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Disease Outbreak Investigation

Flora Ichiou Huang
Biology and Geo-Science Department
Stuyvesant High School
New York, New York

and

Manuel Bayona
Department of Epidemiology
School of Public Health
University of North Texas
Fort Worth, Texas

Contents

Introduction

Objective

This module aims to illustrate, with historical examples, the steps by which analysis of patterns of disease occurrence leads to understanding of the spread and control of important diseases.

Background

The study of epidemiology involves understanding certain patterns that exist in the occurrence of different diseases. This study is not just confined to infectious diseases. Epidemiologists also focus on environmental diseases extensively, and even chronic diseases such as heart disease and diabetes, because these diseases also affect different segments of the population differently.

By understanding the patterns of a certain disease, an epidemiologist can use this information to determine the cause of a sudden outbreak of a known disease or to investigate the cause of an outbreak of an unknown disease by comparing it with known diseases that have similar characteristics. For example, one can compare a newly discovered mosquito-borne disease with other known mosquito-borne or vector-borne diseases.

The purpose of the lessons in this module is to help students learn what an epidemiologist must do to investigate the cause of an epidemic. These investigations help epidemiologists find out how to control a current outbreak of a disease and to prevent further outbreaks of the disease. Lessons such as these can be used in an environmental science, biology or statistics class. The lesson on cholera can also be taught in a history class, and the lesson on the leukemia cluster discovered in Woburn, Massachusetts, can also be taught in a government or political science class.

Organization

There are three lessons in this module. The first is a lesson that introduces students to a standard food-borne outbreak investigation. The second lesson introduces students to the scientific investigations done by John Snow on the bacterial disease cholera. The last lesson focuses on a noninfectious disease—in this case the leukemia cluster that was discovered in

Woburn, Massachusetts, which inspired the book and movie *A Civil Action*. Students learn how environmental diseases are investigated.

The lessons on the food-borne and cholera outbreak investigations can be taught in a biology class when the digestive system is being covered. The John Snow–cholera lesson and the leukemia cluster lesson can also be taught in an environmental science class. Because the lessons involve a lot of number crunching, they can also be used in a math and statistics class.

Lesson Plan

SUBJECT AREA: Biology, environmental science, statistics, social studies.

OBJECTIVES:

- To familiarize students with the steps that are taken to conduct an epidemic investigation, particularly for an unknown disease
- To demonstrate how students can apply the knowledge they have learned in their science, math and social studies to investigate an outbreak investigation
- To show students the similarities and differences between the investigations of an infectious and environmental disease
- To illustrate the procedures of an outbreak investigation by using historical cases of outbreak investigations

TIME FRAME: Two to three 40-minute periods for each lesson.

PREREQUISITE KNOWLEDGE:

- Nature of infectious and environmental diseases
- Understanding of the biological, ecologic and social factors that promote the spread of a disease

MATERIALS NEEDED:

- Handouts that are included in this module
- Access to the Internet for some of the assignments
- Arithmetic calculator for some of the assignments

PROCEDURE: Students will perform the class exercise that is related to a particular outbreak investigation. The module includes three lessons related to a particular outbreak investigation. Two lessons deal with infectious disease, and the third one centers on an environmental disease. Two of the lessons are historical cases that help students learn what was done in the past to investigate famous outbreaks.

Teachers do not need to assign all three to their students because each lesson can be taught separately. However, the lessons on John Snow–Cholera and the leukemia cluster in Woburn, Massachusetts, complement each other very well. The food-borne outbreak lesson can also follow the John Snow–Cholera lesson.

ASSESSMENT: Quizzes and assignments are included in each of the three lessons.

LINKS TO STANDARDS:

National Science Education Standards:

- Identify questions and concepts that guide scientific investigations
- Design and conduct scientific investigations
- Use technology and mathematics to improve investigations and communications
- Formulate and revise scientific explanations and models using logic and evidence
- Recognize and analyze alternative explanations and models
- Communicate and defend a scientific argument
- Develop an understanding of:
  - Personal and community health
  - Environmental quality and natural resources
  - Natural and human-induced hazards
  - Science and technology and in local, national and global challenges
  - Science as a human endeavor
  - Nature of scientific knowledge
  - Historical perspectives

Available at: http://www.nap.edu/readingroom/books/nses/html/6e.html

National Social Studies Standards:

- Social studies programs should include experiences for the study of people, places and environments.
- Social studies programs should include experiences that provide for the study of relationships among science, technology and society.
- Social studies programs should include experiences that provide for the study of interactions among individuals, groups and institutions.
- Social studies programs should include experiences that provide for the study of global connections and interdependence.

Available at: http://www.socialstudies.org/standards/2.0.html

REFERENCES: Included in each lesson.

GLOSSARY: Included in each lesson.

Lesson Outlines

Lesson 1: Food-Borne Outbreak

Topics Covered:

- General symptoms and pathologies of food-borne gastrointestinal illnesses
- Attack rate for different types of food eaten and not eaten
- Relative risk of eating one type of food, as opposed to not eating that type of food
- Developing an epidemic curve to determine some characteristics of the illness that is being investigated
- Proper food-preparation handling practices that prevent the occurrence of food-borne illnesses

Lesson Activities:

- Students are given a scenario of determining the source of a food-borne illness.
- Students are given data, which they will use to calculate the attack rate for each type of food, determine the relative risk of eating a particular type of food, as opposed to not eating that type of food, and determine the mean and median onset time by creating an epidemic curve.
- Students will also compare the statistical information with the way the food was prepared.
- Students can work in groups on this activity.

Lesson Outcome:

- Develop a better understanding of food-borne gastrointestinal illnesses
- Learn proper food-preparation handling methods that prevent food-borne illnesses
- Understand how food-borne investigations are carried out

Lesson 2: Cholera and the Investigations of John Snow

Topics Covered:

- Etiology, transmission and pathology of cholera
- Environmental influence on the spread of many infectious diseases, such as cholera

- Social conditions during Victorian London that promoted the spread of cholera
- Snow's statistical approach to investigating the occurrence of cholera
- Logical steps Snow took to investigate the mode of transmission of cholera

Lesson Activities:

- A Web-based assignment is given, in which students will answer questions based on articles related to the subject, a Web site created by the Dr. Ralph Frerichs of the University of California, Los Angeles (UCLA) School of Public Health, and any other relevant material.
- By working on these questions students will see how the logical sequence of steps that Snow took led him to the source of the spread of cholera.
- Students will compare cases of the nineteenth-century London outbreaks of cholera with more recent cases of cholera.

Lesson Outcome:

- Understand how Snow's investigation helped pioneer the science of epidemiology
- Understand the role of socioeconomic and ecologic–environmental factors and their influence on promoting the spread of a disease

Lesson 3: Case Study of a Leukemia Cluster in Woburn, Massachusetts

Topics Covered:

- Investigation of the source of pollutants for an environmental disease
- The data that must be collected to investigate an environmental disease
- Determining whether a perceived disease cluster is actually real and causal
- The Superfund Program that was established by the Environmental Protection Agency (EPA)

Lesson Activities:

- Students will analyze events that occurred in the early to mid-1970s that led to the suspicion that contaminated groundwater was the source of the leukemia cluster.
- Students will review the data to understand how Anne Anderson began to suspect that the water from Wells G and H was the source of this childhood leukemia cluster.
- Students will learn how the legal actions of the citizens of Woburn, Massachusetts, and the EPA's own investigation eventually led to the litigation of the polluters in this case.

- Students will review the current status of this case, which is found on the EPA's Superfund Web site
- Students can compare this case with leukemia clusters suspected in other areas.
- Showing clips of the movie *A Civil Action* would supplement this lesson very well.

Lesson Outcome:

- Understand how environmental disease investigations are done
- Learn about the legal and logistical difficulties in proving the source of an environmental disease cluster
- Understand how citizens can take action to fight for the health and well-being of themselves and their community
- Learn what is being done to prevent environmentally induced diseases
- Compare this case with the John Snow cholera cases (for those students who worked on both Lessons 2 and 3)

Concepts and Procedures

Definitions

An **outbreak** or an **epidemic** is the occurrence of a health-related event (illness, disease complications and health-related behavior) clearly in excess of the normal expectancy. An epidemic may include any kind of disease, including noninfectious conditions.

There is no general rule about the number of cases that must exist for an outbreak to be considered an epidemic. Rather, an epidemic exists when the number of cases exceeds that of what is expected on the basis of past experience for a given population. For example, one case of smallpox would constitute an outbreak. There is no rule on geographic extent. An outbreak could be in only one area or in several countries. When an epidemic spreads in several countries, usually affecting many people, it is called a **pandemic.** Most flu epidemics that occur during the winter are pandemics. AIDS is considered a pandemic disease.

An outbreak may encompass any time period. It may last a few hours (bacterial food poisoning), a few weeks (hepatitis) or several years (acquired immunodeficiency syndrome, or AIDS).

Endemicity refers to the usual permanence of a disease or infection in a defined geographic area or population group. Therefore an endemic disease is a disease that happens constantly in an area. For example, hepatitis A is endemic in most states of the United States, especially in the southern part of the country.

Purpose and Objectives of an Epidemic Investigation

The purpose of an epidemic or outbreak investigation is to identify ways to prevent further transmission of the disease.

The three main objectives of an epidemic outbreak investigation are to:

1. Identify the responsible etiologic agent.
2. Find the source of infection by studying the occurrence of the disease among persons or in a place or time, as well as determining specific attack rates.
3. Formulate recommendations to prevent further transmission.

Why Epidemics Occur

There are many reasons why an outbreak occurs. However, four common circumstances lead to an epidemic. These are:

1. When susceptible individuals travel into an endemic area where the infectious disease exists.

2. When a new infectious disease is introduced by humans or animals traveling from an endemic area into a susceptible human population in whom the disease is not endemic, or when contamination of food, water or other vehicles takes place by an agent not normally present, such as cyanide (a poison) introduced into Extra Strength Tylenol® accidentally or anthrax spores placed into mail as a terrorist act.

3. When a preexisting infection occurs in an area of low endemicity and reaches susceptible persons as a result of new or unusual social, behavioral, sexual or cultural practices. Examples include migration of refugees during war time and pilgrimages to religious places and churches.

4. When host susceptibility and response are modified by natural or drug-induced immunosuppression (cancer treatment), malnutrition or diseases such as AIDS.

Outbreak Investigation Tasks

An outbreak investigation includes the following basic tasks:

- Define the problem and verify if an outbreak really exists by comparing the number of current cases with information from cases from previous months or years.

- Assemble and organize available health information for analysis.

- Formulate a hypothesis about the cause of the outbreak.

- Test the hypothesis by analyzing data on the distribution of the disease by person (age, gender, occupation), time (study the occurrence of cases of disease throughout time) and place (study the geographic distribution of the disease).

- This analysis is carried out by calculating the rate of disease for each age group, gender, occupation, geographic location and food item eaten. Once the rates are calculated, to find the source of the outbreak, they are compared and contrasted to learn which ones are significantly higher than the rest. For example, let's assume that during an outbreak the rate of disease in young children was 40% and in older individuals was 2%, and it was 65% for those who ate in a popular cafeteria and only 3% for those who ate in other places. Therefore young children eating in the popular cafeteria are the ones who should be investigated regarding specific foods eaten.

- Draw conclusions and make recommendations to prevent further transmission of the disease and prevent a new outbreak.

Why Some Outbreaks End

Outbreaks may end for the following reasons:

- No more susceptible individuals. Everybody who was susceptible got the disease.
- No more exposure to the source. The individuals move away from the source of infection.
- No more source of contamination. The source of contamination ends (all the contaminated food is consumed).
- Individuals decrease their susceptibility. People get immunized (are vaccinated) or use preventive measures to avoid disease.
- The pathogen becomes less pathogenic. Sometimes when some germs (bacteria, viruses, parasites, etc.) pass from one individual to another they change or mutate, becoming less pathogenic, or less capable of producing disease.

Common Interventions Used to Control an Epidemic

Interventions commonly used to control an epidemic are as follows:

- Control the source of the pathogen. Remove the source of contamination (e.g., discard contaminated food), remove persons from exposure (e.g., keep people from being exposed to mosquito bites to prevent West Nile virus encephalitis), inactivate or neutralize pathogen (e.g., disinfect and filter contaminated water) and/or treat infected persons (e.g., treat pregnant patients with AIDS to avoid transmission to the baby).
- Interrupt the transmission. Sterilize or disinfect environmental sources of transmission (e.g., milk, water, air), control mosquito or vector transmission using skin repellents, improve personal sanitation (e.g., washing hands before eating).
- Control or modify the host response to exposure. Immunize the susceptible hosts, use prophylactic chemotherapy, modify behavior or use a barrier (e.g., prevent exposure to mosquito bites by wearing protective clothing and repellents).

Recommended References

Friis RH, Sellers TA. *Epidemiology for Public Health Practice.* Gaithersburg, MD: Aspen Publishers; 1996.

Kelsey LJ, et al. *Methods in Observational Epidemiology.* 2nd ed. *Monographs in Epidemiology and Biostatistics.* New York: Oxford University Press; 1996.

Lilienfeld DE, Stolley PD. *Foundations of Epidemiology.* 3rd ed. New York: Oxford University Press; 1994.

Mausner JS, Kramer S. *Epidemiology—An Introductory Text.* Philadelphia: WB Saunders; 1985.

Lesson 1: Food-Borne Outbreak

Lesson Plan

SUBJECT AREA: Biology, mathematics and statistics, environmental science

OBJECTIVES:

- Introduce students to the principles of epidemic investigation
- Apply basic biology and mathematical knowledge to the study of causes of food-borne epidemics
- Apply descriptive and analytical techniques in epidemiology
- Apply the methods for epidemic investigation

TIME FRAME: Two 45-minute periods guided by the teacher.

PREREQUISITE KNOWLEDGE:

- Understanding of the etiology of infectious diseases, including a basic knowledge of microbiology
- Understanding of the measures of disease frequency and association used in epidemiology, including incidence rates and relative risk
- Understanding of the basic methods of outbreak investigation

MATERIALS NEEDED:

- Handouts included in this module
- Hand calculator

PROCEDURE:

- The teacher reviews with the students the basic methods for outbreak investigations and the calculation and interpretation of incidence rates and relative risk.
- The teacher reads and discusses with the students the background section.
- The teacher reads each question and allows time for the students to answer under her or his guidance.

Recommended References

Friis RH, Sellers TA. *Epidemiology for Public Health Practice*. Gaithersburg, MD: Aspen Publishers; 1996.

Kelsey LJ, et al. *Methods in Observational Epidemiology*. 2nd ed. *Monographs in Epidemiology and Biostatistics*. New York: Oxford University Press; 1996.

Lilienfeld DE, Stolley PD. *Foundations of Epidemiology*. 3rd ed. New York: Oxford University Press; 1994.

Mausner JS, Kramer S. *Epidemiology—An Introductory Text*. Philadelphia: WB Saunders; 1985.

NATIONAL SCIENCE EDUCATION STANDARDS:

Science as Inquiry

- Abilities necessary to do scientific inquiry
- Understanding of scientific inquiry

Science in Personal and Social Perspectives

- Personal and community health
- Natural and human-induced hazards

Unifying Concepts and Processes

- Systems, order and organization
- Evidence, models and measurement

Glossary

Attack rate

The cumulative incidence rate of infection or disease in a group over a period of an epidemic.

Epidemic curve

During an outbreak, the epidemic curve is a histogram of the distribution of cases of a disease or condition by time of onset. It is used to study the distribution of the disease by time. The shape of the epidemic curve is studied to determine the type of epidemic (i.e., point source, common source and propagated). The epidemic curve of point source epidemics can also be used to determine the probable time of exposure whenever the causative agent is known, by looking back in time one incubation period from the peak of the curve. The epidemic curve can also be used in point source epidemics in which the causative agent is unknown, as long as the time of exposure is known. Information about the probable causative agent can be obtained by assessing the approximated median incubation period (time between the known time of exposure and the peak of the curve). The incubation period for toxins is just a few hours, for some bacteria it could be days or weeks and for some viruses it could be weeks, months or even years, as for the human immunodeficiency virus (HIV).

Incidence rate

A measure of disease frequency that indicates the force of morbidity or the probability that a disease will develop in a given period of time. It is calculated by dividing the number of new cases by the total number of susceptible people at the beginning of the study period. As in other rates, the result is multiplied by a multiple of 10 to obtain whole (integer) numbers.

Onset (disease onset)

The beginning of the disease or condition under study.

Outbreak

An outbreak or epidemic is the appearance of an unusual number of cases of a disease or condition in a population in a given period of time and place. The number of cases is clearly in excess of normal expectancy. There is no minimum number of cases that defines whether an epidemic has occurred. For example, one case of smallpox would be an epidemic because smallpox was eradicated from the world more than 25 years ago, and no cases of disease have occurred since then.

Relative risk

The relative risk (RR) is a measure of association between a disease or condition and a factor under study. It is calculated by dividing the incidence rate of those exposed to the factor by the incidence rate of those not exposed to the factor. The RR is a measure of the relative relationship between incidence in the exposed and that in the nonexposed. If the RR = 1, this means that the incidence in the exposed is the same as the incidence in the nonexposed; thus there is no association between exposure and disease. RR > 1 denotes a larger incidence in the exposed than in the nonexposed; thus exposure to the factor seems to increase the probability of developing the disease. With the same reasoning, RR < 1 denotes a smaller incidence in the exposed than in the nonexposed; thus exposure to the factor seems to decrease the probability of developing the disease.

Food-Borne Outbreak (Student's Version of In-Class Exercise)*

Background

An outbreak (epidemic) of gastroenteritis occurred in Greenport, a suburban neighborhood, on the evening of April 28. A total of 89 people went to the emergency departments of the three local hospitals during that evening. No more cases were reported afterward. These patients complained of headache, fever, nausea, vomiting and diarrhea. The disease was severe enough in 19 patients to require hospitalization for rehydration. Gastroenteritis outbreaks like this are usually caused by the consumption of a contaminated or poisoned meal. Meal contamination can often be caused by pathogenic viruses or bacteria. However, acute outbreaks are more often produced by toxins from bacteria such as *Staphylococcius* spp., *Clostridium perfringens, Salmonella* spp. and *Vibrio cholerae*. Food poisoning can also be caused by chemicals or heavy metals, such as copper, cadmium or zinc, or by shellfish toxins.
Please discuss these findings.

Outbreak Investigation

The local health department was notified of a potential food-borne outbreak of gastroenteritis in Greenport, and the epidemic team, including a medical epidemiologist, a microbiology technician and a nurse, visited the local hospitals to interview the attending physicians, the patients and some of their relatives. Some stool samples were obtained from patients for microbiologic identification of the causative agent. The epidemic team knew that these types of outbreak usually occur in a very short time period that lasts no more than a few hours or one to two days after people ingest a contaminated meal.

***Note:** Teachers and students should note that the situation and data presented in this food-borne outbreak exercise have been made up. However, when epidemiologists investigate a food-borne outbreak such as this, they would follow similar procedures.

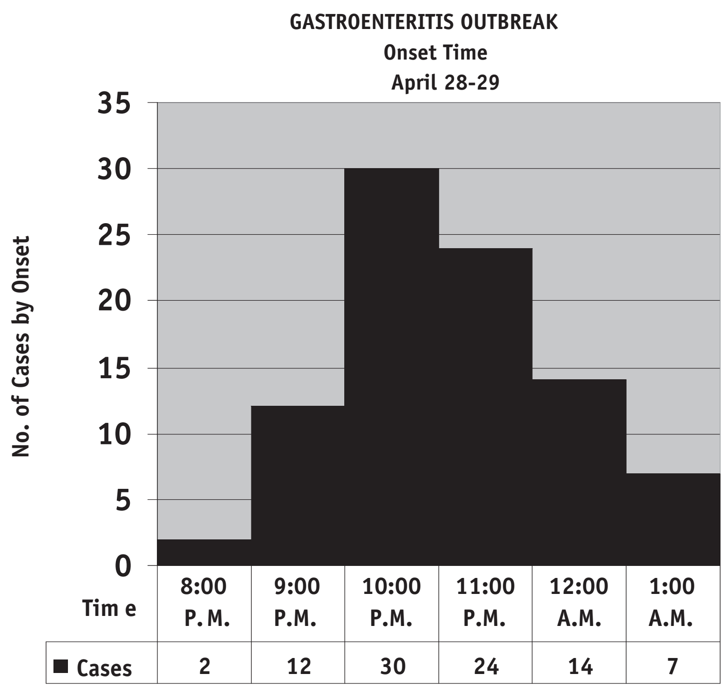
Epidemic investigators gather data to define the distribution of the disease by time (onset time and epidemic curve), place (potential places where the implicated meal was served, such as cafeterias, restaurants and picnics) and person (the distribution of the disease by age, gender and food items eaten). The findings of the initial investigation included the following information.

The distribution of the disease by person (age and gender) was found as follows:

Gastroenteritis Outbreak Findings by Person, Case Distribution by Age and Gender

	Females		**Males**		**Total by Age**	
Age Group (y)	**No.**	**% Females**	**No.**	**% Males**	**No.**	**%**
0–5	1		1			
6–10	38		37			
11 and older	10		2			
Total by gender						

Please calculate the totals for each column and row and their corresponding percentages to try to determine if there are any important differences by age or by gender. Such a task is carried out to investigate if there are any high-risk groups and if the age and gender distribution can give some clues about the source of the outbreak. Interpret your findings.



The epidemic curve above shows the onset time of illness in the 89 patients involved in the outbreak. The epidemic team studied the curve and recognized that this was a typical single source acute outbreak. The team also could see that the onset of symptoms in all patients occurred during a six-hour period. Given the symptoms mentioned above and the epidemic curve, the epidemic team concluded that this type of epidemic usually corresponds to intoxication or food poisoning and that the potentially implicated meal was probably served and consumed within a period of a few hours before the onset of the symptoms. Therefore the epidemic team investigated the places where affected persons, their relatives and neighbors ate that day (April 28). The following table shows the team's findings:

Gastroenteritis Outbreak Findings by Place

Place	People Who Attended	No. Ill	Attack Rate	People Who did Not Attend	No. Ill	Attack Rate	Relative Risk
Local cafeteria	207	61		157	47		
Local restaurant	246	25		122	13		
Lions Club luncheon	475	68		189	29		
Elementary school cafeteria	239	67		495	22		

Please calculate the attack rates per 100 (incidence rates per 100) by place to try to determine where the contaminated meal was served. For each place compare attack rates (AR) for those who attended with attack rates for those who did not, by using the relative risk (i.e., RR = AR in attendees/AR in nonattendees). Interpret your findings.

Once the implicated place was determined, the investigation centered on the food. The following table includes the food items served in that place on April 28:

Gastroenteritis Outbreak Findings by Person

	Ate the Food Item			Did Not Eat the Food Item			
Food Item	**No. People**	**No. Ill**	**Attack Rate**	**No. People**	**No. Ill**	**Attack Rate**	**Relative Risk**
Beef burritos	276	28		266	27		
Cheese burger	218	21		131	14		
Tossed salad	105	49		297	15		
Baked potato	139	11		213	31		
Fruit cocktail	88	48		279	25		
Ice cream	175	18		203	49		

Important note: None of the kitchen personnel were ill. The names of the kitchen personnel and their participation in the food preparation are as follows: Manuel prepared the beef burritos and the potatoes, John prepared the salad and the fruit, Sally served all dishes except the ice cream, and Jane prepared the cheeseburgers and served the ice cream. The ice cream was a commercial brand and was bought at a nearby supermarket.

Please calculate the attack rates per 100 (incidence rates per 100) by food item to try to determine the one that was probably contaminated. Compare attack rates (AR) for those who ate the food item with attack rates for those who did not eat the food item, by using the relative risk (i.e., RR = AR in those who ate the food/AR in those who did not eat the food). Interpret your findings.

Given that the epidemic team worked fast enough and the implicated meal(s) was (were) identified before all food leftovers were discarded, food samples from some meal leftovers were taken to the laboratory. In addition, stool samples were taken from the kitchen personnel who prepared or handled each different food item. The laboratory confirmed that *Salmonella* toxin was present in some of the food samples and that one of the kitchen personnel of that place had the same *Salmonella* species. Furthermore, the *Salmonella* species found in the food and the kitchen worker was the same species found in stool samples of the patients. *Please discuss these findings and identify the kitchen worker possibly responsible for the outbreak*.

Food-Borne Outbreak (Teacher's Answer Key to In-Class Exercise)*

Background

An outbreak (epidemic) of gastroenteritis occurred in Greenport, a suburban neighborhood, on the evening of April 28. A total of 89 people went to the emergency departments of the three local hospitals during that evening. No more cases were reported afterward. The patients complained of headache, fever, nausea, vomiting and diarrhea. The disease was severe enough in 19 patients to require hospitalization for rehydration. Gastroenteritis outbreaks like this are usually caused by the consumption of a contaminated or poisoned meal. Meal contamination can often be caused by pathogenic viruses or bacteria. However, acute outbreaks are more often produced by toxins from bacteria such as *Staphylococcus* spp., *Clostridium perfringens, Salmonella* spp. and *Vibrio cholerae*. Food poisoning can also be caused by chemicals or heavy metals, such as copper, cadmium or zinc, or by shellfish toxins.
Please discuss these findings.

Allow students to discuss this information and ask them questions about the nature of gastroenteritis and outbreak investigation. Ask if anybody has been a victim of an outbreak or learned about any outbreak in the newspaper.

Outbreak Investigation

The local health department was notified of a potential food-borne outbreak of gastroenteritis in Greenport, and the epidemic team, including a medical epidemiologist, a microbiology technician and a nurse, visited the local hospitals to interview the attending physicians, the patients and some of their relatives. Some stool samples were obtained from patients for microbiologic identification of the causative agent. The epidemic team knew that these types of outbreak usually occur in a very short time period that lasts no more than a few hours or one to two days after people ingest a contaminated meal.

Epidemic investigators gather data to define the distribution of the disease by time (onset time and epidemic curve), place (potential places where the implicated meal was served such as cafeterias, restaurants and picnics) and person (the distribution of the disease by age, gender and food items eaten). The findings of the initial investigation included the following information.

*__Note:__ Teachers and students should note that the situation and data presented in this food-borne outbreak exercise have been made up. However, when epidemiologists investigate a food-borne outbreak such as this, they would follow similar procedures.

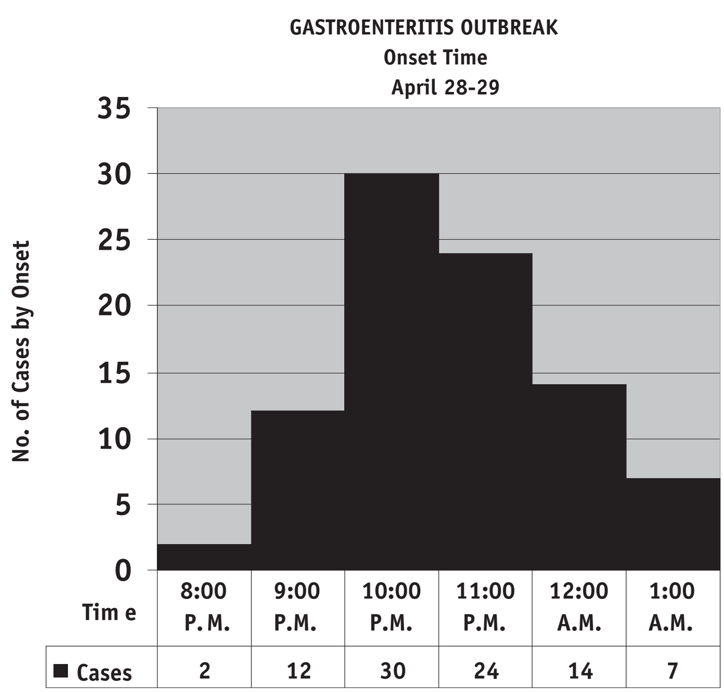
The distribution of the disease by person (age and gender) was found as follows:

Gastroenteritis Outbreak Findings by Person, Case Distribution by Age and Gender

	Females		Males		Total by Age	
Age Group (y)	**No.**	**% Females**	**No.**	**% Males**	**No.**	**%**
0–5	1	**50.0**	1	**50.0**	**2**	**2.2**
6–10	38	**50.7**	37	**49.3**	**75**	**84.3**
11 and older	10	**83.3**	2	**16.7**	**12**	**13.5**
Total by gender	**49**	**55.1**	**40**	**44.9**	**89**	**100**

Please calculate the totals for each column and row and their corresponding percentages to try to determine if there are any important differences by age or by gender. Such a task is carried out to investigate if there are any high-risk groups, and if the age and gender distribution can give some clues about the source of the outbreak. Interpret your findings.

Cases involving females are more numerous in the 11 and older age group (83.3%). The 6–10 age group includes 84.3% of the cases. Therefore the outbreak strongly affected children 6–10 and "adult" females. Allow students to discuss this idea until they arrive at the hypothesis that the outbreak may have happened in a local elementary school.



The epidemic curve above shows the onset time of illness in the 89 patients involved in the outbreak. The epidemic team studied the curve and recognized that this was a typical single source acute outbreak. The team also could see that the onset of symptoms in all patients occurred during a six-hour period. Given the symptoms mentioned above and the epidemic curve, the epidemic team concluded that this type of epidemic usually corresponds to intoxication or food poisoning and that the potentially implicated meal was probably served and consumed within a period of a few hours before the onset of the symptoms. Therefore the epidemic team investigated the places where affected persons, their relatives and neighbors ate that day (April 28). The following table shows the team's findings:

Gastroenteritis Outbreak Findings by Place

Place	People Who Attended	No. Ill	Attack Rate	People Who Did Not Attend	No. Ill	Attack Rate	Relative Risk
Local cafeteria	207	61	**29.5**	157	47	**29.9**	**0.99**
Local restaurant	246	25	**10.2**	122	13	**10.7**	**0.95**
Lions Club luncheon	475	68	**14.3**	189	29	**15.3**	**0.93**
Elementary school cafeteria	239	67	**28.0**	495	22	**4.4**	**6.4**

Please calculate the attack rates per 100 (incidence rates per 100) by place to try to determine where the contaminated meal was served. For each place compare attack rates (AR) for those who attended with attack rates for those who did not, by using the relative risk (i.e., RR = AR in attendees/AR in nonattendees). Interpret your findings.

The highest attack rates were found among those who ate in the local cafeteria (29.5 per 100) and at the elementary school cafeteria (28.0 per 100). However, those who did not eat at the local cafeteria had basically the same high attack rate (29.9 per 100), whereas those who did not eat at the school cafeteria had the lowest attack rate (4.4 per 100). Eating at a local restaurant or at the Lions Club seems not to be associated with the outbreak, as the relative risks are close to 1 (RR ≈ 1.0).

The relative risk for eating at the elementary school shows a strong association with the outbreak (RR = 6.4). These findings were somewhat expected because of the demographic distribution (age and gender) of the cases as shown in the first table.

Once the implicated place was determined, the investigation centered on the food. The following table includes the food items served in that place on April 28.

Gastroenteritis Outbreak Findings by Person

	Ate the Food Item			Did Not Eat the Food Item			
Food Item	**No. People**	**No. Ill**	**Attack Rate**	**No. People**	**No. Ill**	**Attack Rate**	**Relative Risk**
Beef burritos	276	28	**10.1**	266	27	**10.2**	**1.01**
Cheese burger	218	21	**9.6**	131	14	**10.7**	**0.90**
Tossed salad	105	49	**46.7**	297	15	**5.1**	**9.16**
Baked potato	139	11	**7.9**	213	31	**14.6**	**0.54**
Fruit cocktail	88	48	**54.5**	279	25	**9.0**	**6.05**
Ice cream	175	18	**10.3**	203	49	**24.1**	**0.43**

Important note: None of the kitchen personnel were ill. The names of the kitchen personnel and their participation in the food preparation are as follows: Manuel prepared the beef burritos and the potatoes, John prepared the salad and the fruit, Sally served all dishes except the ice cream, and Jane prepared the cheeseburgers and served the ice cream. The ice cream was a commercial brand and was bought at a nearby supermarket.

Please calculate the attack rates per 100 (incidence rates per 100) by food item to try to determine the one that was probably contaminated. Compare attack rates (AR) for those who ate the food item with attack rates for those who did not eat the food item, by using the relative risk (i.e., RR = AR in those who ate the food/AR in those who did not eat the food). Interpret your findings.

The largest attack rates were found for those who ate salad (46.7 per 100) and those who ate fruit cocktail (54.5 per 100). In fact, when these attack rates are compared with those from individuals who did not eat these items, the relative risks show strong associations for these two food items (RR = 9.16 and RR = 6.05, respectively). These two food items seem to be implicated as sources of the outbreak, as they probably were contaminated.

Baked potato and ice cream seem to have an important protective effect, as shown by their relative risks (RR = 0.54 and RR = 0.43). This protective effect is probably due to the choice of food menu at the school cafeteria. The menu selections were beef burritos or cheeseburger, salad or baked potato, fruit or ice cream. Therefore selection of the noncontaminated food item prevented the individual from selecting and eating the contaminated one.

Given that the epidemic team worked fast enough and the implicated meal(s) was(were) identified before all food leftovers were discarded, food samples from some meal leftovers were taken to the laboratory. In addition, stool samples were taken from the kitchen personnel who prepared or handled each different food item. The laboratory confirmed that *Salmonella* toxin was present in some of the food samples and that one of the kitchen personnel of that place had the same *Salmonella* species. Furthermore, the *Salmonella* species found in the food and the kitchen worker was the same species found in stool samples of the patients. *Please discuss these findings and identify the kitchen worker possibly responsible for the outbreak.*

Encourage students to integrate all the available evidence and find that John was very likely to be responsible for the outbreak, as he is a carrier of the *Salmonella* *species* **causing the outbreak. The food contamination probably occurred through poor personal hygienic practices such as not washing hands properly after going to the restroom and before preparing or handling food. To prevent another outbreak at the school cafeteria, John has to improve his hygienic practices. He certainly also needs to take antibiotic treatment to eliminate the** salmonella **organisms that probably are in his liver before he can go back to work. John is not allowed to report back to work until he has received treatment.**

This case is very similar to the Typhoid Mary case. The story of Mary Mallon is an interesting one to tell the students, and this exercise shows that such events can still happen. The only difference is that the science of epidemiology is now more advanced, so cases like this can be identified more quickly.

Food-Borne Outbreak Quiz (Student's Version)

One hundred and fifty people attended a charity luncheon in which two different menus were served. A total of 82 attendees reported symptoms including nausea, vomiting, abdominal cramps and diarrhea. Most of the 82 patients who became sick reported symptoms about six hours after the beginning of the luncheon. The symptoms lasted from four to seven hours. The dishes that were served included baked chicken, meat loaf, mashed potatoes and green beans. The table below shows the data collected from this investigation.

Charity Luncheon Outbreak Data

	Ate Food Item				Did Not Eat Food Item				
Food Item	**Ill**	**Not Ill**	**Total**	**Attack Rate**	**Ill**	**Not Ill**	**Total**	**Attack Rate**	**Relative Risk**
Meat loaf	13	65			64	8			
Baked chicken	64	8			13	65			
Mashed potatoes	11	56			36	31			
Green beans	32	18			35	31			

1. Calculate the total number of people who ate and did not eat each food item and try to elucidate the food items included in each of the two menus served. (1 point)

2. Calculate in the table above the attack rates per 100 for those who ate each food item. Can you tell which food item(s) was(were) responsible for the outbreak? (2 points)

3. Calculate in the table above the attack rates per 100 for those who did not eat each food item. Again, can you tell which food item(s) was (were) responsible for the outbreak? (2 points)

4. Calculate the relative risk of disease for each food item and identify the food item(s) responsible for the outbreak. (3 points)

5. Based on the information given in this scenario, why is it most likely that this food-borne illness is a case of food poisoning (food-borne intoxication) and not a food-borne infection? (2 points)

Food-Borne Outbreak Quiz (Teacher's Answer Key)

One hundred and fifty people attended a charity luncheon in which two different menus were served. A total of 82 attendees reported symptoms including nausea, vomiting, abdominal cramps and diarrhea. Most of the 82 patients who became sick reported symptoms about six hours after the beginning of the luncheon. The symptoms lasted from four to seven hours. The dishes that were served included baked chicken, meat loaf, mashed potatoes and green beans. The table below shows the data collected from this investigation.

Charity Luncheon Outbreak Data

	Ate Food Item				Did Not Eat Food Item				
Food Item	**Ill**	**Not Ill**	**Total**	**Attack Rate**	**Ill**	**Not Ill**	**Total**	**Attack Rate**	**Relative Risk**
Meat loaf	13	65	**78**	**16.7**	64	8	**72**	**88.9**	**0.3**
Baked chicken	64	8	**72**	**88.9**	13	65	**78**	**16.7**	**5.3**
Mashed potatoes	11	56	**67**	**16.4**	36	31	**67**	**53.7**	**0.3**
Green beans	32	18	**50**	**64.0**	35	31	**66**	**53.0**	**1.2**

1. Calculate the total number of people who ate and did not eat each food item and try to elucidate the food items included in each of the two menus served. (1 point)

   After calculation of totals and by looking at the large number of ill people among those who ate some of the food items, it is possible to guess that the two menus served were (1) meat loaf with mashed potatoes and (2) baked chicken with green beans.

2. Calculate in the table above the attack rates per 100 for those who ate each food item. Can you tell which food item(s) was(were) responsible for the outbreak? (2 points)

   Those who ate baked chicken and green beans had the largest attack rates. Either of these two or both could be responsible for the outbreak. However, it is necessary to calculate the attack rates among those who did not eat to confirm these hypotheses and, it is hoped, to find which food item was in fact responsible for the outbreak.

3. Calculate in the table above the attack rates per 100 for those who did not eat each food item. Again, can you tell which food item(s) was(were) responsible for the outbreak? (2 points)

   Those who did not eat baked chicken had the lowest attack rate whereas, those who did not eat green beans had an attack rate similar to the attack rate in those who did not eat mashed potatoes. Therefore it is possible that baked chicken was the only responsible item for the outbreak.

4. Calculate the relative risk of disease for each food item and identify the food item(s) responsible for the outbreak. (3 points)

   It is clear that eating baked chicken was a risk factor for the outbreak. In fact, chicken is probably the only food item implicated. Eating green beans had a relative risk above 1.0. However, those who ate green beans were only 1.2 times (20%) more likely to get sick, which is not a high risk. This is probably because the chicken menu included green beans.

   Notes: Meat loaf and mashed potatoes had a protective effect, as their relative risks were smaller than 1. This protective effect was due to the fact that eating these items prevented attendees from eating the contaminated item.

   People who ate only items that were not implicated in the outbreak and still got sick can be explained by, among other factors, any or all of the following reasons: (1) people shared food and did not report it; (2) people ate leftovers and did not report it; (3) kitchen or table utensils and silverware cross-contaminated food; (4) people forgot which food items were eaten; and (4) investigation questionnaires or investigators or both were not accurate or aggressive enough to collect accurate data.

5. Based on the information given in this scenario, why is it most likely that this food-borne illness is a case of food poisoning (food-borne intoxication) and not a food-borne infection? (2 points)

   Onset time occurred within a few hours (1 point), and duration time of illness also occurred in hours (1 point). These are typical symptoms of an acute food-borne intoxication and not an infection. You can also accept that fever was not present.

Lesson 2: Cholera and the Investigations of John Snow

Lesson Plan

SUBJECT AREA: Environmental science, history, biology; an ideal situation would be an interdisciplinary lesson of science, history, and math and statistics.

OBJECTIVES:

- To help students understand how John Snow developed a systematic method to use statistics to demonstrate that cholera was spread by water
- To help students understand how epidemiologists can discover the transmission or cause, or both, of an unknown disease, even when there is a lack of clinical understanding of this disease
- To familiarize students with the transmission and pathology of cholera so that they realize how devastating an outbreak of this disease can be
- To help students understand how the lack of basic environmental and public health infrastructure can trigger disease outbreaks
- To help students become more savvy with using the Internet as a resource to search for information

TIME FRAME: Two to three 45-minute periods. The lesson can progress faster if students work in groups. They can also do some of the work at home if they have access to the Internet.

PREREQUISITE KNOWLEDGE:

- An understanding of the transmission of infectious diseases, particularly gastrointestinal ones
- An understanding of the conditions of mid-nineteenth century London that helped promote the spread of cholera
- A knowledge of statistics and algebra—helpful but not necessary

MATERIALS NEEDED: Access to the Internet, because it is a Web-based assignment. Most of the information comes from one central Web site. The URL for this Web site is http://www.ph.ucla.edu/epi/snow.html. This Web site was created by Dr. Ralph Frerichs, professor of epidemiology at the University of California, Los Angeles (UCLA) School of Public Health. If a school does not have access to the Internet, teachers can print out a few select Web pages from this one central Web site to access the information needed for this assignment.

One suggestion is to assign students to read two passages that can be retrieved from the John Snow–UCLA Web site. The first one is a reading passage taken from a book written by historian Judith Summers. The book is called *Soho: London's Most Colorful Neighborhood*, and the passage is titled "Broad Steet Pump Outbreak." The second passage is from the British Broadcasting Corporation (BBC), and this passage also gives an account of John Snow's investigations. Most of the questions can be answered from these two passages.

To find the Judith Summers reading passage, go to the main page of the UCLA–John Snow Web site and click on Broad Street Pump Outbreak, or you can type in the URL directly for this page, which is http://www.ph.ucla.edu/epi/snow/broadstreetpump.html. The BBC passage is available at http://www.ph.ucla.edu/epi/snow/bbc_snow.htm. You can also go to the main page of the UCLA/John Snow Web site and click on BBC Online to get that article. If you are not able to access the BBC article from the UCLA Web site, you can access it from the BBC Web site. The URL is http://www.bbc.co.uk/history/historic_figures/snow_john.shtml.

PROCEDURE: Students will be given a worksheet, in which they will be asked to answer a series of questions that are related to the investigations that John Snow conducted. Students should be assigned to read the two passages mentioned above for homework before they work on the assignment. All of the required questions can be answered using the information given in the UCLA–John Snow Web site. The extra credit questions may require outside resources. The World Health Organization (WHO) and the Centers for Disease Control and Prevention (CDC) are good sources to answer those questions.

REFERENCES: Given in the John Snow worksheet

NATIONAL SCIENCE EDUCATION STANDARDS:

Science as Inquiry

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Science in Personal and Social Perspectives

- Natural and human-induced hazards
- Environmental quality; availability and use of natural resources

History and Nature of Science

- Science as a human endeavor; nature of scientific knowledge
- Historical perspectives

Unifying Concepts and Processes

- Change, constancy and measurement
- Evidence, models and explanation

ACKNOWLEDGMENT: The lesson is based on a similar assignment developed by Dr. Philip Alcabes, professor of epidemiology for the Urban Public Health Program at Hunter College, City University of New York. This assignment has been modified for high school students.

Teacher's Notes

In addition to the Web site developed by the UCLA School of Public Health, the School of Public Health at the University of North Carolina (UNC) has also developed its own Web site devoted to the investigations of John Snow. The URL for this Web site is http://www.sph.unc.edu/courses/john_snow/epilogue.htm. The Web site even includes an editorial written by two physicians who lived during the London cholera outbreak. Instead of a tribute to John Snow, as is Dr. Frerich's Web site, the UNC Web site focuses specifically on the cholera investigations and approaches the information in more of a case study format, although the information given in this Web site is certainly not as comprehensive as that in the UCLA Web site.

The ultimate goal of this lesson is to help students see how important John Snow's work was in helping future epidemiologists develop a systematic approach to investigating a disease. His work also helped the scientific community gain a better understanding of how infectious diseases are transmitted, and so his work also contributed to the development of the germ theory. Although Snow did not have any understanding of the etiology, or cause, of cholera, he was able to gather statistics to prove that the illness must have been a water-borne one. Snow can also be credited with pioneering the field of medical geography by developing the maps that showed the exact locations of patients with a particular disease, which is extremely vital in comprehending how a particular disease affects a certain population.

Many public health officials today still make reference to the pump handle. There is a link in Dr. Frerich's John Snow Web site to the School of Public Health at the University of Alabama in Birmingham, which named its school magazine *The Handle,* yet another reference to Dr. Snow's work. Students who do this lesson will appreciate the important role of math and statistics so often used in scientific research.

A good lesson to follow this one is Case Study of a Leukemia Cluster in Woburn, Massachusetts. Both of these lessons focus on diseases that were transmitted by water, but the leukemia cluster found in Woburn, Massachusetts, is an example of a modern epidemic. In this case toxic, carcinogenic chemicals were contaminating the source of drinking water for many local residents. This lesson can be considered a modern version of the John Snow cholera investigations. The field of medical geography is also applied in this lesson.

Cholera and the Investigations of John Snow (Worksheet)

Historical Background

Cholera is a disease that Europeans first recognized in the Indian subcontinent. Portuguese sailors were the first Europeans to observe the wrath of this disease in the early sixteenth century. European ships were responsible for spreading the disease to other parts of the world. Simply, the disease would follow the ships that sailed all over the world. Symptoms of this disease include nausea, vomiting, abdominal pain and a horribly violent case of diarrhea that can cause one to lose as much as 20 liters of fluid and electrolytes per day, leading to extremely severe dehydration. Rice-water stools was a common description of the diarrhea associated with this disease. Most deaths are attributed to shock, because there is a severe reduction in blood volume and blood flow.[1]

The first pandemic of cholera began in 1817. Since then there have been six other pandemics this potentially fatal disease. Five of the seven pandemics occurred during the nineteenth century, and the seventh and most recent one began in 1961 and ended in 1975.[1,2] The epidemic of 1991, which mainly attacked the western coast of South America, is an example of a well-known recent epidemic. When the second pandemic of 1832 reached the United States, many saw the outbreak as an act of God to punish the wicked, so health authorities refused to clean the streets even when residents demanded it, claiming that they would be opposing the will of God. In 1866, which was the beginning of the fourth pandemic, many American physicians began to realize that cholera was a communicable disease and that its spread was promoted by filth and ignorance. So when boatloads of cholera-infected patients arrived between 1887 and 1892 during the fifth pandemic, health authorities had some tools to prevent the disease from spreading too severely in New York and too extensively to the rest of the United States.[2]

During the mid-nineteenth century a British physician named John Snow made his own observations of this feared disease. Without having any biological understanding of the disease, Dr. Snow was able to determine how this disease was spread. He achieved this by carrying out an epidemiologic investigation, in which he gathered demographic data on the victims who were struck with cholera. He was not able to do this without the help of his colleague William Farr, who is credited with developing the vital statistics system in London,[3] but Farr disagreed with Snow about the means of transmission. In 1849 Snow first published his findings in a book called *On the Mode of Communication of Cholera*. In this book Snow explains his hypothesis of how cholera was transmitted. He hypothesized that cholera was caused by a poison and that this disease was a communicable one. He also believed that the poison was found in the feces and vomit of cholera patients. The disease was therefore spread by drinking water that was contaminated with the feces and vomit of other cholera patients.[3–5]

Many other competing hypotheses and theories about cholera existed at that time. It was Dr. Snow, however, who conducted one of the first epidemiologic investigations to explore the possible modes of transmission for the disease. Many credit Snow's systematic approach to scientific disease investigation as the springboard for developing the science of epidemiology, even though his theory on the transmission of cholera was not accepted by the medical community until years after his death. The methods he developed serve as the foundation for the work that many epidemiologists do today.

His studies also helped develop the germ theory, a theory that was established during the late nineteenth century and is often attributed to the scientist Robert Koch, who also developed the four postulates of proof that a disease is spread from one host to the next. The germ theory changed the way people looked at infectious diseases. Another important contribution Snow made to the health sciences with this investigation is that he helped us see how environmental factors are an important influence on how infectious and some noninfectious diseases can be spread among a population. Scientists are now taking a more ecologic approach to controlling and preventing many diseases.[5]

The activity that you will be working on is based on the original data collected by John Snow during the London cholera outbreaks of 1832, 1849 and 1853. You will have the opportunity to analyze the same data that Dr. Snow collected and decide for yourself whether you would have drawn the same conclusions. Attached to this sheet is a set of questions that will help guide you through the field research that was done by Snow. By working on this activity you will become familiar with the processes Snow used to investigate this disease, which will also give you an understanding of how diseases are investigated today. Most of the information can be acquired from (but does not have to be and should not be limited to) a Web site devoted to John Snow, which was created by Dr. Ralph Frerichs, a professor of epidemiology at the UCLA School of Public Health. The URL for this Web site is given in the following list of references.[4] Good luck!

References

1. Black J. Oral and gastrointestinal diseases. In: *Microbiology: Principles and Applications*. Englewood Cliffs, NJ: Prentice Hall; 1993:612–613, 630–631.
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3. Stolley PD, Lasky T. The beginnings of epidemiology. In: *Investigating Disease Patterns: The Science of Epidemiology*. 2nd ed. New York: Scientific American Library; 1998:32–39.
4. Frerichs RR. Department of Epidemiology, UCLA School of Public Health. The Life of John Snow Web site. Available at: http://www.ph.ucla.edu/epi/snow.html
5. DeSalle R. Case study: solving the riddle of cholera through medical geography. In: *Epidemic! The World of Infectious Disease*. New York: American Museum of Natural History & The New Press; 1999:66–67.

Glossary

Endemic	A disease that commonly occurs in a geographic area, among a particular population, and/or in a certain period of time.
Epidemic	Occurs when the increase in the number of cases is clearly in excess of what is expected. Cases of a particular spread of a disease can be described to be of epidemic proportions when the incidence rate is much higher than what it usually is, as incidence rate measures the number of new cases in a given period of time. An epidemic can happen with both infectious and noninfectious diseases.
Incidence rate	Measurement of occurrence of disease that determines how quickly the disease is increasing within the population. This is calculated by finding the number of new cases and dividing it by the population; this figure is then divided by the time period in which these new cases occurred. This method of measurement can be applied to both infectious and noninfectious diseases. In addition to determining how quickly a disease is spreading, incidence can also be used to determine the risk of getting a disease.
Mortality rate	A measurement that is used to determine the number of deaths from a particular disease during a particular time period within a population; it is calculated in the same way as the incident rate (see **Incidence rate**). Because death can occur only once for a person, mortality rate can be considered a type of incidence rate
Pandemic	An epidemic that is occurring in many parts of the world. For example, because HIV/AIDS has spread very rapidly throughout many parts of the world, it can certainly be considered a pandemic problem.

Prevalence	Measures how common a disease is within a population. This is calculated by finding the number of current cases of a disease, prevalent cases and those newly developed, and dividing it by the population. Prevalence is a type of measurement that is considered a proportion, not a rate.
Relative risk	A method of quantifying the risk of a health problem in one group or factor, compared with the risk of another. One way of measuring this is by finding a rate ratio of two values that are used in measuring risk. Since incidence rate (see **Incidence rate**) is often used to quantitatively measure risk, a ratio of two different incidence rates can be used to calculate the relative risk of one factor or group over another.

Questions

1. Snow hypothesized that cholera was spread by water, contaminated with the poison that caused the disease.
   a. What was the main competing hypothesis that existed at that time? Briefly describe this hypothesis.
   b. Which hypothesis was supported by Snow's colleague William Farr?

2. What were the observations Dr. Snow made to hypothesize that cholera was transmitted by contaminated water?

Because Snow believed that cholera was transmitted by water, he focused on the water companies that supplied water to the residents of London. He gathered all the statistics of London residents who died of cholera, and then he looked at the water company that supplied water to them. From collecting this information he was able to determine that there was a significant difference in death rate, or mortality rate, among the customers of the different water companies. (Answers to Questions 3 through 6 can be found on the Location of Water Companies resource page. The URL for this page is http://www.ph.ucla.edu/epi/snow/watercompanies.html, or you can just click on Location of Water Companies from the main page. The data tables that Snow included in his book, which present the death rates for customers of the different water companies, can be retrieved at http://www.ph.ucla.edu/epi/snow/snowbook3.html.)

3. a. During the 1832 outbreak what was the death rate (cases per 10,000 households) for those who received their water from the Southwark Water Company?
   b. Compare this with the death rate for customers of the Lambeth Waterworks Company during this same outbreak. This can be found in Table II of Part Three of Snow's *On the Mode of Communication of Cholera*.
   c. Because both of these companies used unfiltered water from the Thames River, what most likely accounted for the substantial difference in death rates for the customers of the two different water companies?

In 1845 the Southwark Water Company merged with the South London Water Company to become the Southwark and Vauxhall Water Company. Snow also collected data on the residents who died of cholera during the epidemic that began in 1853 and continued into 1854. Once again, he calculated the death rates for consumers of the different water companies. This was often described as the grand experiment.

4. a. What were the death rates (cases per 10,000 households) for consumers of the Southwark and Vauxhall Water Company during the 14-week outbreak of 1854, which ended on October 14, 1854?
   b. What were the death rates for those who lived in homes that had their water supplied by the Lambeth Waterworks Company?
   c. What was the death rate for the rest of London? (Snow presented this data in Table IX in Part III of *On the Mode of Communication of Cholera*.)

5. How much more likely was a consumer of Southwark and Vauxhall Water Company at risk for dying of cholera in 1854 than a consumer of Lambeth Waterworks Company? Epidemiologists now classify this quantitative value as a type of relative risk. This can be calculated by taking the death rate of the Southwark and Vauxhall Water Company consumers and dividing it by the death rate of the Lambeth Waterworks consumers.

6. Why was the cholera death rate so much lower for consumers of the Lambeth Waterworks than for consumers of the Southwark and Vauxhall Water Company?

In the summer of 1854 the Soho section of London saw only a few cases of cholera, but on August 31, an abrupt outbreak attacked the neighborhood. The mortality rate for the parish of the neighborhood reached 12.8%, or 12.8 cases per 100 persons, by September 10, which was twice that of the rest of London. Dr. Snow contacted the Office of Registry to acquire the addresses of all the victims who died of cholera in London, and he focused his efforts on the neighborhood of Soho because it was hit the hardest with this scourge.

7. Snow developed a map showing all of the cholera cases that existed in the area of Soho during the summer of 1854 outbreak. A copy of the map that Snow made can be retrieved at http://www.ph.ucla.edu/epi/snow/snowmap1_1854_lge.htm. Looking at the map, make some of your own observations on how these cases are distributed. Many of the cases seem to be concentrated in a few particular blocks.
   a. Which blocks of Soho are these? (Give an exact location.)
   b. What landmark is found within the area that had the greatest concentration of cholera deaths?

8. When Snow mapped the different cases of cholera in London, many argued that there were cases that Snow's idea of water-borne transmission could not explain. One such case was that of a woman and her niece who died of cholera but did not live in or even near the neighborhood of Soho. Other examples included the Poland Street Workhouse and a local brewery that were also found in the neighborhood, but the workhouse reported only five deaths from cholera among its inmates and none of the workers at the brewery died of the disease. After further investigations by Dr. Snow, it was found that these cases did not weaken his argument. Instead, they strengthened his argument even more. Explain how.

9. When Dr. Snow had the handle of the Broad Street pump removed, the number of cases of cholera began to drop in the neighborhood of Soho. Why was it still difficult for him to convince the authorities and his colleagues that the drinking water was the source of contamination?

10. Who did Dr. Snow and Reverend Henry Whitehead believe was the index case that started the Soho cholera outbreak in 1854? How was this case believed to be responsible for the outbreak?

11. Snow explained the disease of cholera as a deadly poison that caused violent eruptions from the gut. Advances in microbiology and medicine have helped us acquire more knowledge and develop a better understanding of this disease. What is the etiology, or cause, of cholera? Explain the pathology, or how the body becomes damaged, of this disease. What is the poison that Snow described?

12. Who was the scientist who first isolated the causative agent of cholera? Which famous scientist is often credited with isolating the causative agent of cholera by most textbooks?

Extra Credit Questions

13. What are the areas of the world where cholera is still currently endemic?

14. Although cholera is not endemic to the United States, there are isolated cases of this disease. Describe the types of cases that occur in the United States. You may have to use another resource for this question.

15. A recent cholera epidemic occurred in 1991 and took the lives of 2972 people. Most of the cases were found in Peru. How is the 1991 epidemic in Peru similar to the nineteenth-century outbreaks in London? (The answer to this question is not found in the UCLA Web site, so you must use another resource to answer this question.)

Questions (Teacher's Answer Key)

1. Snow hypothesized that cholera was spread by water contaminated with the poison that caused the disease.
   a. What was the main competing hypothesis that existed at that time? Briefly describe this hypothesis.
   b. Which hypothesis was supported by Snow's colleague William Farr?

   a. Miasma—the theory that cholera was spread by bad air, which bred in the slums. Authorities of that time believed that the decay of organic matter from the trash left a poisonous vapor, or miasma, which they believed was the cause of cholera.
   Contagion—the disease was spread by invisible "animalcules."
   Divine intervention—people were being punished for their sins by getting cholera.
   b. William Farr believed in the miasma theory.

2. What were the observations Dr. Snow made to hypothesize that cholera was transmitted by contaminated water?

   Snow observed that he never seemed to get cholera when he was treating patients who were struck with cholera. He noticed this also in others who treated patients with cholera, so he did not believe that the disease was a contagious disease that was transmitted through the air. Snow also believed that the cholera poison must have been ingested, because he observed that the disease always affected the digestive tract.

3. a. During the 1832 outbreak what was the death rate (cases per 10,000 households) for those who received their water from the Southwark Water Company?
   b. Compare this with the death rate for customers of the Lambeth Waterworks Company during this same outbreak. This can be found in Table II of Part Three of Snow's *On the Mode of Communication of Cholera*.

c. Because both of these companies used unfiltered water from the Thames River, what most likely accounted for the difference in death rates for the customers of the two different water companies?

a. Southwark—110 deaths/10,000 households.

b. Lambeth—36.6 deaths per 10,000 households.

c. The Southwark Water Company collected water near London Bridge, whereas the Lambeth Waterworks Company collected water near the Hungerford Market Bridge, which was not as polluted with sewage as water from the area near London Bridge, because the Hungerford Bridge was more upstream than the London Bridge.

4. a. What were the death rates (cases per 10,000 households) for consumers of the Southwark and Vauxhall Water Company during the 14-week outbreak of 1854, which ended on October 14, 1854?

   b. What were the death rates for those who lived in homes that had their water supplied by the Lambeth Waterworks Company?

   c. What was the death rate for the rest of London? (Snow presented this data in Table IX in Part III of *On the Mode of Communication of Cholera*.)

   a. Southwark and Vauxhall—315 deaths per 10,000 households.

   b. Lambeth—37 deaths per 10,000 households.

   c. Rest of London—59 deaths per 10,000 households.

5. How much more likely was a consumer of Southwark and Vauxhall Water Company at risk for dying of cholera in 1854 than a consumer of Lambeth Waterworks Company? Epidemiologists now classify this quantitative value as a type of relative risk. This can be calculated by taking the death rate of the Southwark and Vauxhall Water Company consumers and dividing it by the death rate of the Lambeth Waterworks consumers?

   A customer was 8.5 times more likely to die of cholera if the customer received water from the Southwark and Vauxhall Company, compared with a customer of the Lambeth Water Company; this is an example of a rate ratio, in which two rates are compared:

   315 deaths per 10,000 households/36.6 deaths per 10,000 households = 8.5

6. Why was the cholera death rate so much lower for consumers of the Lambeth Waterworks than for consumers of the Southwark and Vauxhall Water Company?

   The Lambeth Waterworks Company moved its operations more upstream from the Hungerford Market Bridge to Thames Ditton, a location of the Thames that was north of London, so it was free from the sewage of London.

7. Snow developed a map showing all of the cholera cases that existed in the area of Soho during the summer of 1854 outbreak. A copy of the map that Snow made can be retrieved at http://www.ph.ucla.edu/epi/snow/snowmap1_1854_lge.htm. Looking at the map, make

some of your own observations on how these cases are distributed. Many of the cases seem to be concentrated in a few particular blocks.

a. Which blocks of Soho are these? (Give an exact location.)

b. What landmark is found within the area that had the greatest concentration of cholera deaths?

a. The area on Broad Street between Marshall and Cambridge Streets, which is where the Broad Street pump is located (b).

8. When Snow mapped the different cases of cholera in London, many argued that there were cases that Snow's idea of water-borne transmission could not explain. One such case was that of a woman and her niece who died of cholera but did not live in or even near the neighborhood of Soho. Other examples included the Poland Street Workhouse and a local brewery that were also found in the neighborhood, but the workhouse reported only five deaths from cholera among its inmates, and none of the workers at the brewery died of the disease. After further investigations by Dr. Snow, it was found that these cases did not weaken his argument. Instead, they strengthened his argument even more. Explain how.

   The Poland Street Workhouse had its own pump, so it did not need to get water from the Broad Street pump. The brewery also had its own pump, and the workers were also given an allowance of free beer from the brewery. According to observations of the brewery supervisor, the workers seemed to drink only beer. However, if they did drink any water, it would have been from the pump that the brewery provided. The woman who lived in Hampstead once lived in Soho and liked the taste of the water from the Broad Street pump. She would often send a servant to Soho to collect water from that pump. The woman's niece came to visit her right before she was struck with cholera and may have also drunk the water from the Broad Street pump.

9. When Dr. Snow had the handle of the Broad Street pump removed, the number of cases of cholera began to drop in the neighborhood of Soho. Why was it still difficult for him to convince the authorities and his colleagues that the drinking water was the source of contamination?

   The cases were already beginning to decrease when he ordered the handle of the pump to be removed. Furthermore, his colleagues were not convinced by the map because so many pumps were found throughout London that it could have been coincidence that the cases of death due to cholera were concentrated near that particular pump.

10. Who did Dr. Snow and Reverend Henry Whitehead believe was the index case that started the Soho cholera outbreak in 1854? How was this case believed to be responsible for the at outbreak?

   An infant who lived at 40 Broad Street. The mother of this infant would wash the child's nappies (diapers) in a pail of water, which she would empty out into the

opening of a cesspool nearby. Because the cesspool was poorly maintained, its contents leaked into the pipes that were connected to the Broad Street pump.

11. Snow explained the disease of cholera as a deadly poison that caused violent eruptions from the gut. Advances in microbiology and medicine have helped us acquire more knowledge and develop a better understanding of this disease. What is the etiology, or cause, of cholera? Explain the pathology, or how the body becomes damaged, of this disease. What is the poison that Snow described?

    Cholera is an acute enteric disease caused by the bacterium *Vibrio cholerae*. The poison that Snow talked about is an enterotoxin released by the bacteria into the intestinal tract of its host. This enterotoxin causes a type of reverse osmosis by binding to the wall of the digestive tract, making it more permeable for water to pass out and into the digestive tract. This results in a violent case of diarrhea that leads to severe dehydration, in which a patient can lose about 10 to 20 liters of water and electrolytes per day. The violent diarrhea that is often associated with cholera is often described as rice-water stools or rice-water evacuations because the stools contain water and mucous fluid present in the human intestines.

    A handout on cholera that was taken from the Centers for Disease Control and Prevention (CDC) has been included on page 00 of this module. A cholera fact sheet from the World Health Organization (WHO) has also been included on page 00 of this module. Additional information could be found on the CDC and WHO Web sites. The URL for the CDC Web site is http://www.cdc.gov, and the URL for the WHO Web site is http://www.who.int. The home page for both of these Web sites includes a link to an index for all different kinds of health topics. On the CDC home page it is labeled A–Z Index. On the WHO home page it is labeled Health Topics.

12. Who was the scientist who first isolated the causative agent of cholera? Which famous scientist is often credited with isolating the causative agent of cholera by most textbooks?

    Although most textbooks credit Koch with isolating and discovering the *Vibrio cholerae* bacterium, it was actually the Italian physician and scientist Filippo Pacini who first isolated the bacteria. Pacini, however, is credited with discovering the corpuscle that bears his name, the pacinian corpuscle.

Extra Credit Questions

13. What are the areas of the world where cholera is still currently endemic?

    Cholera is endemic to South and Southeast Asia, sub-Saharan Africa and parts of South America. Cases of cholera often occur as isolated epidemics in countries that have either poor sewage treatment or none at all. (This information can be obtained from

going to the main Web site and clicking on Current Cases of Cholera in the news. There is a link to a map supplied by WHO that shows all the recent cases of cholera. There is also a link to the CDC, giving traveler's information about cholera.)

14. Although cholera is not endemic to the United States, there are isolated cases of this disease. Describe the types of cases that occur in the United States. You may have to use another resource for this question.

    Most of the sporadic cases that occur in the United States are from people traveling into areas where cholera is endemic. Other cases result from travelers bringing in seafood from areas where the disease is endemic, even though it is illegal to do this. Cases may also result from importing seafood from areas where cholera is endemic. There have also been cases of people ingesting seafood that was caught in the coastal states of the Gulf of Mexico.

    This question can be answered by using a microbiology or parasitology textbook. The information can also be obtained from the CDC Web site, available at http://www.cdc.gov. Once students access the main page, they should click on A–Z Index. When they get on that page, they should be able to find information about cholera and cholera cases in the United States.

15. A recent cholera epidemic occurred in 1991 and took the lives of 2972 people. Most of the cases were found in Peru. How is the 1991 epidemic in Peru similar to the nineteenth-century outbreaks in London?

    This cholera epidemic was also believed to have been spread by cargo ships. Lack of basic public health infrastructure, such as sewage treatment plants and adequate drinking water treatment, allowed for the spread of the bacteria throughout the population. Because raw sewage was dumped directly into the waterways, many contracted the disease by either ingesting contaminated water or eating seafood that was caught in waters polluted with sewage.

    Many public health authorities criticized Alberto Fujimori, president of Peru at that time, for eating raw fish on television to show his citizens that the fish was safe to eat, when the reality was that the fish he ate was caught hundreds of miles off the coast, where the water was not polluted with sewage. President Fujimori was criticized for protecting the interests of the fishing industry over the health of the Peruvian people.

    This question cannot be retrieved from the Web site. Students are expected to do their own research. The CDC and WHO Web sites have a wealth of information on this subject, as well.

Technical Information on Cholera

Clinical Features	Profuse watery diarrhea, vomiting, circulatory collapse and shock. Many infections are milder diarrhea or asymptomatic.
Etiologic Agent	*Vibrio cholerae* serogroup O1 or O139 that produces cholera toxin.
Incidence	0–5 cases per year in the United States. A major cause of epidemic diarrhea throughout the developing world. Ongoing global pandemic in Asia, Africa and Latin America for the last four decades.
Sequelae	25–50% of typical cases are fatal if untreated.
Transmission	Contaminated drinking water or food. Large epidemics often related to fecal contamination of water supplies or street vended foods. Occasionally transmitted through eating raw or undercooked shellfish that are naturally contaminated.
Risk Groups	Virtually none in the United States. Risk extremely low (1 per million) even in travelers. Persons living in poverty in the developing world.
Surveillance	All reported cases are laboratory confirmed in state laboratories or at CDC.
Trends	Modest increase in imported cases since 1991 related to ongoing epidemic that began in 1991. Since 1995, over 80% of reported cases have occurred in Africa.
Challenges	Large population migrations into urban centers in developing countries are straining existing water and sanitation infrastructure and increasing disease risk. Epidemics are a marker for poverty and lack of basic sanitation. Multiple routes of transmission mean that successful prevention may require different specific measures in different areas. Natural infection and currently available vaccines offer incomplete protection of relatively short duration; no multivalent vaccines available for O139 infections. Simple rehydration treatment saves lives, but logistics of delivery in remote areas remains difficult during epidemic periods. Adjunct antibiotic treatment is helpful but may be difficult because of growing antimicrobial resistance. Natural reservoir in warm coastal waters makes eradication very unlikely.

Opportunities A powerful stimulus to develop needed infrastructure for sanitation and for public health in general, including improvements in sanitation, safer water handling, and public health capacity for surveillance and response to epidemics.

December 2003

Source: The Centers for Disease Control and Prevention Web site Available at: http://www.cdc.gov/ncidod/dbmd/diseaseinfor/cholera_t.htm

World Health Organization Fact Sheet on Cholera

Cholera is an acute intestinal infection caused by the bacterium *Vibrio cholerae*. It has a short incubation period, from less than one day to five days, and produces an enterotoxin that causes a copious, painless, watery diarrhoea that can quickly lead to severe dehydration and death if treatment is not promptly given. Vomiting also occurs in most patients.

Most persons infected with *V. cholerae* do not become ill, although the bacterium is present in their faeces for 7–14 days. When illness does occur, more than 90% of episodes are of mild or moderate severity and are difficult to distinguish clinically from other types of acute diarrhoea. Less than 10% of ill persons develop typical cholera with signs of moderate or severe dehydration.

Background

The vibrio responsible for the seventh pandemic, now in progress, is known as *V. cholerae* 01, biotype El Tor. The current seventh pandemic began in 1961 when the vibrio first appeared as a cause of epidemic cholera in Celebes (Sulawesi), Indonesia. The disease then spread rapidly to other countries of eastern Asia and reached Bangladesh in 1963, India in 1964, and the USSR, Iran and Iraq in 1965–1966.

In 1970 cholera invaded West Africa, which had not experienced the disease for more than 100 years. The disease quickly spread to a number of countries and eventually became endemic in most of the continent. In 1991 cholera struck Latin America, where it had also been absent for more than a century. Within the year it spread to 11 countries, and subsequently throughout the continent.

Until 1992, only *V. cholerae* serogroup 01 caused epidemic cholera. Some other serogroups could cause sporadic cases of diarrhoea, but not epidemic cholera. Late that year, however, large outbreaks of cholera began in India and Bangladesh that were caused by a previously unrecognized serogroup of *V. cholerae,* designated O139, synonym Bengal. Isolation of this vibrio has now been reported from 11 countries in South-East Asia. It is still unclear whether *V. cholerae* O139 will extend to other regions, and careful epidemiological monitoring of the situation is being maintained.

Transmission

Cholera is spread by contaminated water and food. Sudden large outbreaks are usually caused by a contaminated water supply. Only rarely is cholera transmitted by direct person-to-person contact. In highly endemic areas, it is mainly a disease of young children, although breastfeeding infants are rarely affected.

Vibrio cholerae is often found in the aquatic environment and is part of the normal flora of brackish water and estuaries. It is often associated with algal blooms (plankton), which are influenced by the temperature of the water. Human beings are also one of the reservoirs of the pathogenic form of *Vibrio cholerae*.

Treatment

When cholera occurs in an unprepared community, case-fatality rates may be as high as 50%—usually because there are no facilities for treatment, or because treatment is given too late. In contrast, a well-organized response in a country with a well established diarrhoeal disease control programme can limit the case-fatality rate to less than 1%.

Most cases of diarrhoea caused by *V. cholerae* can be treated adequately by giving a solution of oral rehydration salts (the WHO/UNICEF standard sachet). During an epidemic, 80–90% of diarrhoea patients can be treated by oral rehydration alone, but patients who become severely dehydrated must be given intravenous fluids.

In severe cases, an effective antibiotic can reduce the volume and duration of diarrhoea and the period of vibrio excretion. Tetracycline is the usual antibiotic of choice, but resistance to it is increasing. Other antibiotics that are effective when *V. cholerae* are sensitive to them include cotrimoxazole, erythromycin, doxycycline, chloramphenicol and furazolidone.

Epidemic Control and Preventive Measures

When cholera appears in a community it is essential to ensure three things: hygienic disposal of human faeces, an adequate supply of safe drinking water, and good food hygiene. Effective food hygiene measures include cooking food thoroughly and eating it while still hot; preventing cooked foods from being contaminated by contact with raw foods, including water and ice, contaminated surfaces or flies; and avoiding raw fruits or vegetables unless they are first peeled. Washing hands after defecation, and particularly before contact with food or drinking water, is equally important.

Routine treatment of a community with antibiotics, or "mass chemoprophylaxis", has no effect on the spread of cholera, nor does restricting travel and trade between countries or between different regions of a country. Setting up a *cordon sanitaire* at frontiers uses personnel and resources that should be devoted to effective control measures, and hampers collaboration between institutions and countries that should unite their efforts to combat cholera.

Limited stocks of two oral cholera vaccines that provide high-level protection for several months against cholera caused by *V. cholerae* 01 have recently become available in a few countries. Both are suitable for use by travellers but they have not yet been used on a large scale for public health purposes. Use of this vaccine to prevent or control cholera outbreaks is not recommended because it may give a false sense of security to vaccinated subjects and to health authorities, who may then neglect more effective measures.

In 1973 the WHO World Health Assembly deleted from the International Health Regulations the requirement for presentation of a cholera vaccination certificate. Today, no country requires proof of cholera vaccination as a condition for entry, and the International Certificate of Vaccination no longer provides a specific space for recording cholera vaccinations.

Trade in Food Products Coming from Cholera-Infected Regions

The publication "Guidelines for Cholera Control", available through WHO's Distribution and Sales Unit, states the following:

"*Vibrio cholerae* 01 can survive on a variety of foodstuffs for up to five days at ambient temperature and up to 10 days at 5–10 degrees Celsius. The organism can also survive freezing. Low temperatures, however, limit proliferation of the organism and thus may prevent the level of contamination from reaching an infective dose.

"The cholera vibrio is sensitive to acidity and drying, and commercially prepared acidic (ph 4.5 or less) or dried foods are therefore without risk. Gamma irradiation and temperatures above 70 degrees Celsius also destroy the vibrio and foods processed by these methods, according to the standards of the Codex Alimentarius, and

"The foods that cause greatest concern to importing countries are seafood and vegetables that may be consumed raw. However, only rare cases of cholera have occurred as a result of eating food, usually seafood, transported across international borders by individuals.

". . . Indeed, although individual cases and clusters of cases have been reported, WHO has not documented a significant outbreak of cholera resulting from commercially imported food."

In summary, although there is a theoretical risk of cholera transmission with international food trade, the weight of evidence suggests that this risk is very small and can normally be dealt with by means other than an embargo on importation.

WHO believes that the best way to deal with food imports from cholera-affected areas is for importing countries to agree, with food exporters, on good hygienic practices which need to be followed during food handling and processing to prevent, eliminate or minimize the risk of any potential contamination; and to set up arrangements to obtain assurance that these measures are adequately carried out.

At present, WHO has no information that food commercially imported from affected countries has been implicated in outbreaks of cholera in importing countries. The isolated cases of cholera, that have been related to imported food, have been associated with food which had been in the possession of individual travellers. Therefore, it may be concluded that food produced under good manufacturing practices poses only a negligible risk for cholera transmission. Consequently, WHO believes that food import restrictions, based on the sole fact that cholera is epidemic or endemic in a country, are not justified.

For further information, please contact Office of the Spokesperson, WHO, Geneva (41 22) 791 2599. Fax (41 22) 791 4858.
E-mail: inf@who.int

All WHO Press Releases, Facts Sheets and Features can be obtained on the Internet on the WHO home page available at:
http://www.who.int

Lesson 3: Case Study of a Leukemia Cluster in Woburn, Massachusetts

Lesson Plan

SUBJECT AREA: Environmental science, including the Advanced Placement Program® (AP®) Environmental Science course; social studies

OBJECTIVES:

- To help students understand how some cancer clusters that are discovered can be real and can cause an outbreak
- To help students see how everyday citizens can make discoveries about a clustering of a disease that can be considered an epidemic
- To familiarize students with the Environmental Protection Agency's (EPA's) Superfund Program
- To demonstrate how ordinary citizens can organize and take on large corporations to seek justice
- Students who did the John Snow lesson (Lesson 2 of this module) should be able to draw parallels between these two cases

TIME FRAME: Two 45-minute periods. Students should be assigned to do some of the reading at home.

PREREQUISITE KNOWLEDGE: An understanding of the hydrologic cycle, particularly watersheds and the flow of groundwater; an awareness of point sources and non–point sources of pollution in contaminating groundwater; a basic understanding of environmental legislation; and knowledge of the EPA's Superfund Program.

MATERIALS NEEDED: An environmental science textbook and access to the Internet to answer some of the questions. For schools that do not have access to the Internet, teachers can print some of the information directly from the EPA Web site. Teachers might want to get a copy of the book *A Civil Action* by Jonathan Harr to use as a teaching reference.

PROCEDURE: Students are given a handout to read for homework. A discussion will follow in class. Discussion questions have been included in the handout for teachers to use. A set of assigned questions can be answered either for homework or during the next class day. A good way to get students motivated is to show them the movie *A Civil Action*. This can also be shown after the lesson.

REFERENCES: Included in the handout. Additional references have been given in the answer key to the assignment questions.

NATIONAL SCIENCE EDUCATION STANDARDS:

Science as Inquiry

- Abilities necessary to do scientific inquiry
- Understanding of scientific inquiry

Sciences in Personal and Social Science Perspectives

- Natural and human-induced hazards
- Environmental quality; availability and use of natural resources
- Personal and community health

History and Nature of Science

- Science as a human endeavor; nature of scientific knowledge
- Historical perspectives

Unifying Concepts and Process

- Systems, order and organization
- Change, constancy and measurement
- Evidence, models and explanations

Earth and Space Science

- Geochemical cycles

ADVANCED PLACEMENT ENVIRONMENTAL SCIENCE STANDARDS:

Water Resource Management

- Dynamics of a watershed, including the flow of groundwater and the formation of aquifers
- Point sources of pollution and how they can contaminate the groundwater used as a public water supply

Environmental Law

- Introducing students to examples of federal environmental legislation that has been passed, such as CERCLA, 1980; SARA, 1986; and RCRA, 1976
- Familiarizing students with the EPA's Superfund Program and the National Priorities List that was put together by the Superfund Program
- Introducing students to the Web sites of government agencies like the EPA, which can be used as a research tool to find information

ADDITIONAL NOTES: Although it is not necessary to do all of the lessons in this module, this lesson is a good follow-up to the John Snow–Cholera lesson, because both involve diseases that were transmitted by the contamination of water.

Case Study of a Leukemia Cluster in Woburn, Massachusetts (Student Handout)

In January 1972 James (Jimmy) Anderson, a 3-year-old boy, and his siblings were having symptoms such as coughing, runny nose and a slight fever, which their mother assumed was nothing more than a cold. However, Jimmy's cold symptoms did not go away, when all of his sibling's symptoms did. His fever continued to recur, and his skin was pale with bruises of unknown origin. Jimmy's mother, Anne, found it strange that he would have bruises, considering that he was in bed all day. He was also anemic with profound pallor and lethargy. Mrs. Anderson took Jimmy to Dr. McLean, his pediatrician, who first thought that he might have a platelet deficiency because of the bruises of unknown origin. He suspected that the boy's condition might be a blood disorder of some type because it met all of the classic symptoms: pallor, bruises and persistent fever. He made an appointment for Jimmy to have some blood tests done at Massachusetts General Hospital.

Dr. McLean had a suspicion that it might be leukemia, but he did not want to tell the Andersons because it was a rare condition at that time, with a prevalence of fewer than 4 cases out of 100,000 persons.[1] Dr. Truman, the doctor at Massachusetts General, performed blood tests and a bone marrow test, and Jimmy Anderson was diagnosed with acute lymphocytic leukemia. Mrs. Anderson now began to devote almost all of her time and attention to Jimmy. Kay Bolster, a neighbor of the Andersons who lived one block away on Gregg Street, told Anne that the two families that lived next to her also had children with leukemia and that maybe Anne could contact them for emotional support. These two families were the Zonas and the Nagles. Michael Zona was also diagnosed with acute lymphocytic leukemia in March 1971. Anne found it strange that there were three houses within a block of each other that had cases of childhood leukemia. Then she discovered other cases of childhood leukemia in Woburn, found mostly in the eastern part of Woburn, which was where they all lived.

Kevin Kane Jr. was diagnosed with acute lymphocytic leukemia in June 1973 when he was 2 years old. Like Jimmy he had similar symptoms, including fever, pallor and irritability. Kevin lived on Henry Avenue, which is also located in the eastern part of Woburn. When Mrs. Anderson was at Massachusetts General while taking Jimmy for treatment two years after his diagnosis, she heard of an infant boy named Michael Lilley who had died of leukemia. The Lilleys also lived in Woburn. Anne put together a list of all the childhood leukemia cases that she knew of, including the names of the children, their age, the approximate date of diagnosis and the home address, and she noticed that all of these children lived within close proximity of each other. After looking at the names, she asked herself what all of these children shared or had in common. Because none of these children knew each other, Anne figured that "the water and the air were the only two things that we all shared."[2] The residents of the eastern part of Woburn had always complained about the water, so Anne reasoned that there might be something wrong with the water supply. She thought that perhaps there might be an unknown leukemia-causing virus in the water supply.

If Anne's leukemia-causing virus hypothesis was true, why could one deduce that the leukemia was certainly not being spread by a contagious virus? (That is, if the virus was an air-borne one.)

Many other health professionals at this time also believed that leukemia could be caused by an unknown virus, and they suspected this hypothesis because the disease mostly affected very young children. How does the age demographic of this disease support the hypothesis that leukemia may be caused by an infectious agent? What are some other possible explanations?

The water was always a conversation topic among all of the residents of eastern Woburn, who received their water from the same source, Well G and Well H, which were found in the northeast section of Woburn. The water had a foul chemical odor, and many residents complained that the water would often smell like bleach. Many of the eastern Woburn residents also complained that the water was corrosive, causing their pipes to leak. The Andersons had to get the door of their dishwasher replaced because the water corroded it. Everyday residents of eastern Woburn would often call the public works and health department of the city about the water. They would ask why they could not have the same quality of water supplied to the residents in the rest of Woburn. (For more information about Wells G and H, see Appendix 1, which is found in the back of this handout.)

Anne Anderson mentioned her suspicion to her husband, Charles, and Dr. Truman, who was treating Jimmy at that time. They tried to convince her that this was just a coincidence. Dr. Truman also mentioned that parents of children with leukemia and many other diseases for that matter tend to develop a heightened awareness of that particular disease. His explanation to

Anne was that it might not be that there were more cases of childhood leukemia in Woburn, compared with other neighboring municipalities; it was just that Anne was more aware of the cases in Woburn, because she was more attuned to hearing about cases of leukemia in general. Dr. Truman told Anne that she was therefore basing her suspicions on anecdotal evidence, and that it was very easy to blame a disease on the environment. Anne told Dr. Truman, "When I stand on my front porch, I can see all these houses where children with leukemia live."[3] Dr. Truman responded that this was probably occurring because more people were surviving leukemia.

Dr. Truman's explanation at that time seemed reasonable. Science professionals are trained not to draw conclusions unless there is enough evidence to support them. What would be one way to determine whether the rate of childhood leukemia cases was significantly higher than the rates of leukemia cases in the surrounding areas and the nation?

Mrs. Anderson was still not convinced, and she was even more convinced of her environmental hypothesis when she discovered other cases of leukemia in east Woburn. She became friends with Donna Robbins, who attended the same church as she and whose son Carl Robbins III was also diagnosed with acute lymphocytic leukemia on October 13, 1976. Donna Robbins met a neighbor whose son, Jarrod Aufiero, also was diagnosed with leukemia. The Aufieros lived three minutes away from the Andersons on Pine Street. Mr. Anderson, Dr. Truman and Reverend Bruce Young, the Andersons' pastor, continued to dissuade Anne from her hypothesis that the water was the cause of all these cases of leukemia. They soon began to believe her when news broke out about toxic chemicals that were uncovered near Wells G and H.

In the spring of 1979 the Woburn police were investigating the appearance of 184 barrels of industrial waste on a vacant lot in the northeast section of the city. State environmental inspectors who heard this news ordered samples of water collected from Wells G and H to be tested, because the wells were located a half-mile south of this vacant lot, and the area on which that these barrels were found was a recharge area for the aquifers that Wells G and H pumped into. The lab found 267 parts per billion (ppb) of trichloroethylene (TCE) in Well G and 183 ppb of TCE in Well H. The lab also found traces of four other contaminants, such as tetrachloroethylene (Perc), but in lesser amounts. At that time the Environmental Protection Agency (EPA) listed TCE and Perc, which are both industrial solvents, as "probable" carcinogens. The barrels, however, contained polyurethane resin, so the contents it did not match the contaminants that were found in the well water. The state inspectors continued to wonder how the TCE got into the water supply that was pumped by the two wells. Wells G and H were closed two days later, but Anne Anderson was unaware of this, because she was away when the story broke in the local paper.

Then another article appeared in the *Woburn Daily Times*, and the headline read "Lagoon of Arsenic Discovered in N. Woburn." The article was written by a reporter named Charles Ryan. Mr. Ryan wrote about a half-buried lagoon that was five feet deep and almost an acre in size that was contaminated with lead, arsenic, chromium and other heavy metals. The lagoon was discovered by a construction crew working at the site. They also found the remains of animal hides, hairs and slaughter house wastes, which they believed had been left by the many tanneries that were once found in the city. Of the metals found in the lagoon, arsenic is known to be a cancer-causing agent, and chromium is known to cause tumors in the lungs and nasal passages when it is inhaled. The article mentioned that it was unclear whether the toxic metals had contaminated the groundwater that was being pumped by Wells G and H, which were located one mile south of this lagoon, but the article did mention that Wells G and H were currently being closed because they were found to be contaminated with TCE, another probable carcinogen.

When the Reverend Bruce Young found out about this article, he began to see validity in Mrs. Anderson's hypothesis. He tried to get records of the incidence of leukemia in the past 15 years, but the city did not have these types of records, so he posted a letter in the *Woburn Daily Times* to ask all families with children who had been diagnosed with leukemia within the past 15 years to come to a meeting at the Trinity Episcopal Church. At the end of the meeting Reverend Young and Anne collected information about 12 cases of childhood leukemia that were diagnosed within the past 15 years and plotted all of these cases on a local city map. Of the 12 cases, 8 were found in east Woburn, and 6 of these 8 cases were clustered in the Pine Street neighborhood, which was made up of 200 households.

Look at the map in Appendix 2, which is similar to the map that Reverend Young and Anne Anderson made. The houses of many of the families with childhood leukemia are found on this map. Do you believe that this is a possible cluster?

Reverend Young showed this map to Dr. Truman, who was now convinced that this might actually be a cluster. He contacted a colleague of his from the Centers for Disease Control and Prevention (CDC) named Dr. Clark Heath, who did quite a bit of research on other possible leukemia clusters found in the country. Dr. Heath sent an epidemiologist to meet with Dr. Truman and to collect records of children with leukemia from other Boston area hospitals. Around the same time Charles Ryan wrote another article in the *Woburn Daily Times* about a study of cancer mortality conducted by the Massachusetts Department of Public Health. The study found that cancer deaths of all types had increased by 17% in Woburn during a five-year period in the mid-1970s. The increase in leukemia, and kidney cancer to a lesser extent, was staggering. Reverend Bruce Young contacted Charles Ryan about the map that he and Anne Anderson created, and Charles Ryan followed up with another article with the headline "Leukemia Answers Sought."

Why did the CDC have to collect information about childhood leukemia cases in other Boston area hospitals as well to conduct their study?

The mayor of Woburn at that time criticized the Reverend Young for being irresponsible and creating fear among the city residents. He expressed his concern that all of this extra publicity might cause the values of homes in the Woburn area to go down. Reverend Young, however, was undaunted by this, and he and Anne Anderson were asked by Senator Edward Kennedy to testify in Washington before the Senate Committee on Public Works and the Environment, which they accepted. The *Boston Globe* posted an article about this hearing, which quoted from Anne Anderson's testimonial: "We fear for our children, and we fear for their children. The whole neighborhood lives in fear."[4] In October 1979 many of the Woburn residents formed a citizen group called For a Cleaner Environment (FACE), which served as a voice for the Woburn citizens to address the environmental and public health issues that were related to the contaminated site.

The CDC began to conduct a study with the help of the Massachusetts Department of Public Health. An epidemiologist from Atlanta was asked to design a study to investigate and determine if this leukemia cluster found in Woburn was real and causal. Donna Robbins, for example, was visited by a CDC investigator during July 1980, who asked her different types of questions, such as the medical histories of everyone in her family, how often she was exposed to X rays, and how many pregnancies and miscarriages she had had. They asked for some other information, such as her ethnicity, religion, eating habits and community activities. They also asked whether she smoked cigarettes, painted her apartment, used hairspray or hair dye, and whether her sons waded in the lakes and streams of Woburn, and Donna Robbins answered all of these questions to the best of her knowledge. She noticed, however, that they never asked her any questions about the tap water.

On January 23, 1981, five days after the death of James Anderson, the CDC published a report on their investigation of the increase in leukemia cases in Woburn, Massachusetts. The report mentioned that the number of cases of leukemia in the eastern part of Woburn was unusually high, compared with the national rate, with the incidence of leukemia seven times greater than expected. The rate of childhood leukemia for the rest of Woburn was not significantly higher than the national rate of leukemia. The authors of the report were not able to find a definite link between the increased number of childhood leukemia cases in eastern Woburn and the contaminated drinking water. (At that time the organic contaminants found in the well were not yet established as the cause of leukemia.) However, the report stated that there was reason to suspect that the contaminated drinking water was a possible cause, as Wells G and H were being used during the time period of critical exposure for the children to develop leukemia and as Wells G and H served primarily the eastern part of Woburn. The CDC report also stated that the source of contamination for Wells G and H was still unknown, which is why the EPA was conducting its own investigation to determine the source at that time.

In 1982, while the EPA was still investigating the contaminated site, eight families who had lost children to leukemia, including the Andersons, filed a lawsuit against three companies they believed were responsible for the groundwater contamination. These companies were chosen because their factories were located near Wells G and H and the areas that were found to be contaminated with industrial waste. The three companies were Unifirst, W. R. Grace and Beatrice Foods, which owned John J. Riley Tannery, which was also found near Wells G and H. Unifirst settled for $1 million, but W. R. Grace and Beatrice Foods did not, so their civil suits were brought to court. This highly publicized lawsuit is what the book and movie *A Civil Action* were based on. The jury found W. R. Grace liable but did not find Beatrice Foods liable for the elevated number of leukemia-related deaths. The attorneys for the eight families wound up settling for $8 million from W. R. Grace. After subtracting the fee paid to the attorneys and dividing that settlement among the eight families, this was very little. Furthermore, the families never got, as Anne Anderson mentioned, an apology from the companies who were responsible. (Their attorneys also lost a great deal of money, as their firm spent a large amount to pay for the expenses of proving this case.)

Look at the map of Woburn in Appendix 2. Why was it much more difficult for the attorneys to prove that the Riley Tannery was responsible for contaminating Wells G and H? Why did the attorneys have to hire a team of environmental engineers and geologists to prove that the toxic chemicals that were being dumped by the John J. Riley Tannery could have been responsible for contaminating the groundwater that was being pumped by Wells G and H?

During this civil suit the EPA was still conducting its own investigation of the contaminated site. In December 1982 the 330-acre site of hazardous waste was proposed for the National Priorities List (NPL), which is the EPA's list of hazardous waste sites that are eligible for cleanup under the EPA's Superfund Program. In 1983 the EPA used its authority under the Superfund Program and the Resource Conservation and Recovery Act to order a cleanup from the parties believed to be responsible. Unifirst, W. R. Grace and Beatrice Foods were ordered to study the nature and extent of contamination on their properties. Three other private companies were added to the list of responsible parties. In 1985 Wildwood Conservation Corporation, who bought up the land from Beatrice Foods, was ordered to put up a fence and hire a 24-hour security guard to keep people out of the area of contaminated soil. Olympia Nominee Trust was ordered to remove all abandoned drums and debris, which were located on the western portion of their property in 1986 and 1987. New England Plastics was found to be another responsible party. In 1987 Unifirst was also ordered to install monitoring wells and remove the Perc that was found in a well on their property.

In September 1988 the EPA finished a soil and groundwater investigation, and they concluded that the contamination of the groundwater did come from the five properties located around the municipal wells. As a result, they ordered a long-term cleanup plan from these five property owners. In July 1991 the EPA negotiated $70 million as a Superfund settlement to clean up the contaminated site.[5–7] The companies believed it was much wiser to negotiate with the EPA than to go into further litigation. Of the $70 million that was agreed upon, $58.4 million went to pay for the cleanup, $6.4 million was used to finance the EPA's monitoring of the cleanup, and $2.65 million was used to reimburse the EPA for previous investigation costs. The rest of the money was used to conduct a study of the immediate area surrounding Wells G and H. This involved cleaning up the soil, groundwater, and Aberjona River of volatile organic compounds (VOCs) such as TCE and Perc, polynuclear aromatic hydrocarbons (PAHs), polychloro- biphenyls (PCBs) and toxic metals, such as arsenic, mercury, chromium and zinc. This settlement was, at that time, the largest environmentally related settlement in the history of New England.

Anne Anderson's persistence and astuteness made this EPA investigation possible. She refused to believe that the increase in cases of leukemia was just a mere coincidence and that she was just another hysterical mother. Although she was not trained as an epidemiologist, she took the steps that an epidemiologist would take, which helped her suspect that the drinking water was contaminated, and her suspicions proved to be correct. Making a list of all the childhood leukemia cases in Woburn, including information such as the children's age, date of diagnosis and street address, is an example of what an epidemiologist would do. The map that she and Reverend Bruce Young put together was similar to what John Snow, one of the pioneers of the science of epidemiology, did more than a hundred years ago. This is an example of how ordinary citizens can take on large corporations; they never waited for an expert to take action. Many other environmental and social justice movements have also been started by everyday, ordinary citizens. Anne Anderson never considered herself an activist, just a mother who wanted justice for her son and the other children of Woburn, Massachusetts.

Appendix 1: Profile of Wells G and H

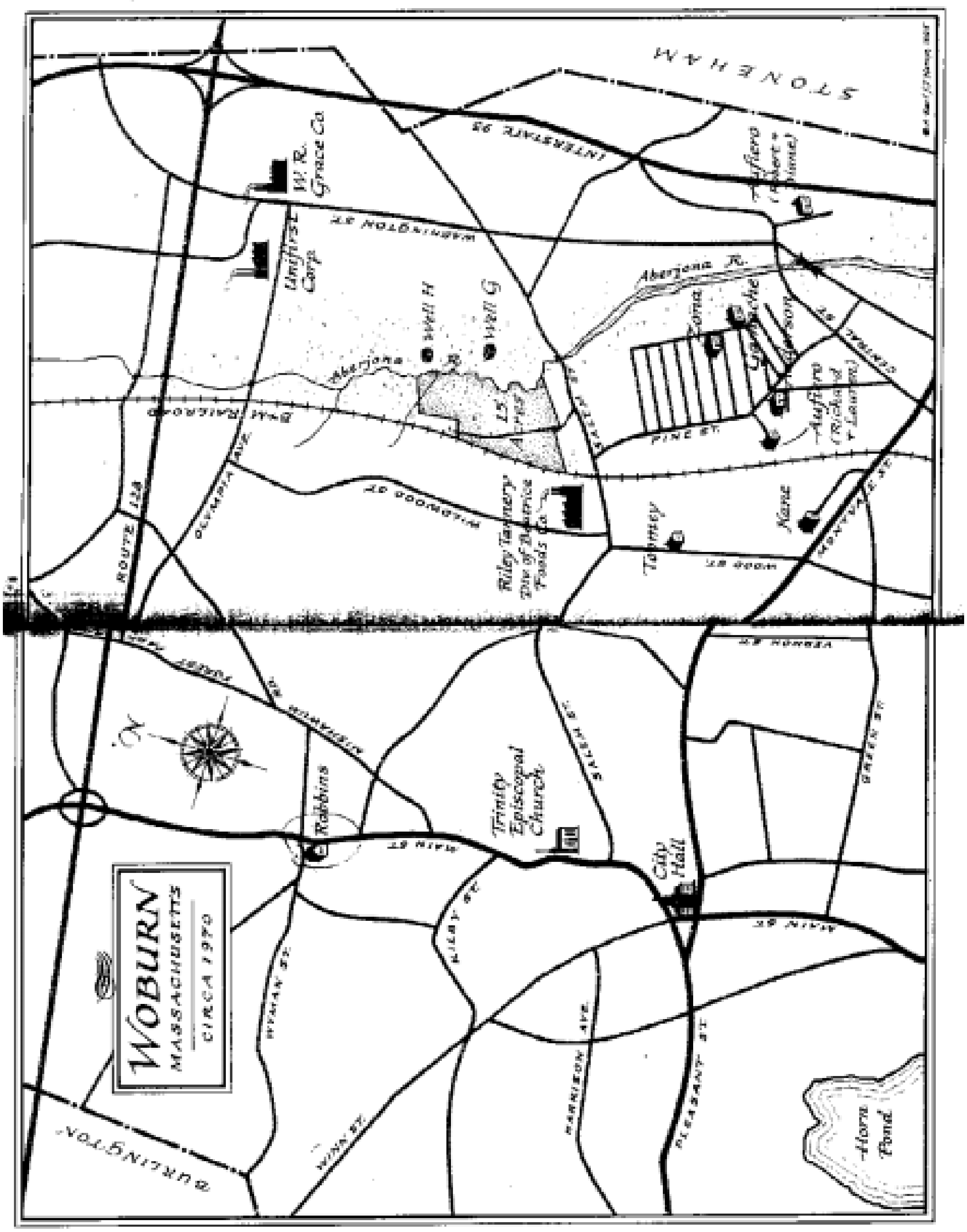
Wells G and H were found in the northeast section of Woburn and pumped water from an aquifer that was part of the Aberjona River watershed. Although they were connected to the rest of the city pipeline, they provided water primarily for the residents of eastern Woburn and some of the homes of the north central section of the city, which accounted for about 30% of the drinking water for the residents of Woburn. (Look at the map in Appendix 2 to see where all of the households with cases of childhood leukemia are located.) These wells were dug to accommodate the increased demand for potable water among the Woburn residents. Well G was drilled in 1964, and Well H was drilled in 1967. All the wells in Woburn are named by letters, so Wells G and H represent the seventh and eighth wells, respectively. At that time the city officials of Woburn thought that these two wells were going to be the solution to all of their drinking water problems because they would not then have to purchase their extra drinking water from other public water systems. Instead, it was the beginning of all of their problems.

Since the time the wells were first open for use, the residents who received water from those two wells had complained about the horrible quality of the water. It had a foul and putrid chemical odor and was even corrosive; residents who received water from Wells G and H always complained about leaky pipes they believed were a result of the poor quality of the water. Water became a regular subject among Woburn residents. The residents of east Woburn would call the department of health and public works everyday to complain so much that it became a daily conversation. Neighbors would ask each other, "Did you call today?" In the summer of 1967 the well was closed by the Massachusetts Department of Public Health for poor bacterial quality, but the city government protested, so the state health department was willing to reopen the well as long as the drinking water was chlorinated. Chlorination began in April 1968. The residents continued to complain of the bleachlike odor and rusty color of the water, but the city engineer argued that this was from the chlorine that was being used to kill bacteria and that the rusty color was just a result of the chlorine leaching out metal from the pipes.

In the spring of 1969 residents petitioned the mayor of Woburn to have the wells closed, and the mayor was willing to do this around October when the peak demand for water was over, but in the following spring the city engineers ordered the wells to start pumping water again. This constant battle between the residents and their municipal government continued. The well would be closed periodically because of pressure from the residents, and then other city officials would order the wells to open again. During the summer of 1972, when the well was closed, the city of Woburn was facing a drought. The city government threatened to open Wells G and H if the residents did not obey the drought restriction rules, such as not watering lawns and washing cars. Use of this threat worked very well. Residents of eastern Woburn followed these drought restriction rules. It was the horrible quality of the water that made Anne Anderson hypothesize that the water was causing all these cases of childhood leukemia. She believed that there was something contaminating it, and whatever this contaminant was, it was probably the cause of the increase in childhood leukemia.

Appendix 2

Map of Woburn, Massachusetts, with the location of Wells G and H, Unifirst Company, W. R. Grace, John J. Riley Tannery and the homes of some of the families with childhood leukemia.



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2. Ibid., 21.

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6. EPA Superfund Web site. Wells G and H Backgrounder resource page. Available at: http://www.epa.gov/region01/superfund/sites.wellsgh/over.html. Last updated October 15, 2002.

7. EPA Superfund Web site. Wells G and H Fact Sheet resource page. Available at: http://www.epa.gov/region01/superfund/sites/wellsgh/factsh.html. Last updated October 15, 2002.

Assignment Questions

Although the civil suit against W. R. Grace, Beatrice Foods and Unifirst was not very successful, the EPA did manage to get these three companies and the other three responsible parties to pay a combined total of $70 million to compensate for the cleanup of the hazardous waste site. This large settlement was accomplished with the legal tools and authority of the EPA's Superfund Program.

1. Describe what the Superfund Program is, including the purpose of the program.

2. What federal environmental legislation was passed to establish the Superfund Program?

3. Further federal legislation was passed to amend the legislation that was mentioned in Question 2. This legislation gave the EPA's Superfund Program even more legal tools and authority to litigate the responsible polluters. What is the name of this legislation?

4. The site of Wells G and H was first proposed to be put on the National Priorities List (NPL) on December 30, 1982. When was the site finally placed on the NPL? What is the current status of the hazardous waste site that surrounds Wells G and H? Has it been taken off the NPL?

   When Anne Anderson first suspected that the drinking water was the cause of all these increased cases of childhood leukemia, many tried to convince her that her suspicions were wrong, including her husband. Mr. Anderson mentioned to his wife, "If it is something as obvious as the water, don't you think someone else would know about it? What makes you think you know something that the public health officials don't know?" (*A Civil Action*, p. 25)

5. Why is this assumption that Mr. Anderson made incorrect?

Optional Assignments

Write a report about one of the following topics:

1. The $70 million settlement that the EPA settled with the six responsible parties is a landmark settlement in the environmental history of New England. This money, as mentioned before, is being used to clean up the hazardous waste site that surrounds Wells G and H. Give a detailed and organized description of the cleanup process that is being done to clean up the soil, groundwater and the Aberjona River.

2. Although many toxic chemicals were found in the hazardous waste site, the two chemical contaminants that were given a lot of attention were trichloroethylene (TCE) and tetrachloroethylene (Perc). Describe the potential deleterious health effects of these chemicals. How were they discovered and determined to be carcinogens? What common type of local business uses TCE to provide its service?

3. Jan Schlictmann, the main attorney for the Andersons and the seven other families that filed the civil suit against Unifirst, W. R. Grace and Beatrice Foods, is now working on another suspected leukemia cluster also in the Northeast, in Toms River, New Jersey. Write a case study about this possible leukemia cluster and compare it with the Woburn leukemia cluster, or compare the Woburn leukemia cluster with a suspected leukemia cluster that has been getting some media coverage in your area.

Assignment Questions (Teacher's Answer Key)

1. Describe what the Superfund Program is, including the purpose of the program.

   Superfund is a program set up by the EPA to clean up the nation's most polluted sites that were abandoned. These polluted sites resulted from companies dumping chemicals into the environment before there were regulations on the proper disposal of industrial waste. These sites are placed on the National Priorities List (NPL). The money that is used to finance the cleanup is collected by litigation of private companies who were found to be responsible for dumping the chemicals on that site.

   This question can be answered by using an environmental science textbook. The About Superfund resource page in the EPA Superfund Web site is another source. The URL for that Web page is http://www.epa.gov/superfund/about.htm.

2. What federal environmental legislation was passed to establish the Superfund Program?

   The legislation that was responsible for putting the Superfund Program into effect was the Comprehensive Environmental Responsive, Compensation and Liability Act (CERCLA), 1980.

   This question can be answered by using an environmental science textbook.

   This information can also found in the EPA Superfund Web site, on the Cercla Overview resource page. When students are on the main page of the Superfund Web site, they can click on Laws, Policies, and Guidance. From there they can click on the CERCLA Overview resource page. The URL for this Web page is http://www.epa.gov/superfund/law/cercla.htm.

3. Further federal legislation was passed to amend the legislation that was mentioned in Question 2. This legislation gave the EPA's Superfund Program even more legal tools and authority to litigate the responsible polluters. What is the name of this legislation?

   The Superfund Amendment Reauthorization Act (SARA), 1986, was the amendment to CERCLA, 1980. This question can also be answered using the same reference given for the answer to Question 2.

4. The site of Wells G and H was first proposed to be put on the National Priorities List (NPL). When was it finally placed on the NPL? What is the current status of the hazardous waste site that surrounds Wells G and H? Has it been taken off the NPL?

Wells G and H were placed on the National Priorities List on September 8, 1983. The cleanup process is still going on, so the waste site has not yet been taken off the list.

This information can be found on the Wells G and H resource page. The URL for this Web page is http://www.epa.gov/region01/superfund/sites/wellsgh.

5. Why is this assumption that Mr. Anderson made incorrect?

   Just because some people have not had a formal training in public health does not mean they cannot make causal inferences. Public health professionals often rely on observations and inferences that have been made by ordinary citizens gathering information about a disease or the occurrence of a disease among a population.

For the optional assignments, some places to start doing research would be as follows:

1. The Environmental Protection Agency. Available at: http://www.epa.gov/
2. The Centers for Disease Control and Prevention. Available at: http://www.cdc.gov/
3. The Agency for Toxic Substances and Disease Registry (ATSDR), which is part of the Centers for Disease Control and Prevention. Available at: http://www.atsdr.cdc.gov/

The ATSDR would be a good resource for information about trichloroethylene and tetrachloroethylene. The EPA is another helpful site.

For information about the cleanup process of Wells G and H, the Web site given before has a lot of information: http://www.epa.gov/region01/superfund/sites/wellsgh.