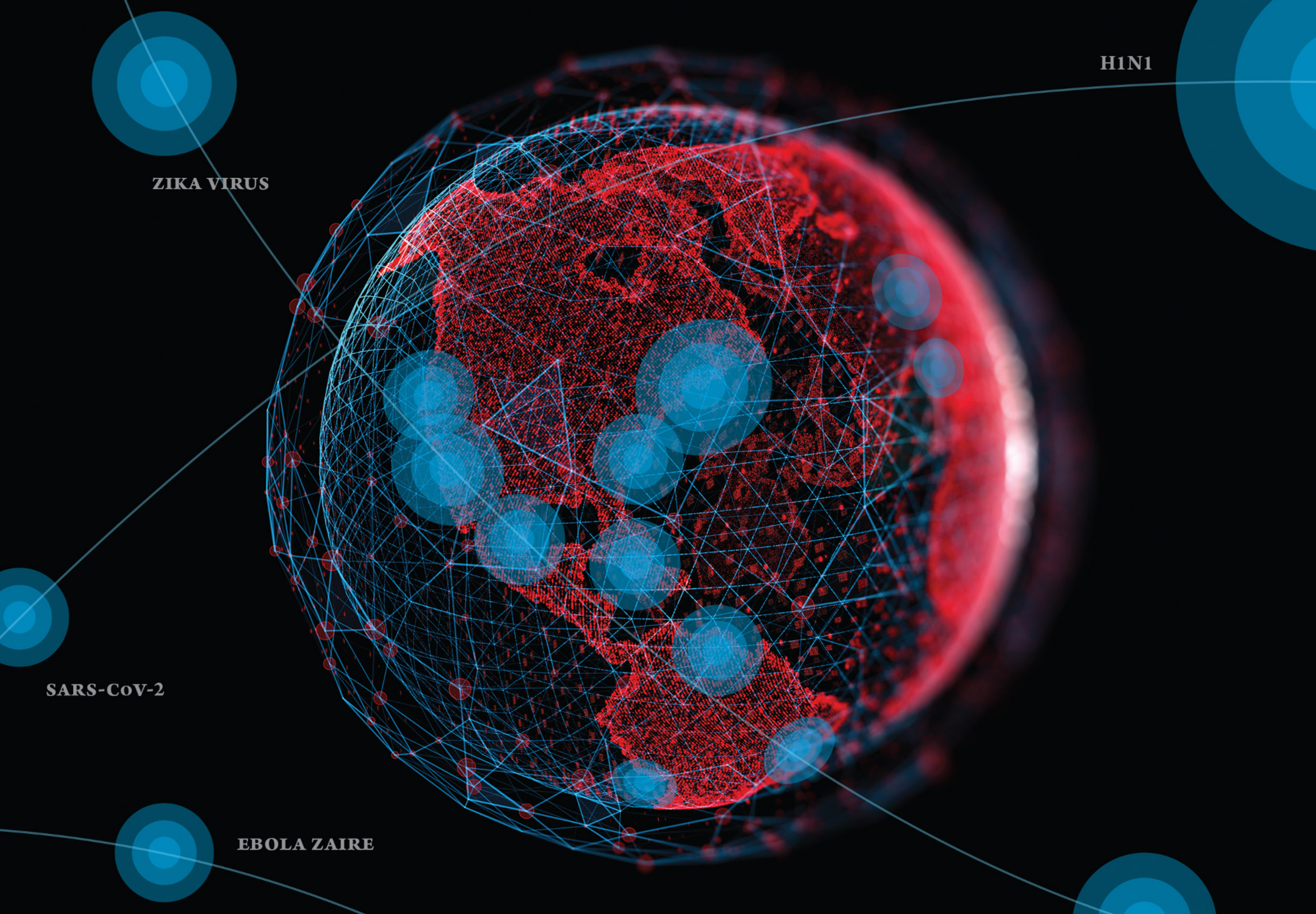
OUTBREAK

CASES IN REAL-WORLD MICROBIOLOGY

SECOND EDITION



RODNEY P. ANDERSON

INFLUENZA

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For Tami, again and always

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Introduction

The science of microbiology is fascinating to those of us who have taken up the challenge of researching and teaching in this largely undiscovered and rapidly expanding field. One of the significant challenges faced by microbiology educators is to balance the need for providing a content foundation to students against the time required to demonstrate how microbiology affects their lives. The goal of *Outbreak: Cases in Real-World Microbiology* is to help students make the important connections between the content of the course, their everyday lives, and the ways in which microbiology impacts society as a whole. These real-world cases provide an opportunity for students to apply practical knowledge and to integrate their solutions to specific problems in cultures where customs, religion, public resources, and infrastructure influence the analysis.

Content

The outbreaks featured in each section are preceded by one or two tables listing the significant pathogens that can cause the infectious disease outbreaks. The cases presented in that section include only diseases caused by pathogens listed in the table(s). The diseases and pathogens chosen are those that are often covered in an introductory microbiology course. Limiting the pool of possibilities helps the students learn the basics thoroughly without having to consider the myriad possible causes normally associated with a differential diagnosis, thus making the activity more appropriate for undergraduate students. Each chapter ends with a set of descriptions of the diseases covered in the case studies. The descriptions are meant to be used by students for reference, if necessary, to gather the information needed to develop appropriate answers to the questions at the end of each outbreak. Each disease description presents information on (i) the causative agent of the disease, (ii) the pathogen's mode of transmission from its reservoir to a new host, (iii) pathogenesis, (iv) the clinical features of the disease, (v) clinical and laboratory diagnosis, (vi) treatment of the disease, and (vii) general principles of prevention of the disease. Throughout each section, there is a balance between outbreaks that allow students to integrate and apply their knowledge and those that also require students to diagnose the pathogenic agent on the basis of lab test data and the clinical features of the disease.

The Appendix directs students to specific reference materials that provide information relevant to the study questions and encourages the students to apply the reference content to the cases they are studying.

Special Features

The last two outbreaks in each section are designated *College Perspective* and *Global Perspective*. The College Perspective presents outbreaks that directly impact the lives of students. The pathogens are typically spread easily in the college-age population, or the outbreaks focus on issues important to students. The Global Perspective presents outbreaks that occur in non-Western cultures. As a result, solutions developed by students for treatment and prevention require them to consider cultures in which differences in customs, religion, public resources, and infrastructure impact the analysis.

Case Studies in the Classroom

There are many ways in which case studies such as the outbreaks presented in this book can be integrated into a typical microbiology class. For example, they can be used as supplemental class readings and assignments to review application of content presented in class and to help students prepare for exams. They can be used to promote discussion to enhance lecture material. Students can become active participants in their learning by solving case studies that either review material already presented or introduce new material. Case studies can serve as the foundation for innovative approaches using cooperative learning groups. Cooperative learning groups can be used instead of lectures to allow students to investigate microbiological topics in depth. Case studies help students develop application, integration, and analysis skills. They can also be used as assessment tools to evaluate a course's ability to develop integration and application skills. Therefore, they can be helpful in preparing for professional admission exams such as the MCAT, NCLEX, and GRE.

As with much of life, the most challenging parts are also the most rewarding. With much of science, learning the content base, although often challenging, is just the beginning. The real objective is to integrate and apply scientific concepts and principles to make a difference in the real world. The best education provides students with opportunities for both.

Features of *Outbreak, Second Edition*

The content of the second edition of *Outbreak* has changed significantly. Twenty-five of the 75 cases in this addition are newly developed. The remaining cases have been re-edited based on classroom feedback. In addition, all cases have an expanded section of questions to allow the students to go into more depth in the analysis of each case or to allow faculty members to choose the questions that will most apply to either the level at which they present their material or where they are in the presenting course material. All reference material has been updated, so content on the epidemiology, diagnostic methods, pathogenesis, treatment, and prevention is current.

As in the first edition, all the case studies are real. When students in the biological sciences are asked to invest their time in analyzing a case study, it is important that the information that is given be real and factual. In no time in their careers as future professionals will current students be required to solve a fictional scenario that imitates real life but is designed to be solved with simple, straightforward answers. Real problems in the world of microbiology do not always agree with our initial expectations, nor do they often lend themselves to simple solutions. As a consequence, to best prepare students for their future careers, it is important to give them opportunities to solve real-world problems where answers require not only knowledge about microbiology but also the realities of social, economic, and health care-related issues.

Recommendations for Using the Case Studies

Like all activities involved in the delivery of excellent health care in today's world, the process requires a team approach. Consequently, when I integrate the case studies into my course, I have students work in collaborative learning groups when completing the case study assignments. The ability to work with others of diverse backgrounds and levels of ability is an important skill to develop for anyone choosing a career in health care. The collaborative learning groups also provide an opportunity for interprofessional education where the groups are composed of students whose goals are to pursue careers in various medical professions such as nursing, pharmacy, physicians, and physician assistants. In order to facilitate the teamwork process, it is important to introduce students to how to work successfully with others in their group by presenting some basic teamwork guidelines and rules. Teams that follow these straightforward guidelines are able to tap into others' knowledge and expertise and present a case study analysis that is more concise and complete.

Acknowledgments

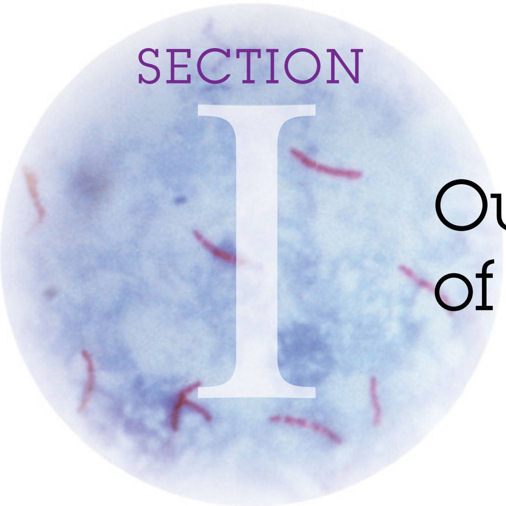
Thank you to Ohio Northern University for providing the sabbatical time that made this work possible. I also thank the staff of and the contributors to the Centers for Disease Control and Prevention's journals and image library. The journals and images are a rich resource of information for educators and the public to use. All images credited to CDC PHIL can be located at https://phil.cdc.gov/default.aspx by using the PHIL numbers provided.

About the Author

Rodney P. Anderson received his PhD in biological sciences from the University of Iowa in 1989. His doctoral work centered on protein synthesis mechanisms in *Escherichia coli*. After graduate school, he began his academic career at Ohio Northern University, where he continues to teach undergraduates in the Department of Biological and Allied Health Sciences. He teaches courses in microbiology for both majors and allied health students as well as courses in genetics. He has also introduced nonmajors to microbiology through interdisciplinary seminars in disease and society.

Dr. Anderson has been actively involved in microbiology education. He is a past chair of the American Society for Microbiology (ASM) Conference for Undergraduate Educators, which developed the core curriculum for undergraduate microbiology courses, and has organized and spoken at a number of education division symposia at the ASM annual meetings. His outreach activities have included microbial presentations at local elementary schools. His interest in microbiology education has resulted in another undergraduate microbiology textbook, *Visualizing Microbiology*, *Second Edition* (John Wiley & Sons, Inc.), and in a children's book, *The Invisible ABCs* (ASM Press). *The Invisible ABCs* emphasizes to children the benefits of the microbial world, rather than the incomplete message that all microbes cause disease.

Dr. Anderson and his wife, Tami, are parents of two adult children, Isaac and Graetel, who are both using their microbiology knowledge in their nursing careers. He loves classic cars, hunting, and traveling.



SECTION I

Outbreaks of Diseases of the Respiratory Tract

Among those who require a visit to a physician, infections of the respiratory system are the most common reason for the visit. These respiratory infections account for an average of ~80 physician visits per 100 persons each year. Infections of the lower respiratory tract, such as pneumonia and influenza, are also the leading cause of death by infectious disease worldwide. Pneumonia, influenza, and tuberculosis result in about 4.3 million deaths per year.

> *For full indeed is earth of woes, and full the sea; and in the day as well as night diseases unbidden haunt mankind, silently bearing ills to men.*
>
> Hesiod, *Works and Days*, ca. line 101
> (Trans., J. Banks, 1856)

Containment of a respiratory outbreak can be complicated by a pathogen's ability to survive outside the body. For example, some cold-causing viruses can remain infective on an environmental surface for several hours. This makes classroom desks and doorknobs potential fomites for the spread of disease. Pathogens on the hands can be inoculated into the eyes and drain into the nose. There they can attack and initiate a respiratory tract infection. Consequently, one important way to decrease spread of respiratory pathogens is to wash hands frequently and to avoid touching the eyes.

The primary method of spread for respiratory tract pathogens is via airborne particles and mucus droplets. Airborne particles can travel over 1 meter through the air and still remain infectious, while mucus droplets travel less than 1 meter through the air. As a result, respiratory pathogens are highly contagious and spread rapidly through a community. Outbreaks of respiratory pathogens are common in colleges. Students who occupy college residence halls usually share rooms with one or more students and are in contact with hundreds of students at sporting events, in recreational facilities, and in classrooms. As a result, the number of opportunities for transmission of respiratory pathogens is greatly increased relative to others who live at home. The frequency of transmission of respiratory pathogens is significantly higher during cold-weather periods, when students are restricted to indoor activities. Therefore, annual winter outbreaks of colds, influenza, strep throat, and bronchitis in this setting are common.

Although several thousand microbes are inhaled each day, the defenses of the respiratory system are very efficient and regularly prevent infection and disease. Mucus is secreted by goblet cells within the respiratory epithelium. This mucus traps most microbes before they travel deep into the respiratory tract. It helps to inhibit attachment of microbes to host cell receptors. Microbes that are trapped in the mucus are swept out of the respiratory system by cilia on the surface of the pseudostratified epithelium. The mucus is swallowed, and the microbes are destroyed in the digestive system. In addition, the mucus has a high concentration of dissolved solutes. The hypertonic environment thus created inhibits the growth of most cellular microbes—bacteria, fungi, and protozoa. In the alveoli of the lungs, macrophages are present to phagocytize microbes that escape the other defenses.

Microbial pathogens have evolved strategies to bypass these defenses. Adhesins on the surfaces of microbes allow pathogens to attach to receptors on epithelial cells so that the microbes are not swept out of the respiratory tract. These adhesins are highly specific and at times limit infections to certain parts of the respiratory tract. For example, rhinoviruses attach to receptors located in the upper respiratory tract and are thus limited to causing a common cold. Influenza A virus, however, attaches all along the respiratory mucosa and can cause a wide range of respiratory diseases, from a common cold to life-threatening pneumonia.

Microbes that can survive in the alveoli of the lungs are the most dangerous, causing a life-threatening infection that blocks gas exchange. *Streptococcus pneumoniae* has an antiphagocytic capsule that inhibits phagocytosis by alveolar macrophages. Strains with a capsule cause pneumonia, while those without a capsule are nonpathogenic. *Mycobacterium tuberculosis*, the causative agent of tuberculosis, a chronic infection of the lungs, and *Legionella pneumophila*, the causative agent of Legionnaires' disease, avoid being digested after being phagocytized by alveolar macrophages.

The outbreaks described in this chapter emphasize the serious nature of respiratory tract infections, the difficulty in consistently and effectively implementing basic disease control measures, and the rapid spread of microbes that travel through the air.

Table I-1 Selected outbreak-causing respiratory pathogens

Organism	Key Physical Properties	Disease Characteristics
Bacteria		
Bordetella pertussis	Fastidious, Gram-negative coccobacillus	Whooping cough in unvaccinated individuals
Chlamydophila pneumoniae	Obligate intracellular bacterium; very small; Gram negative	Pneumonia, bronchitis
Corynebacterium diphtheriae	Gram-positive, club-shaped bacillus	Diphtheria in unvaccinated individuals
Streptococcus pyogenes	Gram-positive streptococcus; beta-hemolytic on blood agar; group A surface antigen	Strep throat, scarlet fever, rheumatic fever
Legionella pneumophila	Fastidious, Gram-negative bacillus	Pneumonia (Legionnaires' disease)
Mycobacterium tuberculosis	Acid-fast bacillus found in chains or cords; cell wall contains mycolic acid, which results in drug and disinfectant resistance	Tuberculosis
Mycoplasma pneumoniae	Wall-less bacterium; variable shape	Walking pneumonia
Streptococcus pneumoniae	Gram-positive diplococcus; alpha-hemolytic on blood agar	Otitis media, sinusitis, conjunctivitis, pneumonia
Viruses		
Adenovirus	Nonenveloped polyhedral capsid with double-stranded DNA	Pharyngitis, bronchiolitis, pneumonia, conjunctivitis
Epstein-Barr virus	Enveloped polyhedral capsid with double-stranded DNA	Mononucleosis
Hantavirus	Enveloped helical capsid with negative-sense single-stranded RNA	Hantavirus pulmonary syndrome; zoonotic disease carried by rodents
Influenza viruses (A, B, and C)	Enveloped pleomorphic capsid with segmented negative-sense single-stranded RNA	Influenza, pneumonia; predisposes to secondary bacterial pneumonia
Mumps virus	Enveloped pleomorphic capsid with negative-sense single-stranded RNA	Mumps
Parainfluenza viruses	Enveloped pleomorphic capsid with negative-sense single-stranded RNA	Croup, bronchiolitis, pneumonia, laryngitis
Respiratory syncytial virus	Enveloped helical capsid with negative-sense single-stranded RNA	Bronchiolitis and pneumonia, primarily in infants
Rhinoviruses	Nonenveloped polyhedral capsid with negative-sense single-stranded RNA	Common cold
Rubella virus	Enveloped polyhedral capsid with positive-sense single-stranded RNA	German measles; can cause significant birth defects when pregnant women are infected
Rubeola virus	Enveloped helical capsid with negative-sense single-stranded RNA	Measles in unvaccinated individuals
Varicella-zoster virus	Enveloped polyhedral capsid with double-stranded DNA	Chickenpox in unvaccinated individuals; shingles as a latent manifestation

A Legionellosis Outbreak—Barceloneta

In the fishing neighborhood of Barceloneta, Spain, on the Mediterranean waterfront, 33 people were hospitalized in respiratory distress. Four of the victims were in serious condition. The area is predominantly inhabited by elderly people. The youngest victim was 49, while the oldest was 92. The common signs and symptoms were fatigue, malaise, high fever, shortness of breath, and coughing. Examination revealed rales (crackling sounds heard during breathing, indicating fluid in the lungs) and bilateral shadowing in the lungs on X ray (indicating fluid accumulation in both lungs).

City health officials carried out bacterial analyses of a ventilation system in the neighborhood located in a seaside building which uses a water tower as part of the cooling system for air conditioning. They isolated *Legionella pneumophila*, a Gram-negative, rod-shaped bacterium (Fig. I-1a and I-1b).

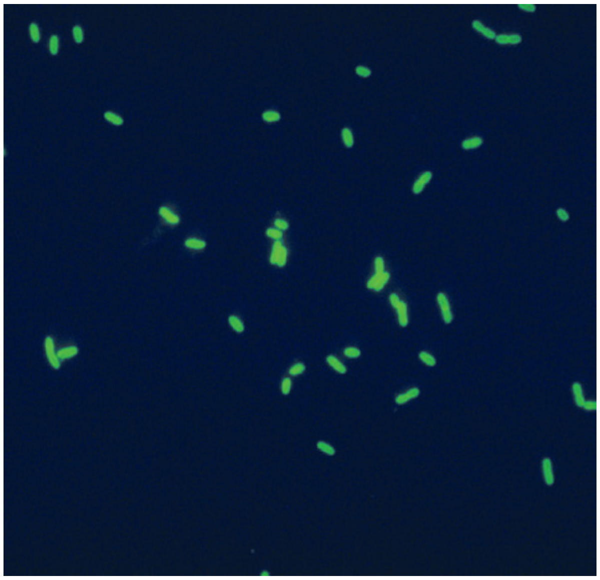


Figure I-1a Micrograph of direct fluorescent-antibody assay of *L. pneumophila* (magnification, ×400). Source: CDC/ Dr. William Cherry, PHIL, 2015, 1978.

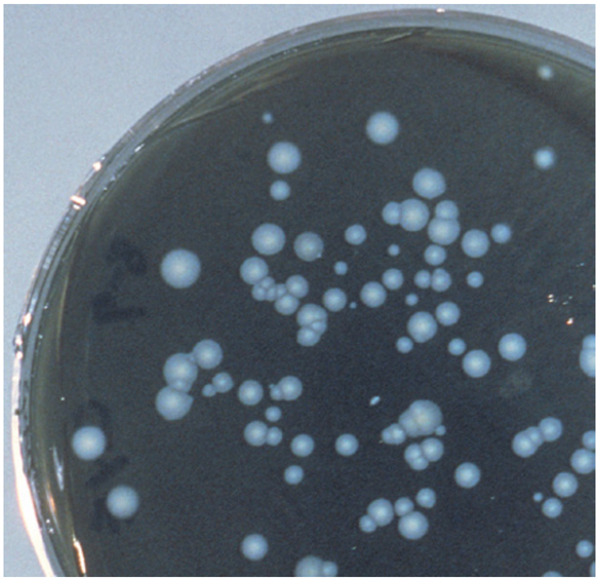


Figure I-1b *L. pneumophila* growing on charcoal-yeast extract agar. Source: CDC/ Dr. Jim Feeley, PHIL, 2137, 1978.

Content Questions

1. How is *Legionella pneumophila* transmitted?
2. What is an appropriate way to manage the disease?

Diagnosis Questions

1. How is legionellosis diagnosed?
2. What are the physical characteristics of the pathogen?

Reason It Out Questions

1. Besides *Legionella*, list four possible microbial causes of pneumonia.
2. How would you prevent future outbreaks of the disease?

An Outbreak of Respiratory Syncytial Virus Infection—Arviat, Canada

An outbreak of respiratory syncytial virus (RSV) disease sent 50 sick babies from the town of Arviat to hospitals in the south. Arviat is a remote community of 1,700 people that is located on the southwestern shore of Hudson Bay. For 2 weeks, the waiting room at the small clinic staffed by Arviat's nurses had as many as 70 sick people looking for treatment, half of them with coughing, crying infants. Nurses worked around the clock with no backup to care for the ill and to decide which children to send out, in medevac batches of three, to Churchill or Winnipeg. The disease was characterized initially as a cold or influenza, but children then developed coughing, fast breathing, wheezing, and difficulty breathing.

Lab tests of respiratory fluids were positive for RSV, an enveloped virus with a helical capsid and single-stranded RNA (Fig. I-2).

Arviat's nursing station was built in 1938 and is no longer adequate for Arviat's population. There is no resident physician in the community and no hospital facilities to treat seriously ill patients. Community leaders have called for better medical services for Arviat, including a full-time doctor, a suggestion that the hard-pressed Keewatin Regional Health Board had not yet acted on. In the year of the outbreak, Arviat was expected to see its population of 1,700 grow by 75 new babies. With a growth rate of more than 4% a year, Arviat was one of the fastest growing communities in the region.

Although the population of Arviat was small at the time of the outbreak, overcrowding was common. It was not unusual for many individuals to live in very small homes. In addition, the public schools and community center were considered too small. In addition, 82 new Nunavut government jobs were planned for Arviat. As a result, the community's population was expected to jump to more than 2,000 residents, and problems with overcrowding would worsen.

At the time of the outbreak, city officials worried that the outbreak would be compounded in the following week by hundreds of Christians from around Nunavut and Nunavik who would be traveling to the area to attend a Holy Spirit Crusade. Arviat's mayor, Mr. Hicks, expressed his concern: "Sitting elbow to elbow, with the lights on, in the heat, makes a great incubator for disease."

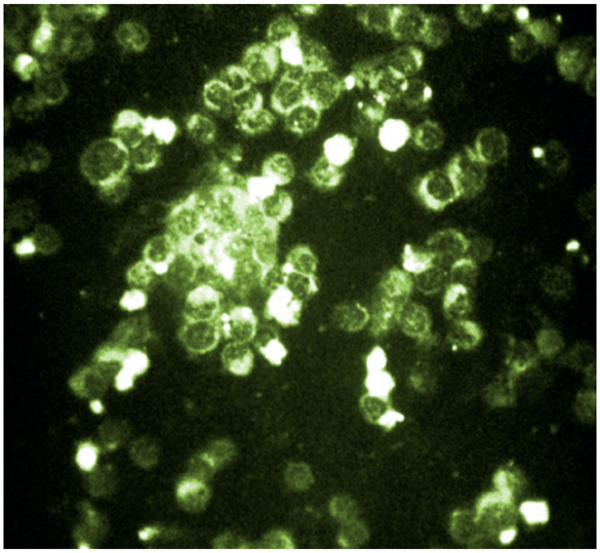


Figure I-2 Direct fluorescent-antibody assay for respiratory syncytial virus. Source: CDC/ Dr. H. Craig Lyerla, PHIL, 6484, 1977.

Outbreak I-2 continues on next page

OUTBREAK I-2 *(continued)*

Content Questions

1. How is this pathogen transmitted?
2. How would you treat individuals affected by this disease?

Diagnosis Questions

1. What are the physical characteristics of the pathogen?
2. What specimen is used to test for the pathogen?
3. How do you test for the pathogen in the medical science laboratory?

Reason It Out Questions

1. What public health actions should be taken to stop the outbreak and prevent future occurrences?
2. What age group is most susceptible to RSV bronchiolitis? Why?

A Tuberculosis Outbreak in a Prison Housing Inmates Infected with HIV—South Carolina

An outbreak of drug-susceptible tuberculosis (TB) occurred in a state correctional facility housing human immunodeficiency virus (HIV)-infected inmates. Before entry, inmates are tested for HIV status. They are then segregated in three dormitories of one prison, with each dormitory partitioned into right and left sides. On admission to the facility, all inmates are also screened for TB infection and disease with a tuberculin skin test and chest radiography.

In early July, an HIV-infected man aged 34 years housed in dormitory A was taken to the prison hospital with a 2-week history of fever, abdominal pain, and cough. His chest radiograph was normal; however, sputum specimens were not obtained for culture, and no acid-fast staining was done to detect acid-fast bacilli (AFB). As a result, he was not placed in respiratory isolation. The inmate was returned to the prison in mid-July without a definitive diagnosis. In mid-August, the man was evaluated at a community hospital. A lab test of his sputum was positive for AFB (Fig. I-3a), and he was diagnosed with active pulmonary TB. Later that year, the medical student who examined the inmate during the initial hospitalization developed active TB with cavities within the lungs (Fig. I-3b).

A contact investigation of dormitory A inmates identified 31 current or former inmates who had signs and symptoms of active TB. They were transferred from dormitory A to the hospital for respiratory isolation and medical evaluation. The exposed group comprised 323 men who had spent 1 to 152 days (median, 135 days) in dormitory A during that period. Of the 31 case patients, 27 (87%) resided on the right side of dormitory A during the exposure period; four (13%) resided on the left.

All case patients were non-Hispanic black men born in the United States and were infected with HIV. The median age was 36 years (range, 23 to 56 years). All of the isolates of the pathogen tested were identical based on DNA fingerprinting analysis. Five case patients had TB diagnosed after being released from prison; all five were released before the source case patient had TB diagnosed in August.

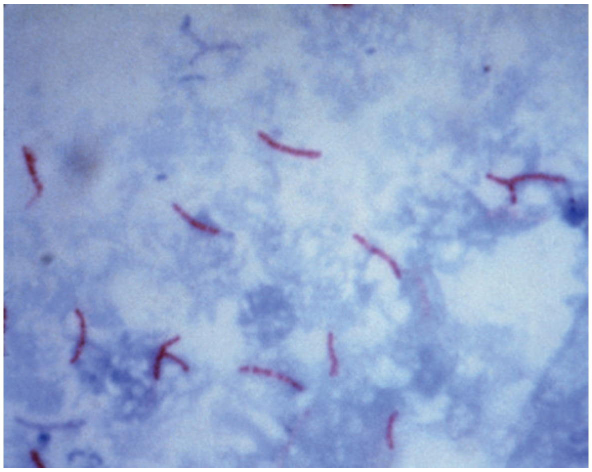


Figure I-3a Acid-fast stain of the pathogen. Source: Lewis L. Tomalty and Gloria Delisle, Queen's University.

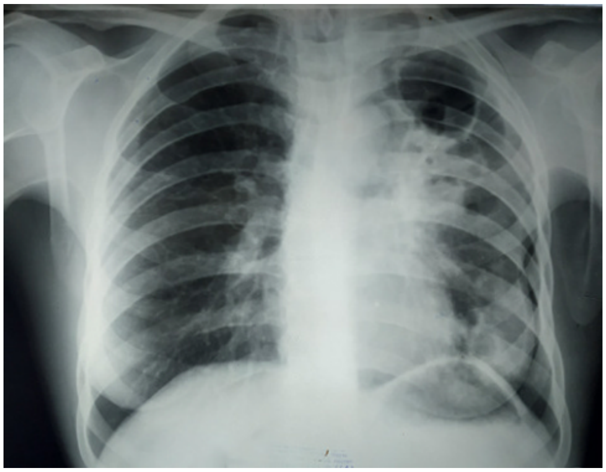


Figure I-3b Chest X ray of a patient with tuberculosis. Source: Giller Boris, Public Domain Wikimedia Commons.

Outbreak I-3 continues on next page

Content Questions

1. How is the pathogen transmitted?
2. What is the pathogenesis of the microbe?
3. What type of results would be expected in a chest X ray of a person who has active TB?

Diagnosis Questions

1. What color do AFB stain? Why?
2. What color do non-AFB stain? Why?
3. What is a tuberculin skin test?
4. What does a positive test indicate?

Reason It Out Questions

1. What pathogen is causing this outbreak?
2. How would you have prevented the spread of the pathogen through the prison?
3. What characteristic of AFB makes them difficult to treat?
4. What characteristics of the pathogen result in the requirement for long-term multidrug therapy?
5. How did the inmates on the opposite side of the dormitory contract TB?
6. How does a person's HIV status influence the risk of developing TB?

An Otitis Media Outbreak in a Child Care Center—Georgia

On December 18, public health officials in southwest Georgia contacted the Georgia Division of Public Health about a child aged 11 months hospitalized for otitis media. Eight days before hospitalization, a culture of drainage obtained from the child's middle ear revealed Gram-positive cocci arranged in chains. The bacteria were resistant to penicillin, clindamycin, erythromycin, trimethoprim/sulfamethoxazole, and tetracycline. The child attended a local child care center.

The child care center was located in a rural county (population, 6,318) in southwest Georgia and served approximately 54 children (age range, 9 months to 10 years). The children were divided into two groups on the basis of age (<18 months and >18 months), and the two groups had separate rooms. Nasopharyngeal (NP) swabs were collected and sent to the Centers for Disease Control and Prevention (CDC) for identification and antimicrobial susceptibility testing.

NP swabs were obtained from 5 of the 12 children who had shared a room at the child care center with the child who was hospitalized; NP swabs also were obtained from 17 of the 42 children from the other room. The pathogen was grown on blood agar under anaerobic conditions (Fig. I-4a). Alpha-hemolytic colonies were Gram stained (Fig. I-4b). The bacterium was isolated from 90% of the NP cultures; of these, 79% were penicillin nonsusceptible (i.e., they had intermediate or high-level resistance and were resistant to more than one antibiotic or class of antibiotics).

A questionnaire was distributed to evaluate risk factors that might be associated with infection. Eighty-two percent of the children in the child care center had had an illness for which they received antibiotic treatment during the 2 months preceding the questionnaire.

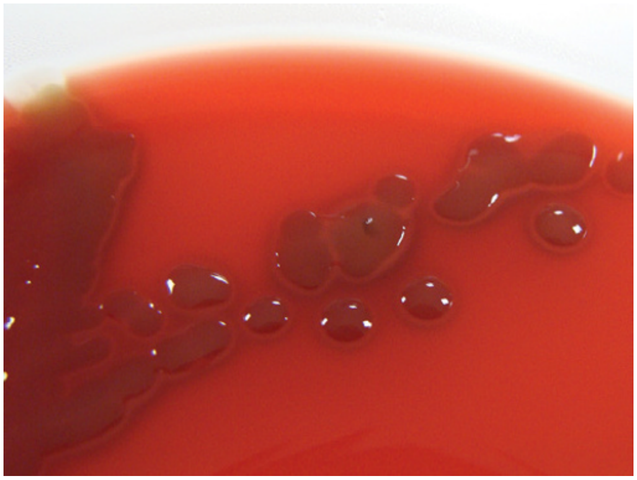


Figure I-4a Growth of the pathogen on blood agar. Source: Nathan Reading, Halesowen, UK, CC-BY 2.0.

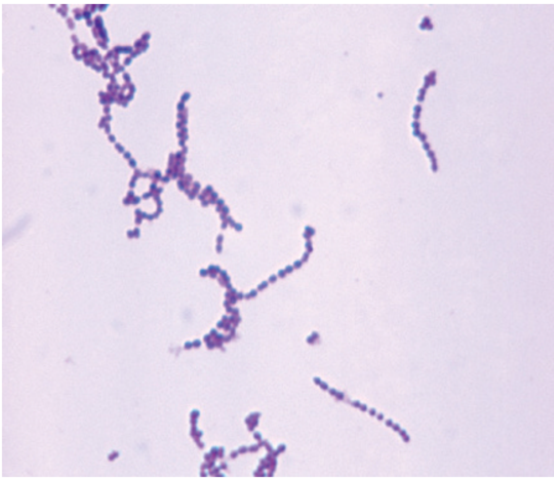


Figure I-4b Gram stain of the pathogen. Source: CDC, PHIL, 2170, 1970.

Outbreak I-4 continues on next page