Airborne Disease: Including Chemical and Biological Warfare

Theodore C. Eickhoff

INTRODUCTION

This contribution examines the influence of Alexander D. Langmuir’s career on our knowledge and understanding of airborne disease. The historical background of airborne infection is presented first, followed by an assessment of Langmuir’s contributions to this broad area. Several phases of his career can be identified insofar as they relate to airborne infections: 1) studies conducted in the 1940s during World War II under the auspices of the Commission on Acute Respiratory Diseases of the Armed Forces Epidemiological Board; 2) chemical and biological warfare considerations and the formation of the Epidemic Intelligence Service during the late 1940s and 1950s; 3) maturing views and the scientific basis for a theory of airborne disease during the late 1950s and 1960s; and 4) reconsideration of conventional epidemiologic theory during the 1970s and 1980s. Finally, the impact of Langmuir’s unique contributions is assessed in relation to our present understanding of airborne infection and to future research directions.

The recent history of understanding airborne infection can be appreciated only by understanding the beliefs that existed at the time Langmuir embarked on his professional career. Earlier views about the relative importance of the airborne route of disease transmission had been cyclic in nature (1). Early philosophers and writers acknowledged an important influence of air. Hippocrates (400 B.C.) believed that air, along with water and places, influenced health. Some 600 years later, Galen noted that one should consider the air that we breathe when many sicken and die at once. The occurrence of major epidemics such as the Black Death in Europe during the 14th century seemed to underscore his observations.

For most of medieval and renaissance history, and lasting until the mid-nineteenth century, virtually all infectious diseases were thought to be transmitted through the air. The “miasmic” theory of disease was in the ascendancy, leading to names like malaria. This era ended rather abruptly when the microbial nature of infectious disease was recognized; the role of contact spread in infectious disease transmission was soon identified and rapidly gained acceptance. By 1910, Charles V. Chapin, the distinguished health officer of the State of Rhode Island and in Langmuir’s view “the greatest American epidemiologist” (A. D. Langmuir, personal communication, October 8, 1967), wrote in his classic treatise The Sources and Modes of Infection: “Without denying the possibility of such [airborne] infection, it may be fairly affirmed that there is no evidence that it is an appreciable factor in the maintenance of most of our common contagious diseases. We are warranted, then, in discarding it as a working hypothesis and devoting our chief attention to the prevention of contact infection” (2, p. 264). Chapin wavered slightly only in the case of tuberculosis, and he considered that disease more likely than any other to be airborne. Chapin’s views persisted for most of the next 40 years.

In 1935, however, William Firth Wells (3), then an engineer at Harvard, began to challenge this dogma. He argued that certain diseases, most particularly measles, were spread through the air by droplet nuclei and thus were truly airborne. An initial trial of ultraviolet irradiation in several schools seemed effective in decreasing transmission, although subsequent trials were less encouraging. Later, in the 1940s, Wells’ challenge was joined in the United States by Robertson (4) and by several investigators in Great Britain (5) after careful study of the occurrence of nosocomial infections on pediatric services and surgical services, and of acute respiratory disease among military recruits. Thus, Langmuir began his career at a time when Chapin’s views on the primacy of contact transmission were widely accepted but were beginning to be reexamined and challenged by a few.

WORLD WAR II AND THE COMMISSION ON ACUTE RESPIRATORY DISEASES

The entry of the United States into World War II in December 1941 led to massive mobilization and train-
ing of recruits in the armed services. As expected, recruit training centers regularly experienced outbreaks of infectious diseases, including respiratory diseases, that seriously compromised the planned training schedules. Although respiratory tract infections caused by group A streptococci and influenza viruses were well known, the cause of the vast majority of respiratory diseases that occurred among military recruits was simply not known. Equally unknown were ways of preventing the transmission of respiratory infections among recruit populations.

Maintaining the health and combat readiness of the armed forces had long been a high priority in the United States, and military leadership recruited the best talent it could find in clinical medicine, preventive medicine, and public health under the aegis of the Armed Forces Epidemiological Board. This board established a number of commissions with specific disease area assignments, and the armed services together with several private foundations provided necessary support. The Commission on Acute Respiratory Diseases (6) was organized, with Langmuir recruited to serve as its epidemiologist. Plans called for establishing a field station at Fort Bragg, North Carolina, where studies to identify the etiology and prevention of acute respiratory disease among recruits were planned, both at Fort Bragg and at other installations where significant respiratory infections were experienced. Langmuir was a major contributor to the design and analysis of these studies and was assigned to the field station at Fort Bragg.

It would be difficult to overstate the importance of the series of studies carried out during World War II by the Commission on Acute Respiratory Diseases for they generated, by careful and painstaking clinical and epidemiologic observations, a foundation of knowledge that would likely have taken decades to accumulate under peacetime conditions. The same could be said of the other commissions as well. Indeed, the roster of the Board and its commissions is a veritable who's who of the academic leadership in infectious diseases, microbiology, epidemiology, and preventive medicine in the United States for the next several decades (7).

Two major respiratory disease syndromes were identified: acute respiratory disease, consisting of cough, coryza, fever, and malaise lasting for 10–14 days; and a much more severe and incapacitating pneumonic process lasting 3–6 weeks, with features different from the usual bacterial pneumonia, and referred to as primary atypical pneumonia (8, 9). Epidemiologic features of these two entities appeared to be similar, although there was usually a 10:1 ratio of acute respiratory disease to primary atypical pneumonia. Recruits were found to be at far more risk of these diseases than seasoned personnel, with the first 4 weeks of recruit training being the highest risk period. More than a decade would elapse before the etiology of most cases of acute respiratory disease was identified as an adenovirus, and most cases of primary atypical pneumonia were shown to be due to *Mycoplasma pneumoniae*.

Most cases of both entities appeared to be due to contact (droplet) spread, but that route of spread alone did not seem to be a sufficient explanation. There was no evidence for water or foodborne spread, and no evidence that insects or birds were involved in transmission. Airborne infection could neither be ruled in nor out. Langmuir and his coworkers did recognize, however, that subclinical or inapparent infections could cloud the epidemiologic picture, and that such cases could result in contact spread (8, 9).

Persisting questions about airborne spread led Langmuir to undertake some intervention studies that evaluated several environmental measures directed toward reducing transmission. One such study (10) evaluated double bunking without concomitant crowding. If droplet spread were important, then double bunking, with more space between bunks, should decrease close contact, and illness should decrease. However, if spread were airborne, there should be no change in the illness rate since the number of cubic feet of air per person within the barracks remained unchanged. During an epidemic of acute respiratory disease, the weekly incidence rate per 1,000 persons in the double-bunked group was substantially less than the control group—11.2 versus 19.6—thus substantiating the role of droplet spread. The same appeared to be true for primary atypical pneumonia.

Other studies (11–13) examined the effect of dust-suppressive measures and ultraviolet irradiation. If airborne spread were important, then measures such as these should reduce transmission. Oiling of floors and bedding was simple, practicable, and popular because it sharply reduced dust and made cleaning easier. During a low endemic period for acute respiratory disease, there appeared to be a modest reduction in illness rate due to such measures; however, no appreciable effect was seen during epidemics. Results of ultraviolet irradiation were inconclusive; overall, respiratory disease rates in irradiated barracks appeared to be lower than in control barracks—up to 25 percent lower at some times, but no effect at all was seen at other times. Furthermore, ultraviolet irradiation was expensive and required regular maintenance. Langmuir and his colleagues concluded that the efficacy of ultraviolet irradiation depended on the degree of air disinfection that was actually achieved and also

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on the degree to which airborne infection is important. There was little accurate information on either issue. Langmuir found the results of these intervention studies disappointing and noted that although much was learned about clinical and epidemiologic features of respiratory tract infection, the control measures that were feasible under the circumstances were unsuccessful. In his view, the experience seemed to be a reaffirmation of Chapin’s conclusions; contact and droplet modes of spread of common respiratory tract infections remained preeminent.

In 1946, the Committee to Evaluate the Effectiveness of Methods to Control Airborne Infection reported at the annual meeting of the American Public Health Association. Among the members of this committee were two individuals who had challenged Chapin’s conclusions, Wells and Robertson; Langmuir served as secretary and prepared the report (14). The thrust of the report was that there was not an adequate basis on which to recommend installation of ultraviolet irradiation or disinfectant vapor dispensers in schools, barracks, or other public places. All members concurred, although Langmuir identified one sentence over which they struggled for some time: “Conclusive evidence is not available at present that the airborne mode of transmission of infection is predominant for any particular disease” (14, p. 19). The theory of airborne infection did not yet have a substantive scientific basis.

CHEMICAL/BIOLOGICAL WARFARE AND THE EPIDEMIC INTELLIGENCE SERVICE

Long a concern on the battlefield, the threat of chemical and/or biological warfare directed against civilian populations seemed, paradoxically, to become a much larger concern after World War II ended and the cold war began. As missile technology developed and means of delivery of chemical or biological agents to any location in the world became more feasible, the potential threat seemed more real.

The discussions, as noted by Langmuir (15), were emotional, sensitive, and often deeply controversial. In 1950, the US government had gone on record, declaring that “an enemy could employ . . . biological warfare against us effectively” (15, p. 387). In a lengthy commentary published in 1951 (15), Langmuir sought to identify areas of scientific agreement among those experts who believed that biological warfare was simply not feasible and equally qualified experts who believed the possibilities were all too real.

In his analysis (15), Langmuir excluded from consideration the possibilities that seemed entirely speculative, that is, the unknown new agent of great virulence and the self-propagating and basically uncontrollable epidemic. Notwithstanding Chapin’s conclusions and the conclusions of the American Public Health Association committee about the preponderance of contact and droplet transmission of infection, there was abundant evidence that certain infections could, under certain conditions, be transmitted by the airborne route. Much of this evidence came from laboratory studies that used animals. In 1926, it was shown that canine distemper virus could readily be spread by the airborne route (16). Influenza A and B viruses infected mice and ferrets by inhalation. Most important, direct airborne infection with tuberculosis had been demonstrated in rabbits; Lurie and his coworkers (17) showed that one tubercle bacillus that reached the alveolus resulted in one tubercle! Working at Camp Detrick, Maryland, Rosebury (18) demonstrated experimental airborne infection by the etiologic agents of brucellosis, melioidosis, tularemia, and psittacosis. In humans, it was recognized that some cases of influenza, measles, and rubella were a result of airborne infection.

Perhaps the strongest evidence of airborne infection resulted from laboratory-acquired infections (19). Although many such infections occurred after breaks in technique that resulted in contact spread, others were more explosive in nature and involved many people under circumstances that could be explained only by airborne spread. Notable examples cited by Langmuir involved epidemics of psittacosis, brucellosis, and Q fever. These laboratory outbreaks documented that a large proportion of the adult US population could be susceptible if a sufficient number of organisms could be delivered to the chosen site. Furthermore, they demonstrated that those infectious agents retained their virulence under laboratory conditions.

Common vehicle epidemics were well known and understood, and there was, therefore, no difficulty in appreciating how contamination of water or food supplies might occur as a result of deliberate sabotage. Langmuir (15) concluded by agreeing with the government statement that chemical and biological warfare was plausible and that it could be employed effectively against this country. He urged that appropriate defensive measures be planned and implemented without delay.

Langmuir became director of the epidemiology program at the Communicable Disease Center (now the Centers for Disease Control and Prevention (CDC)) in 1949; and as the nation’s epidemiologist, he was very much in the middle of the growing concerns about biological warfare. Botulinus toxin and the agents causing plague, typhus, cholera, smallpox, tularemia, brucellosis, anthrax, and others were all possible can...
didates. He reasoned that an enemy would likely choose to use biological weapons only in the expectation that an epidemic would result. Epidemiology would therefore be central to the defense against biological warfare (20).

This vision was the genius of Langmuir, for he clearly recognized the need for a large cadre of trained epidemiologists in the United States in the event of actual chemical or biological warfare, and he developed an innovative and wholly unique plan to meet those needs. In a presentation to the American Public Health Association on biological warfare defense, Langmuir and Andrews (20) outlined some very realistic scenarios that would likely evolve in the event of a biological warfare attack with and without trained epidemiologists in the civil defense organization. Without trained epidemiologists, the scenario from exposure would result in cases whose numbers would increase, then eventually decrease, perhaps concentrated in specific areas of the city, and would lead to overtaxed emergency and medical facilities, overuse of antimicrobial agents, depletion of pharmaceutical supplies, rationing of medical supplies, quarantine measures, lack of public information, and confusion, leading to hysteria and possible mass exodus.

In contrast, with an appropriate civil defense organization that included trained epidemiologists, the scenario described above could be entirely avoided by prompt and accurate reporting, appropriate diagnostic tests, a citywide surveillance program, careful determination of optimal medical treatment, and perhaps most important of all, accurate and up-to-date public information.

Thus was born in 1951 the Epidemic Intelligence Service. There were other reasons the nation needed to train more epidemiologists, to be sure, but epidemic disaster aid was a major justification. Langmuir and Andrews wrote, “Even if the epidemic intelligence officers are never needed to counter biological warfare attacks, this program will have fulfilled its ultimate objective of contributing measurably to the understanding and appreciation of epidemiologic approaches to the control of communicable disease” (20, p. 238).

According to Langmuir and Andrews, the word “intelligence” in the name was chosen quite deliberately, given the definitions quoted from Webster’s Dictionary:

1. “the capacity for knowledge and understanding”;
2. “the power of meeting a novel situation successfully by adjusting one’s behavior to the total situation”;
3. “the ability to apprehend the interrelationships of presented facts in such a way as to guide action toward a desired goal”;
4. “the obtaining and dispensing of information, particularly secret information” (20, p. 238).

The word seemed to be “singularly appropriate in defining the contributions of epidemiologists in peace and war” (20, p. 238).

**SCIENTIFIC BASIS FOR UNDERSTANDING AIRBORNE DISEASE**

Research work and epidemiologic studies carried out in a large number of federal and academic centers during the 1950s and 1960s resulted in a far greater understanding of the modes of spread of infectious diseases and the factors leading to airborne infection. Langmuir (21) cited four areas of research activity that provided the basis for understanding airborne infection: 1) laboratory studies of the creation, measurement, and behavior of aerosols of pathogenic microorganisms; 2) studies of pulmonary host defense mechanisms in health and disease, with particular attention to the deposition and retention of aerosolized particles of varying size throughout the respiratory tract; 3) studies of experimental infections in laboratory animals and in humans with a variety of microorganisms; and 4) continuing epidemiologic studies of both naturally occurring and laboratory-acquired infections.

Although his administrative duties precluded direct participation in such epidemiologic studies, Langmuir regularly assigned Epidemic Intelligence Service officers to work on diseases that were potentially transmitted by the airborne route. Prominent Epidemic Intelligence Service activities included epidemiologic studies of influenza, measles, rubella, histoplasmosis, anthrax, psittacosis, plague, and others. The epidemiologic skills of hundreds of Epidemic Intelligence Service officers were honed by Langmuir’s proudding, questioning, and stimulating critiques. The goal was always to expand and improve our knowledge, and to develop more effective techniques of prevention and control of communicable diseases. Always the epidemiologist, he retained a strong interest in airborne infection as knowledge and understanding increased, and he remained a lively and articulate critic and commentator.

Although there was during the 1960s a substantive understanding of airborne infection, the frequency with which many well-known communicable diseases such as measles, rubella, influenza, and smallpox actually were transmitted by the airborne route remained largely unknown. The major exception was tuberculosis; the classic studies of Riley and coworkers (22, 23)

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at the Baltimore (Maryland) Veterans Administration Hospital convincingly demonstrated that tuberculosis was, for the most part, an airborne infection.

Continuing studies of the epidemiology of nosocomial infections failed to define a major role for airborne infection, again with the notable exception of tuberculosis. It was clearly demonstrated that nosocomial infections due to group A streptococci and Staphylococcus aureus were capable of spread by the airborne route, yet the substantial majority of such infections appeared to be due to contact spread. A few academic surgeons, notably Hart at Duke University, were so convinced of the significant role of airborne infection in postoperative infections that ultraviolet lights were installed in their operating rooms.

Yet, a large multihospital controlled trial of ultraviolet light in operating rooms sponsored by the National Research Council, with epidemiologic consultation provided by Langmuir, found only a very modest beneficial effect of ultraviolet light on postoperative wound infection, and that only in the case of "refined clean wounds." It was quite effective, however, in reducing bacterial counts in operating room air. Again, contact infection appeared to be the likely source of most postoperative wound infections.

A major conference on airborne infection was sponsored by the National Academy of Sciences in 1960 to bring together all that had been learned about this subject in the past 15-20 years of research. Langmuir presented the keynote address. By this time, a large number of infectious diseases had been identified as being primarily airborne; the list included psittacosis, Q fever, brucellosis, the pneumonic forms of tularemia and plague, inhalation anthrax, several pulmonary mycoses including histoplasmosis and coccidioidomycosis, and of course, primary pulmonary tuberculosis. Notably absent from this list were smallpox, rubella, and measles. A great deal of attention was directed, however, to the concept of the dangerous spreader or disseminator, as exemplified by the "cloud baby" concept of Eichenwald et al.

Thus, although airborne infection now had scientific stature and acceptance, Chapin's views on the primacy of contact infection still governed conventional epidemiologic thinking, including Langmuir's. When it came to defining vaccine policy as vaccines became available and immunization programs were planned, beliefs about how transmission might best be interrupted became critically important. For example, if for a given disease transmission was by contact, then an epidemic would cease when each case exposed, on average, less than one new susceptible. The epidemic would be terminated even though a substantial fraction of the population might remain susceptible. Conversely, an epidemic was possible only when the number of susceptibles in the population reached a certain threshold level. In simple mathematical terms, an epidemic could not start until there were enough susceptibles so that each case would infect, on average, more than one new susceptible. This was the classic doctrine of herd immunity, which assumed spread by contact. If, on the other hand, transmission were airborne, then herd immunity would not exist since most or all susceptibles in the population would be exposed.

Langmuir observed that these principles of classic epidemiologic theory, including the concept of herd immunity, were well illustrated by studies of the epidemiology of many common communicable diseases, perhaps most strikingly in the case of measles. The practical application of these principles to vaccination policies was simple: all one had to do was to raise the level of immunity by vaccinating in a population to a point above the threshold level at which epidemics could occur. It was not necessary for the entire population to be immunized.

EPIDEMIOLOGIC THEORY RECONSIDERED

One of Langmuir's great strengths, particularly evident in the years since he left the CDC, was the ability to look back at his own career and critique some of his earlier thinking and the decisions in which he had a determinative role. For example, in 1946 under the authorship of the Commission on Acute Respiratory Diseases, he published a paper entitled "The Periodicity of Influenza." Based on an analysis of influenza epidemics from 1920 to 1944, a 2- to 3-year cycle was identified for influenza A, and a 4- to 6-year cycle for influenza B. Such cyclic outbreaks of influenza appeared to result from the changing balance of immunes and susceptibles; waning immunity would explain the rapid accretion of susceptibles—a new application of the doctrine of herd immunity. Subsequent experience, of course, showed that influenza epidemiology was far more complicated. In the Maxwell Finland Lectureship presented to the Infectious Diseases Society of America in 1986, he reflected on that paper and commented, "I now read this with unmitigated horror—such pious, pompous poppycock!" (30, p. 354).

In his history of the Commission on Acute Respiratory Diseases, Jordan recalled that Langmuir was so confident of his ability to forecast the year and viral type of influenza epidemics that he would regularly wager a bottle of Scotch with any colleague who would venture to do so. Legend has it that he lost more bets than he won; but because one of the conditions of the wager was that the loser must participate in the consumption of the contents, it seemed to matter little,
and he never wavered from identical wagers on a variety of issues about which he felt strongly.

Another major conference on airborne infection was held in 1980, this time under the auspices of the New York Academy of Sciences. Again, Langmuir presented a major address (21), reflecting on the changing concepts of airborne infection, revisiting classic epidemiologic theories, and critiquing some of his previous decision making. It is an instructive paper that summarizes his thinking about airborne infection over his entire career in epidemiology. He used three diseases to exemplify his evolving thinking: smallpox, measles, and rubella.

**Smallpox**

The Global Eradication Program was based on a confident belief in contact spread of the disease. Initial progress appeared to be good, although in some areas small outbreaks continued to smolder in small sub-populations of individuals who opposed vaccination on religious or other grounds and who remained in close contact with each other. Based on the studies of Foeg and coworkers (31), immunization strategy was modified to emphasize intensive case finding, contact tracing, and "ring" vaccination. These efforts were extraordinarily successful, thus reinforcing belief in the contact spread of smallpox.

In late 1969 and 1970, however, a major outbreak of smallpox occurred in a small hospital in Meschede, Germany (32). A single index patient, a 20-year-old German electrician who had been in Pakistan, infected 17 other persons, including patients and personnel. Two additional cases occurred in the second generation, leading to a total of 19 cases including three deaths. Epidemiologic study of the outbreak left absolutely no doubt that transmission was airborne and again raised concerns about the dangerous spreader or disseminator.

This event cast some doubt on the theoretical basis for the entire smallpox eradication program, but the program leadership was convinced of its earlier success and that the outbreak in Meschede would prove to be a unique exception to the rule. History has shown that they were quite correct.

**Measles**

The measles experience in the United States was described by Langmuir as a "rather egregious blunder in prediction" (21, p. 40). He and two colleagues (33) had previously noted in a paper defining the epidemiologic basis for measles eradication in the country that the infection was spread by direct contact, although a comment was added about the possibility of airborne transmission among susceptibles in enclosed spaces. Furthermore, they added the highly optimistic prediction that effective use of measles vaccine in the year ahead would ensure the eradication of measles in the United States in 1967!

The real blunder, in Langmuir's view, was great overconfidence in the acceptance of measles vaccine by the public and the health professions and in the infallibility of herd immunity. Continuing and sophisticated epidemiologic field studies of measles were neglected. As a result, even in 1980 it was not clear to Langmuir whether measles was primarily airborne, as Wells had believed, or whether contact and airborne spread both played major roles, but under differing circumstances. It was clear, however, that airborne transmission was sufficiently common as to be a major factor in the continuing occurrence of measles in the United States.

**Rubella**

Langmuir admitted to being most insecure about rubella. The epidemiology of rubella is still poorly understood, and reporting is highly inconsistent. He was slowly becoming convinced that rubella was probably a primarily airborne infection, and he based his judgment on reappraisal of school outbreaks that had been studied in England, on some of his own personal experiences, and on more recent studies that were carried out in this country. In his view, many recorded rubella epidemics could be accounted for only on the basis of airborne infection.

Langmuir related his personal experiences at Fort Bragg with the Commission on Acute Respiratory Diseases to illustrate his concern (21). A major wave of rubella occurred during a 2-month period in the late winter of 1943 and moved through 31 training batteries of 250 men each. He was puzzled that the distribution of numbers of rubella cases among the different batteries followed a perfectly random distribution. He wrote as follows in his notes: "Difficult to account for such a distribution on the basis of contact person-to-person spread. Only logical explanation would be random distribution of susceptibles with exhaustion at the end of epidemic. Airborne infection?" (21, p. 42). The data were incomplete, however, and he never published those observations.

He ended his paper with the following comments: "More intensive, imaginative, critical and continuous epidemiological field studies, surveillance and investigations will be necessary for both measles and rubella if solutions are to be found. Furthermore, the epidemiologists of the future should clearly practice their profession with a greater humility and skepticism of their past teachings than some, at least one, epide-

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miologist of my close personal acquaintance" (21, p. 43). It is easy to imagine the twinkle in his eye as he made that comment.

AFTER LANGMUIR: FUTURE RESEARCH DIRECTIONS

A portion of Langmuir’s legacy for future research directions is capsulized in the previous quotation. He clearly stated the need to continue epidemiologic studies of measles and rubella due to the continuing uncertainty about the relative roles played by airborne versus contact transmission of many infections. His career has emphasized that no epidemic is so mundane that it requires no study; on the contrary, there is always something to be learned by careful epidemiologic study. In practice, of course, because available resources are finite and do not permit detailed study and analysis of every communicable disease outbreak that occurs, one must pick and choose the detailed study outbreaks that offer the strongest possibilities of providing new knowledge or new hypotheses for subsequent testing.

Langmuir’s legacy also mandates a healthy skepticism of conventional wisdom or “classical” theories; epidemiologic investigators must always be open to examine alternative hypotheses to explain seemingly aberrant findings. He identified his own misplaced reliance on the doctrine of herd immunity and the primacy of contact spread in a number of instances. It gradually became apparent in many of his own studies and in those carried out by his Epidemic Intelligence Service trainees and alumni that a number of common communicable diseases were capable of being spread by either the contact or airborne route, depending on the epidemiologic circumstances, and that a number of well-known infectious diseases were spread primarily by the airborne route.

The lessons and the challenges are quite similar in the case of nosocomial infections: Although contact spread appears to be the predominant route of spread, airborne spread of some nosocomial infections, such as some staphylococcal and streptococcal infections, has been well documented. In addition, certain nosocomial infections such as legionellosis and aspergillosis, as well as nosocomial tuberculosis, are transmitted almost solely by the airborne route (34). Thus, in future epidemiologic studies of infectious diseases, it is critically important to be aware of the possibility of airborne transmission and to acquire the information necessary to support or refute that possibility.

Perhaps the greatest epidemiologic challenges today lie in the area of emerging infections. It is necessary to carry out careful studies of these infections as they are detected, to identify the likely route of transmission as well as other salient epidemiologic information. Notable recent examples are Hantavirus infections and viral hemorrhagic fevers. Recent outbreaks of Ebola virus infection have served to emphasize our uncertainties about the route of transmission. There is incontrovertible evidence of airborne transmission among primates under laboratory conditions, but no convincing evidence of such transmission among humans. Yet, can we be assured that airborne transmission will not occur among humans in the future?

Finally, Langmuir’s legacy should remind us about one other challenge for the future, that is, the threat of chemical/biological warfare or, possibly more likely, terrorism. World events in recent years underscore this concern. We are fortunate that Langmuir’s Epidemic Intelligence Service officers never had to respond to chemical or biological warfare attacks, but we should not be lulled into believing that such events will never happen in the future. The need for a continuing supply of trained epidemiologists in the United States is no less now than it was in 1951. Indeed, with the additional threat of emerging infections, a compelling case could be made that the need for epidemiologic resources has never been greater.

REFERENCES

11. Commission on Acute Respiratory Diseases and the Commis-


