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An Outbreak of Legionnaires' Disease

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Contents

Lesson Plan

TITLE: An Outbreak of Legionnaires' Disease

SUBJECT AREA: Biology, mathematics, environmental science

OBJECTIVES: At the end of the module, the student will be able to:

- Use the distribution of cases of a cluster of health-related events (disease) to generate hypotheses about the cause
- Recognize the characteristic features of a common source outbreak
- Critically judge the evidence supporting or refuting a particular hypothesis about the cause of the outbreak
- Appreciate the role of the environment constructed by humans in contributing to environmental health problems

TIME FRAME: A minimum of three 45-minute lessons, with extensive homework assignment between the second and third sessions.

PREREQUISITE KNOWLEDGE: Familiarity with the basic steps of epidemic investigation (such as that gained from the modules on outbreak investigation in a community hospital or disease outbreak investigation—food-borne illness) and understanding of the case–control method (such as that gained from the module on case–control studies). Familiarity with spreadsheet programs would be useful.

MATERIALS NEEDED: Computer with Excel; handouts.

PROCEDURE: This advanced module provides students with the opportunity to work with a detailed dataset from an actual outbreak. The first class session involves introductory information about Legionnaires' disease, a bacterial infection spread through water sources in the environment. Students are told about the occurrence of 34 cases of Legionnaires' disease and asked to decide whether an outbreak has occurred and what might have been the source. They are then asked to consider what additional studies might be done to prove the source. In the second class session, the studies done by the investigators are discussed. Students are given the actual dataset from the case–control study and asked to work in groups to analyze it as homework. Depending on the level of analysis, students may come to the same conclusion as the original investigators or find evidence that leads to a different conclusion. The third class session permits sharing of

analyses of the case–control study and presentation of the results of follow-up studies that may help the class reach a conclusion about the source and cause of the outbreak.

ASSESSMENT: Students analyze data from a small hospital-based outbreak of streptococcal wound infections to determine the source.

LINK TO STANDARDS:

NATIONAL SCIENCE EDUCATION STANDARDS

Content Standard A: Science As Inquiry

- Abilities necessary to do scientific inquiry

Students Should:	Performance Indicators
• Identify questions and concepts that guide scientific investigations.	• Students should formulate a testable hypothesis and demonstrate the logical connections between the scientific concepts guiding a hypothesis and the design of an experiment. • They should demonstrate appropriate procedures, a knowledge base and conceptual understanding of scientific investigations.
• Design and conduct scientific investigations.	• Students must use evidence, apply logic and construct an argument for their proposed explanations.
• Formulate and revise scientific explanations and models using logic and evidence.	• Student inquiries should culminate in formulating an explanation or model. • In the process of answering questions, students should engage in discussions and arguments that result in the revision of their explanations.
• Recognize and analyze alternative explanations and models.	• Students should be able to use scientific criteria to find the preferred explanations.

- Understandings about scientific inquiry; Students should understand that:
  - Scientists conduct investigations for a wide variety of reasons. For example, they may wish to discover new aspects of the natural world, explain recently observed phenomena or test the conclusions of prior investigations or the predictions of current theories.
  - Scientific explanations must adhere to criteria such as: a proposed explanation must be logically consistent; it must abide by the rules of evidence; it must be open to questions and possible modification; and it must be based on historical and current scientific knowledge.

Content Standard E: Science and Technology

As a result of activities in grades 9–12, all students should develop awareness that:

- Scientists in different disciplines ask different questions, use different methods of investigation and accept different types of evidence to support their explanations. Many scientific investigations require the contributions of individuals from different disciplines, including engineering. New disciplines of science, such as geophysics and biochemistry, often emerge at the interface of two older disciplines.

Content Standard F: Science in Personal and Social Perspectives

As a result of activities in grades 9–12, all students should develop understanding of:

- Personal and community health
  - Hazards and the potential for accidents exist. Regardless of the environment, the possibility of injury, illness, disability or death may be present. Humans have a variety of mechanisms—sensory, motor, emotional, social and technological—that can reduce and modify hazards.
- Environmental quality
  - Natural ecosystems provide an array of basic processes that affect humans. Those processes include maintenance of the quality of the atmosphere, generation of soils, control of the hydrologic cycle, disposal of wastes and recycling of nutrients. Humans are changing many of these basic processes, and the changes may be detrimental to humans.

Notes for Teachers

Goals and Objectives of this Module

The goal of this module is to permit students who have learned the basic principles of epidemiology and who have some familiarity with the approach to epidemic investigation to exercise some independence in working through data from an actual outbreak. Students will gain additional experience in using descriptive epidemiology to demonstrate that an epidemic has occurred and to generate hypotheses about its cause. They will use their knowledge of the case–control design to test their hypotheses. They will be called on to determine whether associations that they find are causal. They will be asked to combine information from epidemiologic, environmental and microbiological studies to confirm their tentative conclusions. Some students may discover that their first conclusion is not necessarily the correct one; they will experience the scientist's frequent uncertainty about what truth is and when it has been found.

Background

Legionnaires' disease is a bacterial infection that causes 0.5–1.0% of the pneumonia cases that occur in the United States. Its incidence is 3–7/100,000 per year, with a peak in the summertime. It takes its name from the American Legion, whose convention in Philadelphia in 1976 was the venue of the first recognized outbreak. The agent is *Legionella pneumophila,* a gram-negative bacterium that thrives in water, particularly warm water, and that finds a protected niche by living inside aquatic single-cell organisms like amoebae. Most cases of Legionnaires' disease are sporadic, but outbreaks occur each year. Outbreaks have been traced to the inhalation of aerosols of contaminated water (such as those produced by cooling towers, evaporative condensers, whirlpool spas and misting machines) and to plumbing systems (particularly in hospitals and hotels). Person-to-person spread has not been found. The incubation period is generally 2–10 days. Legionnaires' disease is fatal in ~20% of people who acquire it, but certain antibiotics are effective in lowering the case fatality rate to ~5%. The elderly, smokers, men, and people with impairment of their immune system are more susceptible to Legionnaires' disease. Outbreaks of the disease can be halted by identifying the source and turning it off or decontaminating it. Regular cleaning and maintenance of cooling towers and evaporative condensers limit the growth of *L. pneumophila,* as does chlorination of water systems or maintenance of potable hot water at or above 50°C.

Structure of the Module

The module has three parts, the first two of which can each be presented in a single 45-minute class period. The third part is best presented after students, working in small groups, have had a few days to analyze the raw data and formulate their tentative conclusions.

The first part introduces the outbreak by describing the situation as it first presented itself to the investigators and the information they initially gathered about the 34 cases. Class discussion of that information should focus on the next steps investigators should have taken to determine the scope of the problem and identify the source.

The second part introduces the datasets that the investigators assembled in the course of their investigation. These include more detailed maps of the outbreak area, a case–control study, historical information on people hospitalized with pneumonia, environmental survey of potential aerosol sources, bacterial culture results from aerosol-generating machinery and history of repairs to the community's water distribution system.

The third part involves reports by groups of four to six students on the conclusions of their analysis of the data and their reasoning in support of those conclusions. Subsequent class discussion can be used to probe that reasoning and raise issues that students may not have identified. A summary of the actual investigation results can be distributed at the end of this class.

Matching

The investigators of this outbreak of Legionnaires' disease selected the controls for the case–control study by matching two controls for each of the first 30 cases. Controls were matched to their case by time and place of hospitalization, town of residence and age (within 10 years). Matching tends to protect against bias, because cases and controls are assured of similar frequencies of the variables for which they were matched. However, by matching on, say, age, one gives up the ability to study the influence of age on acquiring the disease. Moreover, analysis of matched studies requires a different method for calculating odds ratios from that used for unmatched studies.

To illustrate, in an unmatched case–control study, the odds ratio is estimated as follows:

$$OR = ad/bc \qquad [1]$$

where a = no. of cases with the exposure, b = no. of cases without the exposure, c = no. of controls with the exposure and d = no. of controls without the exposure.

In a matched study, each matched group is considered separately, and the estimate of the odds ratio is

$$OR = [\sum a_i d_i / T_i] / [\sum b_i c_i / T_i] \quad [2]$$

where a_i = no. of cases with the exposure in the ith-matched group, b_i = no. of cases without the exposure in the ith-matched group, c_i = no. of controls with the exposure in the ith-matched group, d_i = no. of controls without the exposure in the ith-matched group and T_i = no. of cases and controls in the ith-matched group. Note that matched groups in which all cases and controls are exposed (or all are not exposed) contribute no information to the estimation of the odds ratio.

For case–control studies with two controls per case, Equation [2] simplifies to

$$OR = [n_1 + 2n_2] / [n_3 + 2n_4] \quad [3]$$

where n_1 is the number of case–control triplets in which the case and exactly one control is exposed, n_2 is the number of case–control triplets in which the case but neither control is exposed, n_3 is the number of case–control triplets in which the case and exactly one control are not exposed and n_4 is the number of case–control triplets in which the case is not exposed but both controls are exposed. For example, walking exposure at Farmington and Nine Mile is associated with an estimated odds ratio of 2.4 based on matched analysis, because $n_1 = 7$, $n_2 = 6$, $n_3 = 2$ and $n_4 = 3$:

Walking Exposure to Farmington and Nine Mile

		Case	
		+	−
	0	6	11
Control	**1**	7	2
	2	1	3

$OR = [7 + 12]/[2 + 6] = 2.4$

If one had estimated the odds ratio based on Equation [1], the estimate would have been 2.2 (= $[14 \times 43]/[16 \times 17]$) if only the first 30 cases were included and 1.8 (= $[14 \times 43]/[20 \times 17]$) if all 34 cases were included. In general, using unmatched analysis for matched data will tend to bias the estimate of the odds ratio toward 1.

If one wishes to examine matched data for confounding, however, one may need to break the match in order to perform the analysis.

Lesson: An Outbreak of Legionnaires' Disease (Student Version)

Part I

Background on Legionnaires' Disease

Legionnaires' disease is a bacterial infection that causes 0.5–1.0% of the pneumonia cases that occur in the United States. Its incidence is 3–7/100,000 per year, with a peak in the summertime. It takes its name from the American Legion, whose convention in Philadelphia in 1976 was the venue of the first recognized outbreak. The agent is *Legionella pneumophila*, a gram-negative bacterium that thrives in water, particularly warm water, and that finds a protected niche by living inside aquatic single-cell organisms like amoebae. Most cases of Legionnaires' disease are sporadic, but outbreaks occur each year. Outbreaks have been traced to the inhalation of aerosols of contaminated water (such as those produced by cooling towers, evaporative condensers, whirlpool spas and misting machines) and to plumbing systems (particularly in hospitals and hotels). Cases are most common in late summer. Person-to-person spread has not been found. The incubation period is generally 2–10 days. Legionnaires' disease is fatal in ~20% of people who acquire it, but certain antibiotics are effective in lowering the case fatality rate to ~5%. The elderly, smokers, men and people with impairment of their immune system are more susceptible to Legionnaires' disease. Outbreaks of the disease can be halted by identifying the source and turning it off or decontaminating it. Regular cleaning and maintenance of cooling towers and evaporative condensers limit the growth of *L. pneumophila*, as does chlorination of water systems or maintenance of potable hot water at or above 50°C.

The Outbreak

On Tuesday, October 15, 1996, the Michigan Department of Community Health (MDHC) was contacted by the chief of the Infectious Disease Service at Botsford Hospital in Farmington Hills.* He reported that the hospital had three patients with illness compatible with Legionnaires' disease. All three were positive by urine antigen testing, and one had a positive culture for *Legionella*. Oakland County Health Division (OCHD) was simultaneously contacted by the Botsford Hospital infection control nurse.

Staff of the OCHD contacted the infection control departments at the three largest general hospitals serving Farmington and Farmington Hills (which have a combined population of about

*The description of the initial investigation is adapted from A Community Outbeak of Legionnaires' Disease in the Farmington–Farmington Hills Area, Michigan, October 1996, Communicable Disease Epidemiology Division, Bureau of Epidemiology, Michigan Department of Community Health, November 8, 1996. 6 pp.

480,000) and several other referral hospitals in southeastern Michigan. Infection control staff at those hospitals were asked to contact their laboratories daily to identify patients admitted recently with positive *Legionella* urine antigen tests or cultures. They were asked to report those who were from the Farmington and Farmington Hills area and those from surrounding communities who had been in that area prior to the onset of illness. MDHC contacted each identified patient or family members at the hospital or by telephone. Information concerning the patient's illness and medical history was collected. The locations and route of travel between the patient's home and workplace, and all other places visited during the two weeks prior to onset of illness, were recorded. The initial information collected from patients allowed investigators to define an area of approximately six square miles that was judged likely to contain the source of exposure, and to identify an approximate exposure interval.

A case was defined as a person with chest X-ray film evidence of pneumonia who tested positive for *L. pneumophila* by either culture or urinary antigen, had onset in late September or early October, and lived in, worked in or visited the likely exposure area (within one mile of the segment of Grand River Avenue that lies between Farmington and Middlebelt Roads—see Map 1). Table 1 lists the 34 people who met the case definition. Map 2 shows their places of residence.

Map 1. Map of Farmington and Farmington Hills, Michigan, with selected details (and with water system boundary slightly offset).

Table 1. Line List of Legionnaires' Disease Cases, Farmington and Farmington Hills, Michigan, September–October 1996

IDNUM	AGE	SEX	ONSET	HOSPITAL
1	74	F	9/30	PR
2	48	F	9/30	BMT
3	62	M	10/02	BOT
4	56	M	10/03	PR
5	70	M	10/03	PR
6	76	F	10/03	BMT
7	45	M	10/03	BMT
8	73	F	10/03	BOT
9	26	M	10/07	BOT
10	54	M	10/07	PR
11	34	F	10/07	PR
12	72	M	10/08	PR
13	57	M	10/09	BOT
14	65	F	10/09	BMT
15	70	F	10/10	BOT
16	84	F	10/12	PR
17	75	?	10/14	PR
18	71	F	10/14	PR
19	94	F	10/15	PR
20	87	M	10/05	BOT
21	74	?	10/16	PR
22	74	M	10/16	PR
23	67	F	10/17	PR
24	71	M	10/17	BOT
25	81	F	10/17	BOT
26	70	F	10/18	BOT
27	56	F	10/18	BOT
28	63	M	10/18	BOT
29	76	M	10/18	PR
30	34	M	10/18	PR
31	60	M	10/17	BMT
32	50	F	10/08	PRV
33	54	F	10/15	NOT ADM
34	72	F	10/05	BMT

BMT = William Beaumont Hospital, BOT = Botsford General Hospital, PR = Provident Hospital, PRV = unspecified place of hospitalization, NOT ADM = not hospitalized.

Map 2. Places of residence in Legionnaires' cases. Triangles with shadows represent homes that are off the map, 2–3 miles north of the indicated locations.

Questions

1. Has there been an outbreak of Legionnaires' disease?

2. Who has been affected?

3. If there has been an outbreak, what can you infer about its source from the information in Table 1 and Map 2?

4. What studies would you want to conduct to further investigate the possibility of an outbreak and its source?

Part II

Studies Done

1. Cases of pneumonia in the months leading up to and including the apparent outbreak.

Records of one hospital were reviewed for 1994 through 1996 (see document on Beaumont Hospital pneumonia cases, pages 31-34).

2. Case–control study of exposure history in cases and comparable controls without Legionnaires' disease.

Two matched controls without a diagnosis of pneumonia or febrile condition were selected for each of the first 30 cases. Matching was on the following criteria: hospitalization at the same time and place as the case, residency in the same municipality as the case, within 10 years of age as the case. The survey inquired about walking or driving exposure to 11 intersections and 26 specific establishments (see Questionnaire for Cases (page 35), Questionnaire for Controls (page 38), Case–Control Excel File (available at collegeboard.com/yes/legionnaires; a static image of this file is reproduced on pp. 42–44) and Key to Case–Control Excel File (page 45). In the coding of the questionnaire for the Case–Control Excel File, 1 = yes, 2 = no, w = walking exposure to an intersection and d = driving exposure to an intersection; a and b are designations for controls matched to the case with the same IDNUM.

3. Subtyping of isolates from cases.

Ten of the patients with Legionnaires' disease were culture positive for *L. pneumophila*. Isolates for all 10 were tested for serogroup, monoclonal antibody subtype and pulsed gel electrophoresis pattern (see Case Isolates, page 46).

4. Identification of aerosol-producing machinery in suspected area.

Survey by state helicopter revealed 35 buildings with rooftop machinery resembling cooling towers, potential aerosol sources. Environmental health staff visited 35 buildings and identified 17 potential sources; 4 more potential sources were identified in other ways (see Environmental Survey, pages 47–51).

5. Culture of aerosol-producing machinery in suspected area.

Eleven of the 21 potential sources had been operational during the presumed exposure interval and were still operating at the time of inspection, and so were cultured (see Environmental Cultures, pages 52–54). Those judged to have evidence of bacterial growth were recommended to be cleaned and disinfected. Water specimens from the houses of several ill persons were cultured.

6. Mapping of municipal water system.

A map of the Farmington municipal water system was obtained (see Map 1).

7. History of water main breaks.

Records of water main breaks in the Farmington municipal water supply were abstracted for 1995 and 1996 (see Water Main Breaks, pages 55–56).

Questions and Assignment

1. What additional information would you like to have about the studies?

2. Working in groups of four to six over the next several days, analyze the various documents and datasets in order to determine the likely source(s) and suggest control measures. To justify your conclusions, include in your analysis tables that demonstrate the association of illness with potential sources and indicate whether or not that association is causal.

3. How might you have improved the original investigation?

Part III

Reports of Study Teams

Analyze the reports that follow and determine whether there was an outbreak and, if so, of what disease; how the disease was spread; what potential sources are associated with the disease epidemiologically; what steps were taken to control the outbreak and whether they were successful.

Lesson: An Outbreak of Legionnaires' Disease (Teacher's Annotated Version)

Part I

Background on Legionnaires' Disease

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480,000) and several other referral hospitals in southeastern Michigan. Infection control staff at those hospitals were asked to contact their laboratories daily to identify patients admitted recently with positive *Legionella* urine antigen tests or cultures. They were asked to report those who were from the Farmington and Farmington Hills area and those from surrounding communities who had been in that area prior to the onset of illness. MDHC contacted each identified patient or family members at the hospital or by telephone. Information concerning the patient's illness and medical history was collected. The locations and route of travel between the patient's home and workplace, and all other places visited during the two weeks prior to onset of illness, were recorded. The initial information collected from patients allowed investigators to define an area of approximately six square miles that was judged likely to contain the source of exposure, and to identify an approximate exposure interval.

A case was defined as a person with chest X-ray film evidence of pneumonia who tested positive for *L. pneumophila* by either culture or urinary antigen, had onset in late September or early October, and lived in, worked in, or visited the likely exposure area (within one mile of the segment of Grand River Avenue that lies between Farmington and Middlebelt Roads—see Map 1). Table 1 lists the 34 people who met the case definition. Map 2 shows their places of residence.

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7	45	M	10/03	BMT
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9	26	M	10/07	BOT
10	54	M	10/07	PR
11	34	F	10/07	PR
12	72	M	10/08	PR
13	57	M	10/09	BOT
14	65	F	10/09	BMT
15	70	F	10/10	BOT
16	84	F	10/12	PR
17	75	?	10/14	PR
18	71	F	10/14	PR
19	94	F	10/15	PR
20	87	M	10/05	BOT
21	74	?	10/16	PR
22	74	M	10/16	PR
23	67	F	10/17	PR
24	71	M	10/17	BOT
25	81	F	10/17	BOT
26	70	F	10/18	BOT
27	56	F	10/18	BOT
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Map 2. Places of residence in Legionnaires' cases. Triangles with shadows represent homes that are off the map, 2–3 miles north of the indicated locations.

Questions

1. Has there been an outbreak of Legionnaires' disease?

   Farmington and Farmington Hills have a combined population of about 480,000. The Centers for Disease Control and Prevention (CDC) estimates that 8,000–18,000 cases of Legionnaires' disease occur annually in the United States, for an annual incidence rate of 3–7/100,000. Thus one might expect 15–35 cases per year in Farmington and Farmington Hills residents (although most would probably go undiagnosed). One has

to add to this number the cases that might occur in the unknown number of visitors. Even with the seasonality of Legionnaires' disease, it would be distinctly unusual to have 34 cases in this population in less than one month, so there almost certainly was an outbreak in 1996. In this instance, the shape of the epidemic curve is not very helpful in confirming the presence of an outbreak, in part because the case finding was restricted to late September and early October. It would have been helpful to have equivalent case finding for at least early September and late October to permit testing of the presumption that there were no (or few) cases in those intervals before and after the evident outbreak.

2. Who has been affected?

   Without knowledge of the age and sex distribution of Farmington and Farmington Hills, one cannot calculate age- and sex-specific incidence rates. Roughly equal numbers of men and women are affected (which is unusual for Legionnaires' disease, which more commonly affects men) and more than half are over the age of 70. The spot map of residence shows cases widely distributed.

3. If there has been an outbreak, what can you infer about its source from the information in Table 1 and Map 2?

   A source within Farmington or Farmington Hills seems likely, although one might have wanted to see a larger spot map to confirm that cases clustered there. There is the suggestion that cases cluster along Grand River Avenue in Farmington. One might suspect a source to which older people are exposed.

4. What studies would you want to conduct to further investigate the possibility of an outbreak and its source?

   Open discussion of a wide range of possible studies—epidemiologic, environmental and microbiological—should be encouraged here. As homework, students might be asked to write a brief description of the studies that they think should have been done to determine whether an outbreak has occurred and to identify its source.

Part II

In the actual outbreak investigation some studies were done, and other plausibly useful studies were not. Thus potentially useful studies to be discussed here can be considered to fall in one of three groups: (1) studies suggested by students and (in some form) done by the investigators, (2) studies suggested by students but not done by the investigators, and (3) studies not suggested by students but done by the investigators. Because the author of this module cannot anticipate what studies your students will suggest, the discussion below lumps (1) and (3) together and considers them first.

Studies Done

1. Cases of pneumonia in the months leading up to and including the apparent outbreak.

Records of one hospital were reviewed for 1994 through 1996 (see document on Beaumont Hospital pneumonia cases, pages 31-34).

A study of pneumonia hospitalizations over three years could show whether the outbreak involved large numbers of cases not diagnosed as Legionnaires' disease and could show whether the Legionnaires' disease outbreak was limited to September and October 1996. The particular study that was done is limited by the fact that only one of three major hospitals was surveyed. Analysis should be limited to residents of Farmington and Farmington Hills.

2. Case–control study of exposure history in cases and comparable controls without Legionnaires' disease.

Two matched controls without a diagnosis of pneumonia or febrile condition were selected for each of the first 30 cases. Matching was on the following criteria: hospitalization at the same time and place as the case, residency in the same municipality as the case, within 10 years of age as the case. The survey inquired about walking or driving exposure to 11 intersections and 26 specific establishments (see Questionnaire for Cases (p. 35), Questionnaire for Controls (p. 38), Case–Control Excel File (available at www.collegeboard.com/yes/legionnaires; a static image of this file is reproduced on pp. 42–44) and Key to Case–Control Excel File (page 45). In the coding of the questionnaire for the Case–Control Excel File, 1 = yes, 2 = no, w = walking exposure to an intersection and d = driving exposure to an intersection; a and b are designations for controls matched to the case with the same IDNUM.

The case–control design is the most efficient way to determine differences in cases and noncases in regard to exposures to potential sources of *Legionella* as well as conditions that might predispose to infection. Having two controls per case helps to maximize information when the outbreak is rather small. Matching helps to ensure that cases and controls are comparable, although it creates some difficulties in the analysis. The investigators' decision to focus exposure questions on intersections and certain establishments resulted from initial interviews in early cases. Just what constitutes exposure to an intersection is problematic. The investigators hedged their bets, asking about both walking exposure and driving exposure. One had to enter an establishment to be considered exposed to it.

To achieve comparability, case-patients and controls should be asked the same questions in the same order. The investigators of this outbreak used one form for most of the cases and another for all the controls. Students should reflect on whether the differences in the questionnaires might have affected responses and therefore introduced bias in the analysis.

3. Subtyping of isolates from cases.

Ten of the patients with Legionnaires' disease were culture positive for *L. pneumophila*. Isolates for all 10 were tested for serogroup, monoclonal antibody subtype and pulsed gel electrophoresis pattern (see Case Isolates, page 46).

Subtyping of isolates is an important tool in "molecular epidemiology." It permits more detailed understanding of which cases are related and which are not. For proper interpretation, one needs to know not only the subtypes of strains associated with the outbreak but also the distribution of subtypes of strains not associated with the outbreak. If the outbreak subtype is unusual, the subtyping is particularly helpful to the epidemiologist.

4. Identification of aerosol-producing machinery in suspected area.

Survey by state helicopter revealed 35 buildings with rooftop machinery resembling cooling towers, potential aerosol sources. Environmental health staff visited 35 buildings and identified 17 potential sources; 4 more potential sources were identified in other ways (see Environmental Survey, pages 47–51).

Few jurisdictions have records of the presence of aerosol-producing devices, so those devices must be sought when a Legionnaires' disease outbreak occurs. Survey by helicopter is imaginative (and dramatic) but may miss many devices that are covered or inside buildings. The investigators in this situation followed up on foot but still missed some. Most of the aerosol-producing devices were either cooling towers or evaporative condensers, both of which are designed to transfer heat from cooling equipment to the environment. In evaporative condensers, recirculating water cascades over pipes containing Freon (or other coolants) in gas phase, cooling the Freon and allowing it to be compressed into liquid phase and recirculated. In cooling towers, the cascading liquid cools pipes containing water, which cools the Freon in a second step, elsewhere in the system. In both cases, powerful fans blow air past the cascading water, facilitating heat exchange through evaporation but also creating water droplets that are released into the environment and may be inhaled by people downwind.

5. Culture of aerosol-producing machinery in suspected area.

Eleven of the 21 potential sources had been operational during the presumed exposure interval and were still operating at the time of inspection, and so were cultured (see Environmental Cultures, pages 52–54). Those judged to have evidence of bacterial growth were recommended to be cleaned and disinfected. Water specimens from the houses of several ill persons were cultured.

There is a tension between awaiting the epidemiologic study results in order to focus the environmental sampling and proceeding directly to environmental sampling so

that one can clean (or shut off) potentially infectious devices as soon as possible without losing valuable microbiological information.

6. Mapping of municipal water system.

A map of the Farmington municipal water system was obtained (see Map 1).

Because *Legionella* lives in fresh water, it is useful to know the water distribution system and its interconnections.

7. History of water main breaks.

Records of water main breaks in the Farmington municipal water supply were abstracted for 1995 and 1996 (see Water Main Breaks, pages 55–56).

Rapid changes in pressure in water systems shake loose biofilm, which contains unicellular aquatic forms in which *Legionella* often resides. Such pressure changes are suspected as triggers for the spread of *Legionella* and the seeding of downstream devices like cooling towers and evaporative condensers.

Studies Not Done

1. Study of Legionnaires' disease cases elsewhere in Michigan in September and October 1996.

One might have wanted a systematic look outside the apparent epidemic area to ensure that the Legionnaires' disease outbreak was not more widespread. The investigators evidently judged that the telephone calls to referral hospitals outside Farmington and Farmington Hills would have turned up a wider outbreak if there had been one.

2. Census of Farmington and Farmington Hills.

To determine which groups are at highest risk of Legionnaires' disease in this outbreak, one would need to know the denominators as well as the numerators. Doing a census would not have been practical, but it would have been helpful to collect information on age, sex and census tract distributions from existing sources.

3. Case–control study with community controls.

Controls chosen from hospitalized patients are on average going to be less well than those chosen from the community, and arguably less well than people who acquire Legionnaires' disease in the community. On the other hand, choosing controls from hospitalized patients does ensure that cases and controls come from the same catchment area. In the ideal world one might have done a case–control study with two sets of controls, one from the hospital and one from the community.

4. Culture of potable water.

   Specimens of potable water were taken from the homes of some ill people, but the water distribution system in the presumed area of exposure was not sampled.

Questions and Assignment

1. What additional information would you like to have about the studies?

2. Working in groups of four to six over the next several days, analyze the various documents and datasets in order to determine the likely source(s) and suggest control measures. To justify your conclusions, include in your analysis tables that demonstrate the association of illness with potential sources and indicate whether or not that association is causal.

3. How might you have improved the original investigation?

Part III

Reports of Study Teams

One might discuss the reports of the study teams according to the following elements of an infectious disease outbreak investigation:

1. What is the disease?

   Legionnaires' disease was well documented here. Indeed, isolating *L. pneumophila* from 10 of 34 cases is an extraordinary achievement, as the organism is hard to grow.

2. Is there an outbreak?

   Yes, although a more systematic look at other times and other places would have made the argument even more solid.

3. In whom, where and when is it occurring?

   In Farmington and Farmington Hills, in late September and early October 1996, particularly in active older people.

4. What is the mode of spread?

   ***L. pneumophila* is generally spread by inhalation of infectious aerosols, at close range or at distances up to 50 meters or more. The pattern in this outbreak is consistent with airborne spread, as no one exposure was common to all, and some exposures were at a distance from the apparent source(s).**

5. What might be the source(s)?

   With Legionnaires' disease, one thinks first of aerosol-producing machinery like cooling towers, evaporative condensers, humidifiers, whirlpool spas and grocery sprays or of aerosols of warm potable water, including sinks and showers.

6. What potential sources are associated with disease epidemiologically?

   Of all the exposures tested in the case–control study, walking exposure to the intersection of Grand River and Orchard Lake and entering Cattleman's Market were associated most strongly with acquiring Legionnaires' disease:

Walking Exposure to Grand River and Orchard Lake (Matched Analysis)

		Case	
		+	−
	0	15	4
Controls	**1**	8	0
	2	2	1

OR = 19.0.

Exposure to Cattleman's (Matched Analysis)

		Case	
		+	−
	0	13	10
Controls	**1**	4	3
	2	0	0

OR = 10.0.

Walking exposure to the intersection of Orchard Lake and Ten Mile was more weakly associated.

Walking Exposure to Orchard Lake and Ten Mile (Matched Analysis)

		Case	
		+	−
	0	11	7
Controls	**1**	5	5
	2	2	0

OR = 5.4.

7. What is the evidence that the association is causal?

The strength of the associations and their biological plausibility (particularly in light of the similarity of the *L. pneumophila* strains isolated from the Cattleman's evaporative condenser and from 10 people with cases) weigh in favor of a causal relation with the Cattleman's evaporative condenser. The presence of the same strain in the nearby Krueger cooling tower complicates the assessment of causality, because it too is near Grand River and Orchard Lake (and Cattleman's) and so could have been the source of cases. Few people visited Krueger, however, and colony counts were lower there, tending to justify the investigators' conclusion that Cattleman's was the source.

One would be more comfortable with this conclusion, however, if there were clear evidence of a dose-response relationship between exposure and risk of illness. The investigators initially sought to gather information to assess dose response (see Questionnaire for Cases and Questionnaire for Controls) but ended up not coding information on dose, apparently because they did not judge their measures of dose to be reliable. One can create a proxy of dose, however, from their coded data by summing the individual establishments in the vicinity of each intersection. If one does that, one finds little evidence of dose response to exposure in the vicinity of Grand River and Orchard Lake, but a notable dose response in regard to exposure to establishments in the vicinity of Orchard Lake and Ten Mile:

Dose-Response Relationship with Exposure to Sites Near Orchard Lake and Ten Mile

	Number of Specified Sites Visited					
	0	**1**	**2**	**3**	**4**	**5**
Case	14	8	4	3	1	0
Control	49	8	3	0	0	0

Compared with 0 sites visited, the odds ratios associated with more sites can be calculated as follows:

1 site: $OR = (8 \times 49)/(14 \times 8) = 3.5$

2 sites: $OR = (4 \times 49)/(14 \times 3) = 4.7$

3 sites: $OR = \infty$

4 sites: $OR = \infty$

Note that the analysis is done by breaking the matching of the 30 cases and their 60 controls in order to assess dose response. The finding of a dose response associated with sites at Orchard Lake and Ten Mile raises the interesting possibility that sites near both intersections might have been sources of *Legionella*.

To investigate that possibility further, one might examine separately those 10 cases in which the distinctive outbreak strain was isolated. (In general, restricting analysis to cases with the strongest diagnostic evidence—in this case, positive culture—will tend to increase the observed strength of association with the actual source [because false-positives are minimized] and lower the precision of the estimate of association [because some information is ignored]). Remarkably, those culture-positive cases,

when compared with their controls, were strongly associated with exposure to Orchard Lake and Ten Mile and not with exposure to Grand River and Orchard Lake (Table 2).* Conversely, the remaining cases, diagnosed only by urinary antigen, are found to be associated with exposure near Grand River and Orchard Lake, but not with exposure near Orchard Lake and Ten Mile. This further suggests that there were (at least) two different environmental sources of *Legionella* in this outbreak.

Table 2. Risk of Legionnaires' Disease†

			Number of 5 Sites Visited near Orchard Lake and Ten Mile				
			0	**1**	**2**	**3**	**4**
Epidemic Strain–Positive Cases and Their Controls	**Walked near Grand River and Orchard Lake**	**Cases**	2	3	2(3)‡	0	0
		Controls	7	1	0	0	0
	Did Not Walk near Grand River and Orchard Lake	**Cases**	1	0	0	1	0
		Controls	9	1	0	0	0
Epidemic Strain–Negative Cases and Their Controls	**Walked near Grand River and Orchard Lake**	**Cases**	8	6	1	2	1
		Controls	3	2	1	0	0
	Did Not Walk near Grand River and Orchard Lake	**Cases**	3(6)‡	0	0	0	0
		Controls	30	4	2	0	0

†With culture either positive for the epidemic strain or negative, as a function of the number of sites visited near Orchard Lake and Ten Mile, with analysis stratified by walking exposure near Grand River and Orchard Lake, Michigan, 1996.

‡( ) = Number including cases for which no controls were selected.

8. What steps are taken to control the outbreak?

Early in the investigation, the evaporative condenser at Cattleman's was drained and cleaned. When that did not clear it of culturable *Legionella,* it was taken out of service.

*Statistical testing is largely beyond the scope of this module. However, such testing using the Cochrane-Armitage trend test or exact logistic regression shows that the dose response (as illustrated in Table 2) associated with exposure to the five sites at Orchard Lake and Ten Mile is statistically significant for culture-positive (but not culture-negative) cases and their controls, even when controlled for walking exposure at Grand River and Orchard Lake.

9. Did the control measures succeed?

The outbreak stopped. However, it stopped before the Cattleman's evaporative condenser was cleaned on October 22, so the effectiveness of that control measure is hard to assess. A cooling tower at Bel-Aire Lanes, near Orchard Lake and Ten Mile, was found on October 30 to be "very dirty," but it had been turned off for the season sometime during October 1–5* and so was not cultured. Given the incubation period of Legionnaires' disease and the association with exposure near Orchard Lake and Ten Mile, the timing of the turning off of the Bel-Aire Lanes cooling tower suggests that may have contributed to the control of the outbreak. One can speculate that the water main break on September 9 might have seeded both the evaporative condenser at Cattleman's and the cooling tower at Bel-Aire Lanes (and perhaps other devices) on the Farmington water distribution system, but in the absence of contemporary investigation of the potable water system in the area, one cannot be sure.

*The summary log of environmental samples (Environmental Survey, page 47) suggests that this cooling tower was turned off on September 11, but the original field notes show the October 1–5 dates.

Documents Relating to Outbreak Investigation

William Beaumont Hospital, Royal Oak:
1994–1995–1996, All Admissions with Pneumonia from Farmington and/or Farmington Hills

	Admitting Date	City	Zip Code
1	94/01/03	FARMINGTON HILL	48335
2	94/01/04	FARMINGTON HILL	48335
3	94/01/22	FARMINGTON HILL	48337
4	94/01/26	FARMINGTON	48335
5	94/01/28	FARMINGTON HILL	48334
6	94/02/04	FARMINGTON HILL	48334
7	94/02/06	FARMINGTON HILL	48334
8	94/02/11	FARMINGTON HILL	48334
9	94/02/16	FARMINGTON HLLS	48331
10	94/02/22	FARMINGTON HILL	48331
11	94/02/27	FARMINGTON	48336
12	94/03/08	FARMINGTON HILL	48331
13	94/03/29	FARMINGTON HILL	48334
14	94/04/04	FARMINGTON HILL	48331
15	94/04/05	FARMINGTON HILL	48331
16	94/04/11	FARMINGTON HILL	48334
17	94/04/29	FARMINGTON HILL	48334
18	94/05/05	FARMINGTON	48335
19	94/06/04	FARMINGTON HILL	48335
20	94/06/10	FARMINGTON	48336
21	94/07/05	FARMINGTON HILL	48334
22	94/07/11	FARMINGTON HILL	48331
23	94/07/15	FARMINGTON HILL	48334
24	94/07/24	FARMINGTON HILL	48018
25	94/07/28	FARMINGTON	48336
26	94/08/02	FARMINGTON HILL	48331
27	94/08/11	FARMINGTON	48335
28	94/09/03	FARMINGTON HILL	48334
29	94/09/04	FARMINGTON HILL	48334
30	94/09/13	FARMINGTON HILL	48331
31	94/09/21	FARMINGTON HILL	48331
32	94/09/27	FARMINGTON HILL	48334
33	94/10/13	FARMINGTON HILL	48331
34	94/10/15	FARMINGTON HILL	48334
35	94/10/22	FARMINGTON HILL	48331
36	94/10/27	FARMINGTON HILL	48336
37	94/10/29	FARMINGTON HILL	48334
38	94/11/01	FARMINGTON HILL	48337
39	94/11/03	FARMINGTON HILL	48334
40	94/11/19	FARMINGTON HILL	48331
41	94/11/21	FARMINGTON HILL	48331
42	94/11/24	FARMINGTON HILL	48334

	Admitting Date	City	Zip Code
43	94/11/28	FARMINGTON HILL	48336
44	94/12/04	FARMINGTON HILL	48337
45	94/12/12	FARMINGTON HILL	48331
46	94/12/25	FARMINGTON HILL	48334
47	94/12/27	FARMINGTON HILL	48334
48	95/01/13	FARMINGTON HILL	48334
49	95/01/15	FARMINGTON HILL	48331
50	95/01/24	FARMINGTON HILL	48336
51	95/01/30	FARMINGTON HILL	48334
52	95/01/30	FARMINGTON HILL	48331
53	95/02/07	FARMINGTON HILL	48336
54	95/02/20	FARMINGTON HILL	48335
55	95/03/02	FARMINGTON	48335
56	95/03/31	FARMINGTON HILL	48336
57	95/04/08	FARMINGTON HILL	48334
58	95/04/16	FARMINGTON HILL	48334
59	95/05/03	FARMINGTON HILL	48331
60	95/05/16	FARMINGTON HILL	48336
61	95/05/29	FARMINGTON HILL	48334
62	95/06/02	FARMINGTON HILL	48334
63	95/06/08	FARMINGTON HILL	48334
64	95/06/13	FARMINGTON HILL	48331
65	95/07/01	FARMINGTON HILL	48334
66	95/07/31	FARMINGTON HILL	48331
67	95/08/02	FARMINGTON HILL	48334
68	95/08/15	FARMINGTON HILL	48331
69	95/08/23	FARMINGTON HILL	48334
70	95/08/28	FARMINGTON HILL	48331
71	95/09/07	FARMINGTON HILL	48334
72	95/10/01	FARMINGTON HILL	48334
73	95/10/02	FARMINGTON HILL	48334
74	95/10/03	FARMINGTON HILL	48334
75	95/10/09	FARMINGTON HILL	48336
76	95/10/10	FARMINGTON HILL	48336
77	95/10/13	FARMINGTON HILL	48336
78	95/10/23	FARMINGTON HILL	48334
79	95/11/02	FARMINGTON HILL	48331
80	95/11/03	FARMINGTON HILL	48334
81	95/11/03	FARMINGTON HILL	48336
82	95/11/12	FARMINGTON HILL	48334
83	95/11/15	FARMINGTON HILL	48331
84	95/11/18	FARMINGTON HILL	48334

	Admitting Date	City	Zip Code
85	95/11/22	FARMINGTON HILL	48331
86	95/11/28	FARMINGTON HILL	48331
87	95/11/30	FARMINGTON HILL	48334
88	95/12/03	FARMINGTON HILL	48331
89	95/12/06	FARMINGTON	48336
90	95/12/06	FARMINGTON HILL	48336
91	95/12/10	FARMINGTON HILL	48334
92	95/12/16	FARMINGTON	48335
93	96/01/03	FARMINGTON HILL	48331
94	96/01/13	FARMINGTON HILL	48331
95	96/01/15	FARMINGTON HLS	48334
96	96/01/18	FARMINGTON HILL	48336
97	96/01/25	FARMINGTON	48336
98	96/01/27	FARMINGTON HILL	48331
99	96/02/05	FARMINGTON HILL	48331
100	96/02/08	FARMINGTON HILL	48331
101	96/02/09	FARMINGTON HILL	48334
102	96/02/22	FARMINGTON	48336
103	96/02/22	FARMINGTON HILL	48336
104	96/02/27	FARMINGTON HILL	48331
105	96/03/11	FARMINGTON HILL	48334
106	96/03/15	FARMINGTON HILL	48336
107	96/03/26	FARMINGTON HILL	48336
108	96/03/27	FARMINGTON HILL	48331
109	96/04/01	FARMINGTON HILL	48334
110	96/04/02	FARMINGTON	48335
111	96/04/03	FARMINGTON	48336
112	96/04/06	FARMINGTON HILL	48331
113	96/04/10	FARMINGTON HILL	48336
114	96/04/15	FARMINGTON HILL	48331
115	96/04/18	FARMINGTON HILL	48334
116	96/04/22	FARMINGTON HILL	48331
117	96/04/27	FARMINGTON HILL	48334
118	96/04/30	FARMINGTON HILL	48336
119	96/05/01	FARMINGTON HILL	48336
120	96/05/02	FARMINGTON	48335
121	96/05/10	FARMINGTON HILL	48331
122	96/05/16	FARMINGTON HILL	48334
123	96/05/18	FARMINGTON HILL	48331
124	96/05/25	FARMINGTON	48336
125	96/05/31	FARMINGTON HILL	48336
126	96/06/09	FARMINGTON HILL	48334

	Admitting Date	City	Zip Code
127	96/06/14	FARMINGTON	48335
128	96/07/03	FARMINGTN HLS	48334
129	96/07/05	FARMINGTN HLS	48331
130	96/07/08	FARMINGTN HLS	48334
131	69/07/24	FARMINGTN HLS	48334
132	96/08/13	FARMINGTON HILL	48334
133	96/08/15	FARMINGTN HLS	48331
134	96/08/26	FARMINGTN HLS	48334
135	96/09/05	FARMINGTN HLS	48331
136	96/09/06	FARMINGTN HLS	48335
137	96/09/12	FARMINGTN HLS	48334
138	96/09/14	FARMINGTON HILL	48334
139	96/09/19	FARMINGTON	48335
140	96/10/03	FARMINGTN HLS	48336
141	96/10/04	FARMINGTON HILL	48336
142	96/10/06	FARMINGTON	48335
143	96/10/07	FARMINGTON	48336
144	96/10/07	FARMINGTON HILL	48336
145	96/10/20	FARMINGTON	48335
146	96/10/20	FARMINGTON	48335
147	96/10/21	FARMINGTN HLS	48336
148	96/10/24	FARMINGTN HLS	48331
149	96/11/01	FARMINGTON	48336
150	96/11/05	FARMINGTN HLS	48331
151	96/11/11	FARMINGTN HLS	48331
152	96/11/16	FARMINGTN HLS	48334
153	96/11/23	FARMINGTN HLS	48331
154	96/11/26	FARMINGTN HLS	48331
155	96/11/26	FARMINGTN HLS	48334
156	96/12/06	FARMINGTN HLS	48331
157	96/12/09	FARM HILLS	48018
158	96/12/09	FARMINGTN HLS	48336
159	96/12/14	FARMINGTON	48335
160	96/12/15	FARMINGTN HLS	48334
161	96/12/17	FARMINGTN HLS	48331
162	96/12/21	FARMINGTON HILL	48335
163	96/12/28	FARMINGTN HLS	48336

Questionnaire for Cases

Case _____ Control_____

Legionnaires' Disease Questionnaire

Name _____ Physician Name_____

Address_____ Telephone #_____

City _____ Hospital_____

Phone_____ Onset date_____

Admit date_____

Do you have a work location? Y N

If yes, where do you work?

What route do you take to get there?

From (Wednesday, September 25) through the time you became ill:

Have you walked or driven in the vicinity (within one block) of any of the following places in Farmington/Farmington Hills:

Location	**Date and Time # Hours**	**Walk (W) or Drive (D)**
Middlebelt and GR		
GR and Farmington		
Donut Mall		
Fountain @ City Hall		
TJ Maxx		
GR bet Drake and Farmington		
Oakwood Cemetery on GR		
Freedom and Farmington		
LOC Credit Union		
Folsom bet OL and Middlebelt		
Botsford Nursing Home		

OL and 10 Mi

Office Building

IGA

Bicycle Shop

Barber Shop (Bellaire)

Rite-Aid drugstore

Farmington & 9 Miles

Farmer Jack

OL & Shiawassee

Medical Office Bldg

****

Other Activities Since September 25, 1996:

Church:

Car Wash:

Hair style/Barber shop:

Bank:

Exercise:

Restaurants:

Other shopping:

Finally, I'd like to ask you a few questions about your own health status>

Age

Do you smoke? Y N

If yes, how many packs per day?

If quit, how many years ago?

Do you have any of the following medical conditions?

Diabetes	Y	N
Emphysema or chronic bronchitis	Y	N
Asthma	Y	N
Heart disease	Y	N
Cancer	Y	N

if yes, what kind? _____

Other medical illness_____

Do you take any of the following medications?

steroids (such as prednisone) Y N

chemotherapy medications (for cancer or autoimmune diseases) Y N

(prompt with methotrexate, cyclophosphamide, cytoxan, immuran)

Questionnaire for Controls

Case _____ Control_____

Legionnaires' Disease Questionnaire

Name _____ Physician Name_____

Address_____ Telephone #_____

City _____ Hospital_____

Phone_____ Onset date_____

Admit date_____

Hello, I am _____ with the Michigan Department of Community Health in Lansing. I'm calling in regards to the recent outbreak of Legionnaires' Disease in the Farmington area.

We obtained your name from the hospital as a patient who was not likely to have Legionnaires' Disease.

I'd like to take about 10 minutes of your time and ask you a few questions about your own health and activities. Is now a good time? If not, when_____.

IT MIGHT BE HELPFUL TO USE A CALENDAR FOR THIS NEXT PART

First, I"d like to ask you a few questions about your own health status>

In the period since _____ to _____ (determine from case onset date), did you have an illness with fever or were you diagnosed with pneumonia? Y N

IF YES, THEN THIS PERSON IS NOT APPROPRIATE TO USE AS A CONTROL.

Age

Do you smoke? Y N

If yes, how many packs per day?

If quit, how many years ago?

Do you have any of the following medical conditions?

Diabetes Y N

Emphysema or chronic bronchitis Y N

Asthma Y N

Heart disease Y N

Cancer Y N

if yes, what kind? _____

Other medical illness_____

Do you take any of the following medications?

steroids (such as prednisone) Y N

chemotherapy medications (for cancer or autoimmune diseases) Y N

(Prompt with methotrexate, cyclophosphamide, cytoxan, immuran)

Do you have a work location? Y N

If yes, where do you work?

What route do you take to get there?

From_____to_____(determine from case admit date):

Have you walked or driven in the vicinity (within one block) of any of the following places in Farmington/Farmington Hills:

Location	**Date and Time # Hours**	**Walk (W) or Drive (D)**
Middlebelt and GR		
GR & Tuck @ 9 Mile (West River Mall)		
Target,		
Kohl's,		
Cinema,		
Office Max,		
Country Lanes Bowling		
Office Bldg @ 22000 GR		
GR and OL (Plaza Mall)		

Cattlemen"s Market,

JAX car wash

Ameritech Office Bldg

Self-service car wash

GR at Power Rd

Farmington Place Senior Ctr

Camille Haddad office bldg

GR and Farmington

Exotic Rubber & Plastic,

Greenery Nursing Home

GR and Farmington

Donut Mall

Fountain @ City Hall

TJ Maxx

GR bet Drake and Farmington

Oakwood Cemetery on GR

Freedom and Farmington

LOC Credit Union

Folsom bet OL and Middlebelt

Botsford Nursing Home

OL and 10 Mi

Office Building

IGA

Bicycle Shop

Barber Shop (Bellaire)

Location	**Date and Time # Hours**	**Walk (W) or Drive (D)**

Rite-Aid drugstore

Farmington and Nine Mile

Farmer Jack

OL & Shiawassee

Medical Office Bldg

****

Other Activities Since September 25, 1996:

Church:

Car Wash:

Hair style/Barber shop:

Bank:

Exercise:

Restaurants:

Other shopping/activities:

Static Image of Case–Control Excel File

							1	2	3	4	5	6	7	8	9	10	11	12	13	14
IDNUM		Case	Control	SEX	AGE	SMOKE	MBGR	MBGR1WD	GRTK	GRTKWD	TARGET	KOHLS	CINEMA	OFFICEMAX	CLBOWLING	GROLO1	GROLWD	CATTLEMANS	JAX	AMERITECH
1		1	0	F	74	N	1	d	1	w	0	0	0	0	0	1	w	1	0	0
1	a	0	1	F	71	N	1	d	1	d	0	0	0	0	0	1	w	1	0	0
1	b	0	1	M	81	N	0	0	1	d	0	0	0	0	0	1	d	0	0	0
2		1	0	F	48	Y	0	0	1	w	0	0	0	1	0	1	w	1	0	0
2	a	0	1	M	49	N	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	b	0	1	F	41	N	0	0	0	0	0	0	0	0	0	1	d	0	0	0
3		1	0	M	62	Y	1	w	1	w	0	0	0	0	1	1	w	0	0	0
3	b	0	1	F	69	Y	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	a	0	1	?	72	N	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4		1	0	M	56	Y	0	0	1	w	1	0	0	0	0	1	w	1	0	0
4	a	0	1	F	50	N	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	b	0	1	M	46	N	1	d	1	d	0	0	0	0	0	0	0	0	0	0
5		1	0	M	70	N	1	d	1	w	0	0	0	0	0	1	w	0	0	0
5	a	0	1	M	62	N	1	d	0	0	0	0	0	0	0	1	w	1	0	0
5	b	0	1	M	69	N	1	d	1	d	0	0	0	0	0	1	d	0	0	0
6		1	0	F	76	Y	1	w	1	w	0	1	0	0	0	1	w	1	0	0
6	a	0	1	F	75	N	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	b	0	1	F	67	N	0	0	1	w	0	1	0	0	0	1	w	1	0	0
7		1	0	M	45	Y	1	d	1	d	0	0	0	0	0	1	w	1	0	0
7	a	0	1	F	37	Y	1	d	1	w	0	0	1	0	0	1	w	0	1	0
7	b	0	1	M	49	N	1	w	1	w	0	0	1	0	0	1	w	0	1	0
8		1	0	F	73	Y	0	0	1	w	1	1	0	0	0	1	w	1	0	0
8	a	0	1	M	73	Y	1	d	0	0	0	0	0	0	0	1	d	0	0	0
8	b	0	1	M	69	N	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9		1	0	M	26	Y	1	d	1	d	0	0	0	0	0	1	w	0	0	0
9	a	0	1	F	31	N	1	w	1	w	1	0	1	0	0	1	w	1	0	0
9	b	0	1	M	33	N	1	w	1	w	1	1	1	0	0	1	w	0	0	0
10		1	0	M	54	Y	1	d	1	d	0	0	0	0	0	1	w	0	1	0
10	a	0	1	M	60	N	0	0	1	w	1	0	0	0	0	0	0	0	0	0
10	b	0	1	M	58	N	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11		1	0	F	34	Y	1	w	1	w	1	0	0	0	0	1	w	1	0	0
11	a	0	1	F	29	N	1	w	1	w	0	0	0	0	0	1	d	0	0	0
11	b	0	1	F	37	N	1	d	1	w	0	0	0	1	0	1	d	0	0	0
12		1	0	M	72	N	0	0	0	0	0	0	0	0	0	1	w	1	0	0
12	a	0	1	F	75	N	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	b	0	1	F	66	N	1	d	1	w	1	1	0	1	0	1	d	0	0	0
13		1	0	M	57	Y	0	0	1	w	0	0	0	0	0	1	w	1	0	0
13	a	0	1	M	62	N	1	w	1	w	1	1	0	0	0	1	w	1	0	0
13	b	0	1	F	48	N	1	w	0	0	0	0	0	0	0	0	0	0	0	0
14		1	0	F	65	N	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	a	0	1	M	65	N	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	b	0	1	M	71	N	1	w	1	w	0	0	0	0	0	0	0	0	0	0
15		1	0	F	70	Y	0	0	1	w	1	0	0	0	0	1	w	1	0	0
15	a	0	1	F	76	N	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	b	0	1	M	75	N	1	d	1	w	1	0	0	0	0	1	d	0	0	0
16		1	0	F	84	N	0	0	0	0	0	0	0	0	0	1	w	1	0	0
16	a	0	1	F	67	N	0	0	1	w	1	1	0	0	0	0	0	0	0	0
16	b	0	1	F	75	N	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17		1	0	F	75	N	0	0	1	w	0	1	0	0	0	1	w	1	0	0
17	b	0	1	M	71	N	0	0	1	w	0	1	0	0	0	0	0	0	0	0
17	a	0	1	M	74	N	1	d	1	w	0	0	0	0	0	1	w	1	0	0
18		1	0	F	71	N	0	0	1	w	0	0	0	0	0	1	w	0	0	0
18	a	0	1	F	72	N	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	b	0	1	M	78	Y	1	d	0	0	0	0	0	0	0	0	0	0	0	0
19		1	0	F	94	N	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	a	0	1	F	92	N	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	b	0	1	M	87	N	1	d	1	d	0	0	0	0	0	1	d	0	0	0
20		1	0	M	87	N	0	0	0	0	0	0	0	0	0	1	d	0	0	0
20	a	0	1	F	79	N	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	b	0	1	F	89	N	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21		1	0	?	74	Y	1	d	0	0	0	0	0	0	0	1	w	0	0	0
21	a	0	1	F	81	N	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	b	0	1	F	82	N	1	d	0	0	0	0	0	0	0	0	0	0	0	0
22		1	0	M	74	Y	1	d	1	w	1	0	0	0	0	1	w	1	0	0
22	b	0	1	F	71	N	1	w	1	w	1	1	0	0	0	1	d	0	0	0
22	a	0	1	F	70	N	1	d	1	d	0	0	0	0	0	0	0	0	0	0
23		1	0	?	67	N	0	0	1	w	1	0	0	0	0	1	w	1	0	0
23	a	0	1	M	77	N	1	d	1	d	0	0	0	0	0	1	d	0	0	0
23	b	0	1	F	68	N	1	d	1	d	0	0	0	0	0	1	w	0	1	0
24		1	0	M	71	N	0	0	1	d	0	0	0	0	0	1	w	0	0	0
24	a	0	1	M	65	N	1	d	0	0	0	0	0	0	0	0	0	0	0	0
24	b	0	1	M	72	N	1	d	1	w	1	0	0	0	0	1	w	1	0	0
25		1	0	F	81	N	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	a	0	1	F	91	N	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	b	0	1	F	83	N	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26		1	0	F	70	N	0	0	1	d	0	0	0	0	0	1	w	1	0	0
26	a	0	1	F	68	Y	1	w	1	w	1	1	0	0	0	0	0	0	0	0
26	b	0	1	M	73	N	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27		1	0	F	56	Y	0	0	1	w	1	0	0	0	0	1	w	1	0	0
27	a	0	1	F	64	N	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	b	0	1	M	58	N	1	w	0	0	0	0	0	0	0	0	0	0	0	0
28		1	0	M	63	Y	1	d	1	d	0	0	0	0	0	1	w	0	0	0
28	a	0	1	M	70	Y	1	d	1	d	0	0	0	0	0	1	d	0	0	0
28	b	0	1	M	69	Y	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29		1	0	M	76	N	1	w	1	w	0	0	0	0	0	1	w	1	0	0
29	a	0	1	M	84	N	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	b	0	1	M	71	N	1	d	0	0	0	0	0	0	0	1	w	0	1	0
30		1	0	M	34	N	0	0	1	w	1	0	0	0	0	1	d	0	0	0
30	a	0	1	?	25	N	1	d	1	w	1	1	0	0	0	1	w	0	0	0
30	b	0	1	F	33	N	1	w	1	w	1	0	1	1	0	1	w	0	1	0
31		1	0	M	60	N	1	d	1	w	1	1	0	0	0	1	w	1	1	0
32		1	0	F	50	N	1	d	1	d	0	0	0	0	0	1	d	0	0	0
33		1	0	F	54	Y	1	d	1	d	0	0	0	0	0	1	d	0	0	0
34		1	0	?	72	N	1	d	1	w	0	0	1	0	0	0	0	0	0	0

15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
SELFCARWAS	GRPOWRRD	GRPOWRDWD	FPSENIORCT	CAMILLEBLD	GRFARM1	GRFARM1W	EXOTIC	GREENERY	GRFARM2	GRFARM2W	DONUTMAL	FOUNTAIN	TJMAXX	GRDRAKE	GRDRAKEW	CEMETERY	FREEDMFR
0	1	d	0	0	1	d	0	0	1	d	0	1	0	0	0	0	1
0	1	d	0	0	1	w	0	0	1	w	0	0	0	1	w	0	1
0	1	d	0	0	1	w	0	0	1	w	0	0	0	0	0	0	0
0	0	0	0	0	1	w	0	0	0	0	0	0	0	0	0	0	1
0	1	d	0	0	1	w	0	0	1	w	0	0	0	0	0	0	0
0	0	0	0	0	1	w	0	0	1	w	0	1	0	0	0	0	1
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	1	w	0	0	1	w	0	0	1	d	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	1	w	0	0	0	0	0	0	1	w	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	1	w	0	0	1	d	0	0	1	d	0	0	0	1	w	0	0
0	1	w	0	0	1	d	0	0	1	d	0	0	0	0	0	0	1
0	1	d	0	0	1	d	0	0	1	d	0	0	0	0	0	0	0
0	1	d	0	0	1	w	0	0	1	w	0	0	0	1	d	0	0
0	0	0	0	0	0	0	0	0	1	w	0	0	1	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	1	d	0	0	1	d	0	0	1	d	0	0	0	1	w	0	1
0	1	d	0	0	1	d	0	0	1	d	0	0	0	1	w	0	0
0	1	d	0	0	1	d	0	0	1	d	0	0	0	1	w	0	1
0	0	0	0	0	1	w	0	0	0	0	0	0	0	0	0	0	0
0	1	d	0	0	1	d	0	0	1	d	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	1	w	0	0	1	w	0	0	1	w	0	0	0	1	w	0	1
0	0	0	0	0	1	w	0	0	1	w	0	1	0	0	0	0	0
1	0	0	0	0	1	d	0	0	1	d	0	0	0	1	w	0	1
0	0	0	0	0	1	d	0	0	1	d	0	0	0	1	d	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	1	w	0	0	1	w	0	0	0	0	0	0	0	1	d	1	1
0	1	d	0	0	1	w	0	0	1	d	0	0	0	1	w	0	1
0	1	w	0	0	1	w	0	0	1	w	0	0	0	1	d	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	1	d	0	0	1	d	0	0	1	w	0	0	1	1	d	0	1
0	0	0	0	0	1	d	0	0	0	0	0	0	0	0	0	0	0
0	1	w	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	1	w	0	0	1	w	0	0	1	w	0	0	0	1	w	1	0
0	0	0	0	0	1	w	0	0	1	d	0	0	0	0	0	0	0
0	0	0	0	0	1	d	0	0	1	d	0	0	0	0	0	0	1
0	0	0	0	0	1	d	0	0	1	d	0	0	0	0	0	0	0
0	1	w	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	1	d	0	0	1	d	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	1	w	0	1	0	0	0	0	1
0	1	w	0	0	1	w	0	0	1	w	0	0	0	1	w	0	0
0	0	0	0	0	1	w	0	0	1	w	0	0	0	0	0	0	0
0	1	w	1	0	0	0	0	0	0	0	0	0	0	1	d	0	0
0	0	0	0	0	1	w	0	0	1	w	0	0	1	1	w	0	0
0	1	d	0	0	1	d	0	0	1	d	0	0	0	0	0	0	1
1	1	d	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	1	w	0	0	1	w	0	0	0	1	d	0	1
0	1	d	0	0	1	d	0	0	1	d	0	0	0	1	d	0	1
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	1	d	0	0	1	d	0	0	1	d	0	0	0	1	d	0	1
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	1	w	1	1	1	1	w	0	1
0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	d	0	1
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	1	d	0	0	1	d	0	0	0	0	0	0	0	1	d	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	1	w	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	1	w	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	1	d	0	0	1	d	0	0	0	1	d	0	1
0	1	d	0	0	1	w	0	0	1	?	0	0	0	1	d	0	1
0	1	d	0	0	1	w	0	0	1	w	0	0	1	1	d	0	1
0	1	d	0	0	1	d	0	0	1	d	0	0	0	1	d	0	1
0	1	d	0	0	1	d	0	0	1	d	0	0	0	1	d	0	1
0	1	w	0	0	1	d	0	0	1	d	0	0	0	0	0	0	1
0	1	d	0	0	1	d	0	0	1	d	0	0	0	1	d	0	1
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	
FREEDMFR	LOCCREDIT	FOLSOMMB	FOLSOMWD	BOTSFORD	OL10MI01	OL10MIWD	OL10OFFIC	IGA	BICYCLE	BELLAIRE	RITEAID	FARM9MI	FARM9MIWD	FARMERJACK	OLSHIAW	OLSHIAWD	OLSHIAOFF	ONSET
d	0	0	0	0	0	0	0	0	0	0	0	1	w	1	0	0	0	930
d	0	0	0	0	0	0	0	0	0	0	0	1	d	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	d	0	
d	0	0	0	0	1	w	0	0	0	0	1	1	w	1	0	0	0	930
0	0	0	0	0	1	w	0	1	0	0	1	0	0	0	0	0	0	
d	0	0	0	0	1	d	0	0	0	0	0	0	0	0	1	d	0	
0	0	0	0	0	1	w	0	1	0	0	0	0	0	0	0	0	0	1002
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	1	w	0	1	1	1	1	1	w	0	0	0	0	1003
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	1	d	0	0	0	0	0	1	w	1	0	0	0	
?	0	0	0	0	0	0	0	0	0	0	0	1	w	1			0	1003
0	0	0	0	0	1	w	0	1	0	0	0	1	d	0	0	0	0	
0	0	0	0	0	1	d	0	0	0	0	0	1	d	0	1	d	0	
0	0	0	0	0	1	w	0	1	0	0	1	0	0	0	0	0	0	1003
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	1	w	0	0	0	0	1	0	0	0	0	0	0	
d	0	0	0	0	1	w	0	1	0	0	0	0	0	0	1	w	0	1003
0	0	0	0	0	1	w	0	0	0	0	0	0	0	0	0	0	0	
d	0	1	d	0	1	w	0	1	0	0	1	1	w	1	0	0	0	
0	0	0	0	0	1	w	0	1	0	0	1	0	0	0	0	0	0	1003
0	0	1	d	0	1	d	0	0	0	0	0	1	d	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
w	0	0	0	0	1	w	0	0	0	0	1	0	0	0	1	d	0	1007
0	0	1	d	0	0	0	0	0	0	0	0	1	w	1	1	d	0	
w	0	1	d	0	1	d	0	0	0	0	0	1	w	1	1	w	0	
0	0	0	0	0	1	w	1	0	0	0	0	0	0	0	0	0	0	1007
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
w	0	1	d	1	1	w	0	1	0	0	1	1	w	1	1	w	0	1007
d	0	1	d	0	1	w	0	1	0	0	0	1	w	0	1	d	0	
0	0	0	0	0	1	w	1	0	0	0	1	0	0	0	1	d	0	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1008
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
d	0	0	0	0	1	d	0	0	0	0	0	1	d	0	1	d	0	
0	0	0	0	0	1	w	0	1	0	0	0	0	0	0	0	0	0	1009
0	0	0	0	0	1	w	0	0	0	0	0	1	w	1	0	0	0	
0	0	0	0	0	0	0	0	0	0	0	0	1	w	1	1	w	0	
0	0	0	0	0	0	0	0	0	0	0	0	1	d	0	0	0	0	1009
d	0	0	0	0	0	0	0	0	0	0	0	1	d	0	0	0	0	
0	0	0	0	0	1	d	0	0	0	0	0	0	0	0	1	d	0	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1010
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
d	0	0	0	0	0	0	0	0	0	0	0	1	w	1	0	0	0	1012
0	0	0	0	0	1	w	0	1	0	0	0	0	0	0	1	d	0	
0	0	0	0	0	0	0	0	0	0	0	0	1	w	1	0	0	0	
0	0	0	0	0	1	d	0	0	0	0	0	1	w	1	0	0	0	1014
0	0	0	0	0	0	0	0	0	0	0	0	1	w	1	0	0	0	
w	0	0	0	0	1	w	0	1	0	0	0	1	w	1	1	w	0	
0	0	0	0	0	1	w	1	0	0	0	0	1	w	0	1	w	1	1014
0	0	0	0	0	1	d	0	0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	0	0	1	w	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1015
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
d	0	1	d	0	1	w	0	0	0	0	1	1	w	1	1	d	0	
0	0	0	0	0	1	w	0	1	0	1	1	0	0	0	0	0	0	1005
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
d	0	0	0	0	1	w	0	1	0	1	1	1	w	1	0	0	0	1016
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
d	0	0	0	0	1	d	0	0	0	0	0	1	d	0	0	0	0	
w	0	0	0	0	0	0	0	0	0	0	0	1	w	1	1	d	0	1016
d	0	0	0	0	1	w	0	0	0	0	1	1	d	0	1	w	0	
d	0	0	0	0	0	0	0	0	0	0	0	1	w	1	0	0	0	
0	0	0	0	0	1	w	0	0	0	0	0	1	w	1	1	d	0	1017
d	0	0	0	0	0	0	0	0	0	0	0	1	w	1	0	0	0	
d	0	0	0	0	1	d	0	0	0	0	0	1	d	0	1	d	0	
w	1	0	0	0	1	w	0	1	0	0	0	1	w	1	0	0	0	1017
0	0	0	0	0	1	w	0	0	0	0	1	0	0	0	0	0	0	
w	0	1	d	0	1	d	0	0	0	0	0	1	d	0	1	d	0	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1017
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
d	0	0	0	0	0	0	0	0	0	0	0	1	w	1	0	0	0	1018
d	0	0	0	0	0	0	0	0	0	0	0	1	w	1	0	0	0	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	1	w	0	1	0	0	0	0	0	0	0	0	0	1018
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	1	d	0	0	0	0	0	0	0	0	1	d	0	1018
0	0	0	0	0	1	d	0	0	0	0	0	0	0	0	1	d	0	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	1	w	0	1	0	1	1	1	w	1	0	0	0	1018
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
d	0	0	0	0	1	d	0	0	0	0	0	0	0	0	1	d	0	
d	0	1	w	0	1	w	0	0	0	0	0	1	d	0	1	w	1	1018
w	1	1	d	0	1	d	0	0	0	0	0	1	w	1	1	d	0	
d	0	1	d	0	1	w	0	0	0	0	0	1	w	0	1	d	0	
d	0	1	d	0	1	w	0	1	0	1	0	1	w	1	1	d	0	1017
d	0	0	0	0	0	0	0	0	0	0	0	1	d	0	0	0	0	1008
d	0	0	0	0	0	0	0	0	0	0	0	1	d	0	0	0	0	1015
0	0	0	0	0	1	d	0	0	0	0	0	0	0	0	0	0	0	1005

Case-Control Excel file is available at www.collegeboard.com/yes/legionnaires

Key to Case–Control Excel File

The Case–Control Excel file summarizes information from questionnaires given to the 34 people with cases of Legionnaires' disease and to 60 controls matched 2:1 with the first 30 cases. The questionnaire used with cases is reproduced in the case questionnaire file, and that used for controls is in the control questionnaire file. Coding of those questionnaires is as follows:

IDNUM = identification number for cases (numbers not followed by letters) and matched controls (numbers followed by "a" or "b").

Case: 1 = case, 0 = not a case

Control: 1 = control, 0 = not a control

SEX: male = M; female = F.

SMOKE: Y = person smokes cigarettes. N = persons does not smoke cigarettes.

MBGR: 1 = person was within 1 block of intersection of Middlebelt and Grand River in the putative exposure interval; 0 = person was not within 1 block of intersection of Middlebelt and Grand River in the putative exposure interval.

MBGR1WD: w = exposure to Middlebelt and Grand River was on foot (walking); d = exposure to Middlebelt and Grand River was only in a vehicle (driving); 0 = no reported exposure with one block of Middlebelt and Grand River.

(Similar coding for other intersections: GRTK = Grand River and Turk; GROL01 = Grand River and Orchard Lake; GRPOWRRD = Grand River and Powers; GRFARM1 = Grand River and Farmington; GRFARM2 = Grand River and Farmington; GRDRAKE = Grand River and Drake; FREEDMF = Freedom and Farmington; FOLSOMM = Folsom, between Orchard Lake and Middlebelt; OL10MI = Orchard Lake and Ten Mile; FARM9MI = Farmington and Nine Mile; OLSHIAW = Orchard Lake and Shiawassee.)

TARGET: 1 = person entered Target store during putative exposure interval (Note: The intersection immediately preceding the store is the intersection to which the store is located most closely.)

(Similar coding for other stores/businesses: KOHLS = department store; CINEMA = movie theatre; OFFICEMAX = office supply store; CLBOWLING = bowling lanes; CATTLEMANS = meat market; JAX = car wash; AMERITECH = office building; SELFCARWAS = self-service car wash; FPSENIORCT = senior center; CAMILLEBLD = office building; EXOTIC = rubber and plastics business; GREENER = nursing home; DONUTMA = donut shop; FOUNTAIN = the fountain at City Hall; TJMAXX = clothing store; CEMETER = cemetery; LOCCRED = credit union; BOTSFOR = nursing home; IGA = food market; BICYCLE = bicycle shop; BELLAIRE = barber shop; RITEAID = drug store; FARMERJACK = food store; OLSHIAOFF = office building.)

ONSET = date of onset (mo-day) of cases.

Case Isolates

Case No.	Isolate	Monoclonal subtype	PFGE
1	L. pneumophila SG 1	1,2,5,6	1-a
6	L. pneumophila SG 1	1,2,5,6	1-a
8	L. pneumophila SG 1	1,2,5,6	1-a
9	L. pneumophila SG 1	1,2,5,6	1-a
13	L. pneumophila SG 1	1,2,5,6	1-a
15	L. pneumophila SG 1	1,2,5,6	1-a
20	L. pneumophila SG 1	1,2,5,6	1-a
24	L. pneumophila SG 1	1,2,5,6	1-a
30	L. pneumophila SG 1	1,2,5,6	1-a
31	L. pneumophila SG 1	1,2,5,6	1-a

Environmental Survey

STATE POLICE HELICOPTER
AERIAL IDENTIFICATION OF ROOF TOP COOLING UNITS
Conducted on Oct. 18, 1996
by
Frank Lauhoff, Manager, City of Farmington
William T. Carlson, OCHD
Morris James, OCHD

WET-TYPE HEAT REJECTION UNITS

Name	Address	Cross Street
HITACHI	34500 Grand River Rd.	@Shiawassee
EXOTIC RUBBER & PLASTIC	34700 Grand River Rd.	@Shiawassee
AMERITECH OFFICE BUILDING	32335 Grand River Rd.	West of Orchard Lake
BOTTSFORD NURSING CENTER	30405 Folson Rd.	Bet. Orchard Lk, & Middlebelt
IGA-ORCHARD MARKET	24065 Orchard Lake Rd.	@ 10 Mile
CATTLEMAN"S MARKET	31550 Grand River Rd.	Grand River at Mooney

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NON WET-TYPE HEAT REJECTION UNITS

Name	Address	Cross Street
FARMER JACKS	22128 Farmington Road	9 Mile @ Farmington Rd.
BASKIN ROBBINS	23629 Farmington Road	Grand River & Farmington Rd.
DIMITRIS RESTAURANT	33200 Grand River	Grand River & Farmington Rd.
RAMS HORNS RESTAURANT	32435 Grand River	Grand River & Power Rd.
GREENERY NURSING HOME	34225 Grand River Rd.	@Shiawassee
OFFICE BUILDING – Plan Tech	22000 Grand River Rd.	Tuck & Grand River
OFFICE BUILDING – Medical	23700 Orchard Lake	So. Of 10 Mile
*TJ MAXX	33609 Grand River Rd.	At Farmington Rd,
PLAZA MALL	31530 Grand River Rd.	At Mooney & Grand River
FARMINGTON PLACE SENIOR CENTER	32900 Grand River Rd.	At Powers & Farmington Rd.
CAMILLE HADDAD OFFICE BUILDING	32580 Grand River Rd.	At Powers
LOC CREDIT UNION	22981 Farmington Rd.	North of Freedom Rd.
A & W ROOT BEER	30732 Grand River	Bet. Tuck & 9 Mile
GOLDEN RIVER CONEY ISLAND	30746 Grand River	Bet. Tuck & 9 Mile
CHALET of FARMINGTON HILLS	30689 Grand River	Grand River & Tuck Rd.
OFFICE MAX	30180 Grand River	Bet. Tuck & Shiawassee
PIZZA HUT	31200 W. 10 Mile	10 Mile and Orchard Lake
BRASS POINTE	24234 Orchard Lk.	10 Mile and Orchard Lake

* Water sample collected from drip pan.

Name	Address	Cross Street
WENDYS # 6	24140 Orchard Lake	10 Mile and Orchard Lake
BIG BOY	24084 Orchard Lake	10 Mile and Orchard Lake
MEDICAL DENTAL BLDG..	23800 Orchard Lake	North of Shiawassee
ARBOR & BLOCKBUSTER	22250 Middlebelt Rd.	Corner of 9 Mile
TOTAL FITNESS	23311 Orchard Lake	North of Shiawassee
ATLANTIC DRAPERY COMPANY	32305 Grand River Rd.	East of Powers
WEST RIVER MALL [8 Facilities]	30020 Grand River Rd.	Tuck & Grand River
COUNTRY LANES BOWLING	30250 9 Mile Rd.	At Tuck
MCDONALD RESTAURANT	24020 Orchard Lake	10 Mile & Orchard Lake

OTHER POTENTIAL AEROSOL EMITTERS

RETENTION-PUMP STATION	32000 9 Mile Rd.	9 Mile and Brookdale
JAXS CAR WASH [Non-recirculating car wash system]	21500 Grand River Road	Orchard Lk & Grand River

OPERATING ROOFTOP COOLING UNITS
from aerial & subsequent ground surveys conducted by
Oakland County Environmental Health Services
Oct. 18–30, 1996

Wet-Type Units

AMERITECH OFFICE BUILDING	32335 Grand River Rd.	West of Orchard Lake Rd.
* Cleaned and sanitized on 11/1/96		
BOTSFORD NURSING CENTER	30405 Folsom	Bet. Orchard Lk. And Middlebelt
* Cleaned and sanitized on 10-22-96		
CATTLEMENS	31550 GRAND RIVER	Grand River & Mooney
* Cleaned and sanitized on 10-22-96 & 11-12-96		
MICRO-MIRROR CORP.	30210 W. 8 Mile Rd.	8 Mile West of Middlebelt
Out of service 10-21-96		
ADAT SHALOM	29910 Middlebelt. Rd.	@ Northwestern Hwy. & Middlebelt
* Cleaned and sanitized on 10-22-96		
FARMER JACKS	23300 Farmington Road	Grand River & Farmington Rd.
[Cooling tower] * Cleaned Sept 5, 1996; Sanitized June 17, 1996		
H. R. KRUEGER	22725 Orchard Lake Rd/.	@ Grand River
* Cleaned and sanitized 11-09-96		
Q & Q CLEANERS	31618 Grand River	@ Grand River & Mooney
[Wet type unit]		
NISSAN	39001 Sunrise Rd.	12 Mile and Haggarty
* Cleaned and sanitized weekly and tested bi-monthly		

Non Wet-Type Units

TJ MAXX	33609 Grand River	Grand River @ Farmington Road
[Air cooled condenser-drip pan]		
EXOTIC RUBBER	34700 Grand River	Grand River & Shiawassee
[Air cooled unit-drip pan]		
LOWENS CHIROPATIC CLINIC	23280 Farmington Rd.	North of Freedom Rd.
[Air cooled unit]		

NON OPERATIONAL WET TYPE HEAT REJECTION UNITS
LEGIONNAIRES' DISEASE OUTBREAK
FARMINGTON/FARMINGTON HILLS
from survey conducted by
Oakland County Health Division
October 18–30, 1996

HITACHI AUTOMOTIVE	34500 Grand River	Grand River & Shiawassee
[Not in service for past 1.5 yrs.]		
IGA-ORCHARD MARKET	24065 Orchard Lake	Orchard Lake @ 10 Mile
[Not in service for past 5 yrs.]		
BELAIRE LANES	24001 Orchard Lake	Orchard lake @ 10 Mile
[Not in service since Sept. 11, 1996]		
MAGIC PLANET	31530 GRAND RIVER	Grand River & Orchard Lake
[Not in service for >1. yr.]		

Environmental Cultures

MDCH #	Date	Site	Source	Isolation	CFU/cc	Monoclonal Subtype	PFGE
LE 143	10/22/96	Adat Shalom	Swab 33	Negative	NA		NA
LE 144	10/22/96	Adat Shalom	Water	Negative	NA		NA
LE 145	10/22/96	Cattlemans	Water	L. pneumophila SG1	>100,000	1,2,5,6	1-a
LE 146	10/22/96	Exotic Rubber & Plas	Water	Negative	NA		NA
LE 147	10/22/96	Cattlemans	Water	L. pneumophila SG1	>100,000	1,2,5,6	1-a
LE 148	10/22/96	Cattlemans	Swab 13	L. pneumophila SG1	NQ	1,2,5,6	1-a
LE 149	10/22/96	Cattlemans	Swab 13-2	L. pneumophila SG1	NQ	1,2,5,6	1-a
LE 150	10/22/96	Fountain	Water	Negative	NA		NA
LE 151	10/22/96	Exotic Rubber & Plas	Swab 2	Negative	NA		NA
LE 152	10/22/96	Fountain	Swab 17	Negative	NA		NA
LE 153	10/22/96	TJ Maxx	Swab 12	Negative	NA		NA
LE 154	10/22/96	TJ Maxx	Water	Negative	NA		NA
LE 155	10/22/96	Ameritech	Water	Negative	NA		NA
LE 156	10/22/96	Ameritech	Swab 2-6	Negative	NA		NA
LE 157	10/22/96	Ameritech	Water	Negative	NA		NA
LE 158	10/22/96	Ameritech	Swab 7	Negative	NA		NA
LE 159	10/22/96	Micro Mirror	Water	Negative	NA		8
LE 160	10/22/96	Botford Nur. Ctr.	Water	Negative	NA		NA
LE 161	10/22/96	Farmer Jacks	Water	Negative	NA		NA
LE 166	10/25/96	Farmer Jacks	Water	L. pneumophila SG 1	10	1,6	6
LE 167	10/25/96	Farmer Jacks	Swab 36	L. pneumophila SG 1	NQ	1,6	6
LE 168	10/25/96	Q&Q Cleaners	Swab 35	Negative	NA		NA
LE 169	10/25/96	Q&Q Cleaners	Water	Negative	NA		NA
LE 170	10/25/96	Farmington Mall	Water	Negative	NA		NA
LE 171	10/25/96	Farmington Mall	Water	Negative	NA		NA
LE 172	10/25/96	HR Krueger	Water	L. pneumophila SG 3	10		NA

MDCH #	Date	Site	Source	Isolation	CFU/cc	Monoclonal Subtype	PFGE
LE 173	10/25/96	HR Krueger	Swab 34	L. pneumophila SG 1	NQ	1,2,5,6	1-a
LE 174	10/25/96	Fox Creartions	Water	Negative	NA		NA
LE 175	10/25/96	Hitachi	Water	Negative	NA		NA
LE 176	10/25/96	Hitachi	Water	Negative	NA		NA
LE 177	10/25/96	Hitachi	Water	Negative	NA		NA
LE 178	10/25/96	Hitachi	Water	Negative	NA		NA
LE 179	10/25/96	Hitachi	Water	Negative	NA		NA
LE 180	10/25/96	Hitachi	Water	Negative	NA		NA
LE 181	10/25/96	Cattlemans	Water	L. pneumophila SG 1	10	1,2,5,6	1-a
LE 188	10/29/96	Charter House	Water	Negative	NA		NA
LE 189	10/29/96	Charter House	Water	Negative	NA		NA
LE 190	10/29/96	Charter House	Water	Negative	NA		NA
LE 191	10/29/96	Charter House	Water	Negative	NA		NA
LE 192	10/29/96	Charter House	Water	Negative	NA		NA
LE 193	10/29/96	Charter House	Water	Negative	NA		NA
LE 194	10/29/96	Charter House	Water	Negative	NA		NA
LE 195	10/29/96	Charter House	Swab 40	Negative	NA		NA
LE 196	10/29/96	Charter House	Swab 41	Negative	NA		NA
LE 197	10/29/96	Charter House	Swab 42	Negative	NA		NA
LE 202	11/1/96	Residence	Swab 43	Negative	NA		NA
LE 203	11/1/96	Residence	Swab 44	Negative	NA		NA
LE 204	11/1/96	Cattlemans	Water	Negative	NA		NA
LE 205	11/1/96	Charter House	Water	Negative	NA		NA
LE 206	11/1/96	Charter House	Water	Negative	NA		NA
LE 207	11/1/96	Charter House	Water	Negative	NA		NA
LE 208	11/1/96	Charter House	Water	Negative	NA		NA
LE 209	11/1/96	Charter House	Water	Negative	NA		NA
LE 210	11/1/96	Charter House	Water	Negative	NA		NA
LE 211	11/1/96	Residence	Water	Negative	NA		NA
LE 212	11/1/96	Residence	Water	Negative	NA		NA
LE 213	11/1/96	Residence	Water	Negative	NA		NA
LE 214	11/1/96	Residence	Water	Negative	NA		NA
LE 215	11/1/96	Ameritech Building	Water	Negative	NA		NA
LE 216	11/1/96	Cadillac Café	Water	Negative	NA		NA
LE 217	11/1/96	Residence	Water	Negative	NA		NA
LE 218	11/1/96	Residence	Water	Negative	NA		NA
LE 219	11/1/96	Residence	Water	Negative	NA		NA
LE 220	11/1/96	Residence	Water	Negative	NA		NA
LE 221	11/1/96	Oldfarm Colony	Water	Negative	NA		NA

LE 222	11/1/96	Residence	Water	Negative	NA			NA
LE 223	11/1/96	Residence	Water	Negative	NA			NA
LE 224	11/1/96	Residence	Water	Negative	NA			NA
LE 225	11/1/96	Nissan	Water	L. pneumophila SG 1		80	1,6	10
LE 226	11/1/96	Nissan	Water	Negative	NA			NA
LE 227	11/1/96	Nissan	Water	Negative	NA			NA
LE 228	11/1/96	Independence Green	Water	Negative	NA			NA
LE 229	11/1/96	Residence	Water	Negative	NA			NA
LE 235	11/8/96	Cattlemans	Water	Negative	NA			NA
LE 236	11/8/96	Cattlemans	Swab 13-3	L. pneumophila SG 1	NQ		1,2,5,6	1-a
LE 241	11/13/96	Cattlemans	Swab 13-4	Negative	NA			NA
LE 242	11/13/96	Cattlemans	Water	Negative	NA			NA
LE 247	11/15/96	HR Krueger	Water	L. pneumophila SG 1		150	1,2,5,6	1-a
LE 248	11/15/96	HR Krueger	Swab 34-2	L. pneumophila SG 1	NQ		1,2,5,6	1-a
LE 249	11/15/96	Cattlemans	Water	Negative	NA			NA
LE 250	11/15/96	Cattlemans	Water	Negative	NA			NA
LE 251	11/15/96	Cattlemans	Water	Negative	NA			NA
LE 252	11/15/96	Cattlemans	Water	Negative	NA			NA
LE 253	11/15/96	Cattlemans	Water	Negative	NA			NA
LE 254	11/15/96	Cattlemans	Water	Negative	NA			NA

NA = not applicable
NQ = not quantitated

Water Main Breaks

Date	Address (Farmington)	Remarks
1/14/95	35175 Drakeshire Ct	6" beam break in cast iron pipe
1/15/95	21241 Birchwood	6" beam break
1/27/95	32965 Cloverdale	6" beam break
2/5/95	36355 Grand River	2" service saddle on 8" iron main
2/23/95	323 Lee Lane	
3/4/95	33305 Grand River	4" cracked pipe
3/8/95	33907 State	6" beam break
3/10/95	23610 Power Rd.	6" pressure break
3/10/95	22712 Lakeway	3/4" service in devil strip
3/10/95	22925 Manning	6" pressure break
3/10/95	30875 Nine Mile	4" pressure break
3/10/95	32340 Shiawassee	Miss dig
3/20/95	33000 Freedom Rd.	
3/23/95	33712 Shulte	6" pressure break
3/23/95	22930 Manning	6" pressure break
3/23/95	32795 Ten Mile	8" pressure break
3/25/95	23801 Farmington Rd.	6" water break
4/2/95	23148 Violet	4" pressure break
4/4/95	23030 Mooney	8" pressure break
7/23/95	34029 Grand River	
7/31/95	32305 Grand River	
8/24/95	31993 Lamar	
8/31/95	31987 Orchard Lake Road	
9/13/95	31923 Lamar	
9/16/95	33101 Orchard St.	
9/28/95	31681 Lamar	
12/28/95	33400 Nine Mile	
12/17/95	State St.	
Dec-95	33400 Nine Mile	
1/20/96	21553 Birchwood	
2/4/95	23633 Wilmarth	6" beam break
2/5/96	31431 Lamar	8" beam break
2/12/96	34135 Drakeshire Ln.	
2/16/96	22820 Manning	
2/23/96	22996 Mayfield	

3/2/96	33519 & 33515 State	
8/28/96	23629 Farmington Rd.	Abandoned dead service
9/2/96	33730 Orchard Lake Rd.	
9/9/96	33704 Shiawassee	5' of 10" pipe with lateral crack
9/13/96	23687 Gill	
9/29/96	32334 Shiawassee	Service line leaking
10/31/96	35041 Grand River	
11/4/96	34166 State	8" beam break
11/8/96	36709 Lansbury	6" service saddle
12/15/96	22750 Mayfield	6" beam break
12/24/96	22796 Frederick	6" beam break
12/25/96	33825 Glenview	6" beam break

Assessment (Student Version)

In November hospital staff reported a large number of streptococcal wound infections in the preceding two weeks, resulting in two deaths. The number of wounds from which group A streptococcus has been isolated from patients has increased from one per month prior to September to two in September, seven in October and four in the first 10 days of November. Thirteen infected patients came from six preoperative wards in the hospital, were of widely varying ages, had undergone a variety of surgical procedures and included members of both sexes. The interval from operation to onset of wound infection was 0.5–2 days for 10 patients. Two of the three others had received prophylactic antibiotics at surgery.

Because streptococcus is usually transmitted from person to person, the investigation focused on people in the operating room during major operations within the epidemic period (September–November). Table 1 is an excerpt of the operating room log, in chronologic order.

1. Is this an outbreak? Why or why not?

2. If this is an outbreak, what do you hypothesize is the source?

3. Summarize evidence that would test this hypothesis.

4. How might you explain cases that are not consistent with your hypothesis, if any?

5. How would you confirm your hypothesis?

Table 1. Operating Room Log

Surgery Case #	Case	Sex	Surgeon	Assistant	Anesthesiologist	Circulating Nurse	Scrub Nurse
1		f	Afram	Quackenbush	Nugent	McCracken	Spinks
2		f	Xiao	Vrabel	Tully	Spinks	Caudill
3	Y	f	Escobar	Afram	Tully	Hsu	Caudill
4		f	Escobar	Walker	Uberman	Ippolito	Spinks
5		m	Xiao	none	none	Queen	Caudill
6		f	Robsen	Sjoberg	Nugent	Kolb	McCracken
7		f	Naughton	Sjoberg	Tully	Ippolito	Spinks
8		f	Turay	Xiao	Nugent	Ippolito	Caudill
9		f	Robsen	Quackenbush	Nugent	Kolb	Caudill
10		m	Escobar	Sjoberg	Tully	Kolb	Spinks
11		f	Lightfoot	Vrabel	Uberman	Queen	McCracken
12		f	Naughton	Wright	Nugent	Queen	Spinks
13		f	Xiao	Escobar	Uberman	Ippolito	Spinks
14		f	Cecil	Afram	Uberman	Tyrpack	Spinks
15		f	Cefaratti	Uberman	Tully	Tyrpack	Ippolito
16	Y	f	Afram	Caulk	Tully	Kolb	Spinks
17		m	Xiao	Vrabel, Naughton	Tully	Kolb	Ippolito
18		f	Cefaratti	Vrabel	Tully	Kolb	Ippolito
19	Y	m	Cefaratti	Debevoise	Tully	Kolb	Ippolito
20		f	Lightfoot	Vrabel	Uberman	Queen	Spinks
21	Y	f	Cecil	Escobar	Tully	Ippolito	Spinks
22		f	Cefaratti	none	Nugent	Queen	McCracken
23		f	Turay	Vrabel	Tully	Queen	Hsu
24	Y	m	Caulk	Johnson	Tully	Ippolito	Spinks
25		f	Naughton	Quackenbush	Uberman	Queen	Spinks
26	Y	f	Afram	Cecil	Tully	Kolb	Spinks
27	Y	f	Afram	Cecil	Tully	Kolb	Spinks
28		f	Naughton	Able	Tully	Tyrpack	Spinks
29		m	Caulk	Escobar	Tully	Tyrpack	Queen
30		f	Naughton	Vrabel	Tully	Kolb	Caudill
31	Y	f	Escobar	Naughton	Tully	Kolb	Queen
32		f	Afram	Cecil	Uberman	Kolb	McCracken
33		f	Xiao	none	none	McCracken	none
34	Y	f	Cecil	Debevoise	Nugent	Ippolito	Spinks
35		m	Naughton	Vrabel	Tully	Queen	Spinks
36		f	Cecil	Afram	Uberman	Ippolito	Queen
37		f	Burns	none	Tully	Queen	none
38		m	Lightfoot	Quereshi	Tully	Queen	Tyrpack
39	Y	f	Naughton	Sjoberg	Uberman	Tyrpack	Caudill

40		f	Cecil	Afram	Uberman	McCracken	Queen
41		m	Naughton	Caulk	Uberman	Kolb	McCracken
42		f	Xiao	Vrabel	Uberman	McCracken	Spinks
43	Y	f	Cefaratti	Xiao	Uberman	Queen	Spinks
44	Y	f	Robsen	Escobar	Tully	Kolb	Spinks
45	Y	f	Xiao	none	Uberman	Ippolito	Caudill
46		f	Naughton	Quereshi	Tully	McCracken	none
47		f	Cecil	Debevoise	none	McCracken	Caudill

Assessment (Teacher's Annotated Version)*

In November hospital staff reported a large number of streptococcal wound infections in the preceding two weeks, resulting in two deaths. The number of wounds from which group A streptococcus has been isolated from patients has increased from one per month prior to September to two in September, seven in October and four in the first 10 days of November. Thirteen infected patients came from six preoperative wards in the hospital, were of widely varying ages, had undergone a variety of surgical procedures and included members of both sexes. The interval from operation to onset of wound infection was 0.5–2 days for 10 patients. Two of the three others had received prophylactic antibiotics at surgery.

Because streptococcus is usually transmitted from person to person, the investigation focused on people in the operating room during major operations within the epidemic period (September–November). Table 1 is an excerpt of the operating room log, in chronologic order.

1. Is this an outbreak? Why or why not?

   Yes. The increase in incidence of streptococcal wound infection from 1 per month prior to September to 13 in the $2\frac{1}{3}$ months since (5.6 per month) is strong evidence of an outbreak.

2. If this is an outbreak, what do you hypothesize is the source?

   Because group A streptococcus is usually spread person to person, ill people had been on a wide variety of floors prior to their operations, and wound infections appeared shortly after the operations, infection was probably acquired from one of the operating room staff during the operation. The most likely hypothesis is that one of the operating room staff members is colonized with the outbreak strain of group A streptococcus and is disseminating it.

3. Summarize evidence that would test this hypothesis.

   Comparing the presence of individuals in operations that were associated with cases and with controls, three surgeons (Afram: 4/13 vs. 3/34; Escobar: 4/13 vs. 4/34; Cecil: 4/13 vs. 5/34), one anesthesiologist (Tully: 10/13 vs. 14/34) and three nurses (Kolb: 6/13 vs. 8/34; Ippolito: 4/13 vs. 8/34; Spinks: 8/13 vs. 13/34) were present more often in the cases. The association was strongest with Tully (OR = 4.8), and his was the only association that was statistically significant at the 0.05 level (χ^2 [1 d.f.] = 5.63; p = 0.018). Therefore, one might hypothesize that Tully was the source of the

*This example is adapted from Feigin RD, Cherry, JD. *Textbook of Pediatric Infectious Diseases,* 5th ed. Philadelphia: WB Saunders; 2004:3222–3223, 3241.

outbreak. However, the association with Spinks is intriguing, particularly because it appears to be present in instances in which Tully was present (6/10 vs. 3/14; OR = 5.5) as well as in instances when Tully was absent (2/3 vs. 8/20; OR = 3.0). Therefore, one would still want to rule out the possibility that Spinks was a source.

4. How might you explain cases that are not consistent with your hypothesis, if any?

   Interviews with the anesthesiology staff determined that it was not uncommon for one anesthesiologist to spell another for brief periods on a long case, without recording that fact on the operating room log. This practice may explain the three cases in which Tully was not recorded as the anesthesiologist.

5. How would you confirm your hypothesis?

   By culturing operating room staff for group A streptococcus, one could try to confirm microbiologically the hypothesis that Tully (+/— Spinks) was the source of the outbreak. In fact, cultures were taken from the throat, nose, skin and anus of two surgeons, Tully and all three nurses. Only from Tully, and only from Tully's anus, were group A streptococci recovered. The strain was M nontypable T 28, the same strain isolated from the cases. Subsequently Tully was treated with antibiotics, and his streptococcal carriage was eradicated. Prospective surveillance for group A streptococcal wound infections of the hospital showed none in the subsequent several months.

Table 1. Operating Room Log

Surgery Case #	Case	Sex	Surgeon	Assistant	Anesthesiologist	Circulating Nurse	Scrub Nurse
1		f	Afram	Quackenbush	Nugent	McCracken	Spinks
2		f	Xiao	Vrabel	Tully	Spinks	Caudill
3	Y	f	Escobar	Afram	Tully	Hsu	Caudill
4		f	Escobar	Walker	Uberman	Ippolito	Spinks
5		m	Xiao	none	none	Queen	Caudill
6		f	Robsen	Sjoberg	Nugent	Kolb	McCracken
7		f	Naughton	Sjoberg	Tully	Ippolito	Spinks
8		f	Turay	Xiao	Nugent	Ippolito	Caudill
9		f	Robsen	Quackenbush	Nugent	Kolb	Caudill
10		m	Escobar	Sjoberg	Tully	Kolb	Spinks
11		f	Lightfoot	Vrabel	Uberman	Queen	McCracken
12		f	Naughton	Wright	Nugent	Queen	Spinks
13		f	Xiao	Escobar	Uberman	Ippolito	Spinks
14		f	Cecil	Afram	Uberman	Tyrpack	Spinks
15		f	Cefaratti	Uberman	Tully	Tyrpack	Ippolito
16	Y	f	Afram	Caulk	Tully	Kolb	Spinks
17		m	Xiao	Vrabel, Naughton	Tully	Kolb	Ippolito
18		f	Cefaratti	Vrabel	Tully	Kolb	Ippolito
19	Y	m	Cefaratti	Debevoise	Tully	Kolb	Ippolito
20		f	Lightfoot	Vrabel	Uberman	Queen	Spinks
21	Y	f	Cecil	Escobar	Tully	Ippolito	Spinks
22		f	Cefaratti	none	Nugent	Queen	McCracken
23		f	Turay	Vrabel	Tully	Queen	Hsu
24	Y	m	Caulk	Johnson	Tully	Ippolito	Spinks
25		f	Naughton	Quackenbush	Uberman	Queen	Spinks
26	Y	f	Afram	Cecil	Tully	Kolb	Spinks
27	Y	f	Afram	Cecil	Tully	Kolb	Spinks
28		f	Naughton	Able	Tully	Tyrpack	Spinks
29		m	Caulk	Escobar	Tully	Tyrpack	Queen
30		f	Naughton	Vrabel	Tully	Kolb	Caudill
31	Y	f	Escobar	Naughton	Tully	Kolb	Queen
32		f	Afram	Cecil	Uberman	Kolb	McCracken
33		f	Xiao	none	none	McCracken	none
34	Y	f	Cecil	Debevoise	Nugent	Ippolito	Spinks
35		m	Naughton	Vrabel	Tully	Queen	Spinks
36		f	Cecil	Afram	Uberman	Ippolito	Queen
37		f	Burns	none	Tully	Queen	none
38		m	Lightfoot	Quereshi	Tully	Queen	Tyrpack
39	Y	f	Naughton	Sjoberg	Uberman	Tyrpack	Caudill

40		f	Cecil	Afram	Uberman	McCracken	Queen
41		m	Naughton	Caulk	Uberman	Kolb	McCracken
42		f	Xiao	Vrabel	Uberman	McCracken	Spinks
43	Y	f	Cefaratti	Xiao	Uberman	Queen	Spinks
44	Y	f	Robsen	Escobar	Tully	Kolb	Spinks
45	Y	f	Xiao	none	Uberman	Ippolito	Caudill
46		f	Naughton	Quereshi	Tully	McCracken	none
47		f	Cecil	Debevoise	none	McCracken	Caudill