasps
Filarial worms

It is noteworthy that the deer tick has few natural enemies (predators).

Study ADL2 Results

Of the 40 deer sampled in the region, 4 (10%) had antibodies for the spirochete bacteria *B. burgdorferi*.

(Follow-up study of rodent exposure to *B. burgdorferi* available—studyADL2b)

Study ADL2b Results

Of the white-footed mice tested in the region, 81% had antibodies for the spirochete bacteria. This establishes the mouse as the "reservoir" for the bacteria in the wild.

Wednesday, May 29, 2002

Dr. Allen Steele, M.D.
Director of Epidemiology
Yale Medical Center
600 Howard Ave.
New Haven, Connecticut 06510

Re: Report of findings, memo #3

Dear Colleagues:

I want to commend you on your apparent discovery of the cause of Emyl arthritis. I understand the root causes are quite complex, so I am looking forward to your report of findings. For the record, I need to have you include

A) The chief cause or causes of the illness in detail

B) Your proposal as to what should be done in the coming weeks within the community and region to head off its continuation and/or spread

Since no one is as knowledgeable as your team as to the root causes of the epidemic, your recommendations will be taken very seriously and implemented wherever possible. **I'm certain you will use discernment in formulating a plan that is both effective as well as ethical**. I'll look forward to your report and recommendations.

Sincerely,

Dr. Allen Steele
Supervisor of Epidemiological Research

Tuesday, May 28, 2002

Dr. Allen Steele, M.D.
Director of Epidemiology
Yale Medical Center
600 Howard Ave.
New Haven, Connecticut 06510

Re: Emyl research expansion, memo #2

Dear Colleagues:

I have forwarded your preliminary findings concerning the Emyl arthritis outbreak and your request to broaden your investigation to the clinic board of directors. I am pleased to inform your research team that permission has been granted, and additional funding has been allocated to expand your research to include health and sanitation as well as field studies.

A team from the county board of health will be able to perform the testing you seek. In addition, a group of field biologists from Yale University will conduct any field studies you deem necessary to shed light on this situation in Emyl. I have included a list of health and field studies that your research team may now perform.

I have received word that the number of those afflicted has climbed since my meeting with Mrs. Murray last week. It is vital that we uncover the cause or causes as soon as possible. I look forward to a full report from your team on this matter and what can or should be done to manage this problem.

Sincerely,

Dr. Allen Steele

Supervisor of Epidemiological Research

Friday, May 24, 2002

Dr. Allen Steele, M.D.
Yale Medical Center
600 Howard Ave.
New Haven, Connecticut 06510

Re: New project research, memo #1

Dear Colleagues:

Two weeks ago, a resident of Emyl, Connecticut, named Polly Murray was referred to our staff regarding a series of unexplained illnesses that she and her family have been suffering for some time. Yesterday Mrs. Murray and I met and discussed her family's medical history at length. Frankly, I have never heard of so many bewildering recurrent symptoms as she described. She and her family have seen numerous general practitioners and specialists but without diagnosis or sustained relief from ailments. What is particularly disturbing is that she believes there may be 35 other possible cases in that same area of Emyl, Connecticut. There appears to be no known disease that fits the description of what seems of be happening in that geographical area. I believe it is safe to say something highly unusual is happening in this tiny community.

As your supervisor, I am recommending you lay aside all previous projects and launch a full-scale epidemiological investigation into this outbreak to determine its origin and eventual management.

I have secured funding for the initial studies, but as always **I will need a full account of your actions taken as well as your results**. Be diligent in documenting your research in your research log.

If your investigation requires expansion into health or field studies, we will need to secure further funding. This should not be a problem, but you will need to inform me **in writing** as to your findings and justification for the expansion.

I have included a transcript of my notes taken from Friday's meeting with Mrs. Murray for your analysis. I'll look forward to your initial report of what you learn in a couple of days.

Sincerely,

Dr. Allen Steele

Supervisor of Epidemiological Research

Thursday, May 23, 2002

Notes from interview with Mrs. Murray, resident of Emyl, Connecticut

- She and her family experienced severe joint swellings, unusual rashes over the past several years.
- Her symptoms began over 10 years ago.
- Mrs. Murray has had multiple hospitalizations—persistent episodic symptoms include fever, joint pain, rashes, headaches, neurological problems, sore throats, and gastrointestinal and inflammatory disorders.
- She and family members suffer from prolonged bouts of insomnia.
- She has had many tests over the years for collagen-type disorders—all inconclusive.
- Mr. Murray recently developed an enormous circular rash that curved from underarm onto back.
- Two sons and husband seemed to be falling victim to the same affliction.
- This might be a growing regional health problem; she has discovered as many as 35 other cases similar to her own family's.
- Joint problems often migrate from joint to joint.
- Antibiotics often helped, but symptoms often recur.
- She noticed even the family dog appears sick, with periods of lameness, twitching limbs.
- Other mothers noticed an unusually high incidence of joint problems in the region, often diagnosed as rheumatic fever or juvenile rheumatoid arthritis (JRA).

Research Log

Questions/Inferences	Actions Taken	Results

Appendix B
Teacher Materials

Possible Questions for Reflection

- Describe an inference that your team made that turned out to be accurate.
- Describe an inference that your team made that turned out to be inaccurate.
- Emergent diseases often occur as a result of environmental changes. What possible environmental trigger or triggers occurred to instigate this event?
- Because the symptoms of the disease are caused by a bacterium, the possibility for the development of a vaccine exists. Should this be initiated considering the circumstances?
- Since the disease is triggered by a bacterium, should doctors simply place the entire town on a regular regimen of antibiotics as a precaution?
- List some actions that could put someone at risk for contracting this illness.
- Discuss the various ways this disease could be spread:
- From organism to organism
- From region to region
- Who should pay for the implementation of your plan to stop the outbreak?
- List some costs to humans and to society that this disease causes. Compare this cost to that of other diseases such as AIDS, cancer, malaria, etc.
- Should pesticides be used in the control of ticks?
- Assuming that the elimination of all the deer is effective at halting the disease's spread,

should organized hunting take place? What are the implications of a more humane approach to rising deer numbers (such as darting and transporting deer out of the region)?

- How risky is it to allow or even encourage wildlife to visit residential property?
- If the high population of the white-tailed deer is a contributor to this disease and its spread, should a natural predator be introduced to reduce their numbers?
- What obligations do the local and national government have in protecting people from Lyme disease? How far do these obligations extend?
- How important a health issue is Lyme disease?

Suggested Instructional Outline for A Ticking Time Bomb

Day 1: Introduce simulation, form groups, outline expectations, discuss assessment rubric, give teams folder of initial documents, assign roles, groups discuss significant facts and inferences, record questions, note possible significant details. **(Conduct informal performance assessments of individuals/groups, answer questions as needed.)**

Day 2: Regroup, distribute initial epidemiological study options, outcomes, follow clues, pen/submit a letter to supervisor reporting findings and requesting expansion of studies to include health and field studies. **(Check attendance, conduct informal performance assessments of individuals/groups, critique written requests for funding, answer questions as needed.)**

Day 3: Regroup, receive feedback from supervisor/hospital board, discuss/choose health and field biology option(s) and record results. Students may move on to determining source of public contact—discuss/choose study option(s) and record results. Pen/submit letter to supervisor reporting findings and requesting expansion to include additional study options. **(Check attendance, conduct informal performance assessments of individuals/groups, critique written requests for funding, answer questions as needed.)**

Day 4: Groups work to discover source of illness through further health and field biology studies and record results and/or pen/submit letter to supervisor reporting findings and requesting expansion to include additional study options, or receive feedback from supervisor/hospital board, discuss and choose tick-human link study(ies) and record results. Begin to prepare a summary of the outbreak and short-term intervention proposal (solution). **(Check attendance, conduct informal performance assessments of individuals/groups, critique written requests for funding, answer questions as needed.)**

Day 5: Optional loop back to any studies (epidemiological, health, field biology, or additional). Complete all studies, begin or continue to write comprehensive summary and solution to situation. **(Check attendance, conduct informal performance assessments of individuals/groups, critique written requests for funding, answer questions as needed.)**

Day 6: All study options terminated, full attention in groups given to pooling information for written summary and intervention/management plan, submit. **(Check attendance, conduct informal performance assessments of individuals/groups, answer questions as needed, score the summaries and management plans according to the guidelines of the assessment rubric.)**

Day 7: Discuss as a class the various management plans of the groups, reveal various nuances of the simulation, reveal the true identity of the outbreak as Lyme disease. **(Provide students with their individual and group assessments.)**

Evaluation: Scoring based on three categories:

1. Personal behavior/involvement

*2. Group cooperation and productivity

*3. Written correspondence with supervisor/proposed solution

*Group score

Studies Flow Chart

Facilitator Resource (Do not give to students)

In order to regulate the flow of information to mirror the actual historical progression of Lyme disease discoveries, it is necessary to create pathways for study options and results. Taking certain options leads to questions and/or discoveries that otherwise would be unknown or unanticipated. Therefore, some study options are withheld until the preliminary study has been chosen. This is seen three times in the initial epidemiological studies (study options A through W). Choosing study A (holding a town meeting) leads to the optional studies AA1 and AA2 (two follow-ups on cases that would otherwise be undiscovered). This also occurs in study choice I (followed up by optional study II) and in study choice U (followed up by optional study UU).

Once permission has been granted to expand the research (see directions for days two and three), health studies and field studies may be performed. Here the progression of study options hinges greatly on choices made. The most understandable way to convey the progression is through a flow chart of choices (see below). Note that additional studies (ADL studies) can only be known to research teams once the cause of the illness has been discovered (results of FB3c, FB5c, and/or FB6c).

Study	To Get To	To Get To	To Get To	To Get To	To Get To	To Get To
FB1						
FB2						
FB3	FB3b	FB3c	ADL1	ADL1b	ADL1c	ADL1d
			ADL2	ADL2b		
FB4	FB4b					
FB5	FB5b	FB5c	ADL1	ADL1b	ADL1c	ADL1d
			ADL2	ADL2b		
FB6	FB6b	FB6c	ADL1	ADL1b	ADL1c	ADL1d
			ADL2	ADL2b		

Additional Information about How the Simulation Aligns with The National Science Education Standards

The National Science Education Standards include what is referred to as unifying concepts and processes, such as

- Systems, order, and organization
- Constancy, change, and measurement
- Evidence, models, and explanation
- Evolution and equilibrium
- Form and function.

The simulation incorporates each of these unifying concepts to a degree, with a particular emphasis on "evidence, models and explanation." Students are constantly challenged by questions, evidence, and a readjustment of their conceptual models in light of the new evidence.

The National Science Education Standards also include content standards for life science for grades 9–12. Four of the six are particularly strong in the simulation:

- Biological evolution
- Interdependence of organisms
- Matter, energy, and organization in living systems
- Behavior of organisms (NSES, p.181)

Finally, the National Science Education Standards list science in personal and social perspectives for grades 9–12. Each of these perspectives is very strongly addressed in the simulation. These include

- Personal and community health
- Population growth
- Natural resources
- Environmental quality
- Natural and human-induced hazards
- Science and technology on local, national, and global levels

Relative to assessment, the National Science Education Standards envision systemic change that seeks to place a greater emphasis on

- Assessing rich, well-structured knowledge
- Assessing scientific understanding and reasoning
- Assessing achievement and opportunity to learn

Again, the simulation incorporates such assessment in both the formative sense (along the way) and in a summative sense (at the end) utilizing written and performance-based assessments that are rubric scored.