

ORIGINAL CONTRIBUTION

## Constructing and Dismantling Frameworks of Disease Etiology: The Rise and Fall of Sewer Gas in America, 1870-1910

Perry G. An

*New York University School of Medicine, Department of Medicine, New York, New York*

*For roughly forty years, from 1870 to 1910, Americans recognized and feared gases emanating from sewers, believing that they were responsible for causing an array of diseases. Fears of sewer gas arose from deeper anxieties toward contact with decomposing organic matter and the vapors emitted from such refuse. These anxieties were exacerbated by the construction of sewers across the country during the mid-to-late-nineteenth century, which concentrated waste emanations and connected homes to one another. The result was the birth of sewer gas and the attribution of sickness and death to it, as well as the development of a host of plumbing devices and, especially, bathroom fixtures, to combat sewer gas. The rise of the germ theory, laboratory science, and belief in disease specificity, however, transformed the threat of sewer gas, eventually replacing it (and the larger fear of miasmas) with the threat of germs. The germ theory framework, by 1910, proved more suitable than the sewer gas framework in explaining disease causation; it is this suitability that often shapes the relationship between science and society.*

Sewer gas claimed the lives of three men in New York City on September 12, 1892. Their deaths signaled a warning against the dangers of what lurked underground in the city's extensive network of sewers:

He had scarcely reached the bottom when he gave a cry for help. Thomas Kane and a number of others living near by went to the scene and lent their aid. A rope was lowered to Vollinski, and he managed to grasp it and was drawn up to the opening, when he became unconscious and fell back. Then Kane went down for him and was overcome by the gas also [1].

In the 1880s and 1890s, Americans regarded sewer gas to be lethal. It was a real public enemy, confirmed by scientists, and it killed thousands each year across the country. Plumbers, doctors, and the general public spoke passionately about sewer gas, referring to it as "slayer," "intruder," and "assassin." Frank Hastings Hamilton eloquently wrote in 1882 about the dangers of sewer gas according to his personal experiences and observations as a physician:

When I assert that it is a daily experience with me to see persons whose general health is suffering from this poison, as manifested by

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\* To whom all correspondence should be addressed: Perry G. An, New York University School of Medicine, Department of Medicine, 620 East 20th Street, Apartment 7G, New York, NY 10009. E-mail: perryan@post.harvard.edu.

malaise, loss of appetite and strength, slight febrile symptoms, diarrhea, physical and mental depression; and that I have seen infants, children, and adults suffering from diphtheria, scarlet fever of a mild type, complicated with this disease and destroying life; those in vigorous health, students in colleges, ambitious and active young men in the professions or in the commercial or financial world, stricken down by typhoid fever, some struggling through the disease and others dying; and that the cause has been demonstrated to be this poison — I only state facts which are common in the experiences of all physicians in the city [2].

Similar reports sprung up across the country, mostly in urban centers, beginning in the 1870s. Popular periodicals, scientific journals, newspapers, and hygiene manuals preached the gospel of sewer gas to a large audience increasingly interested in domestic hygiene and sanitary science. “The Sewer-Gas Danger: an Invisible Enemy in Our Homes,” read one *New York Times* headline in 1878 [3]. In the *Atlantic Monthly*, nationally renowned sanitarian and engineer George E. Waring, Jr., challenged his audience to recognize that even “Under the most favorable conditions, the contained air of a soil-pipe must be offensive, and is likely to become dangerous” [4]. Waring’s phrasing suggests the extent to which the disgusting was self-evidently conflated with the pathogenic.

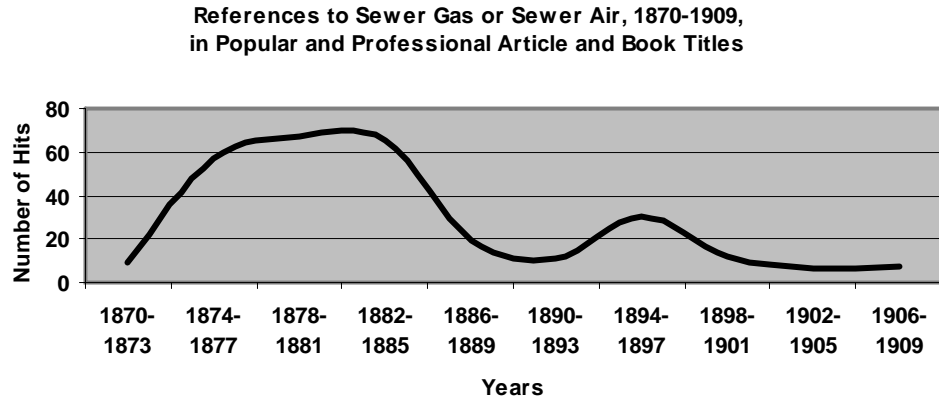
Figure 1 [5] demonstrates that a truly significant number of titles and headlines included the terms “sewer gas” or “sewer air” in American journals, books, and newspapers beginning in 1870. More precisely, 283 titles and headlines included mention of sewer gas or sewer air between 1870 and 1909. Between 1800 and 1870 only five such references were found, and only nine appeared from 1910 until 1927. This quantitative finding reveals the extent to which sewer gas awareness and fears heightened in the late 1870s and early 1880s, only to completely dissipate by 1910. The second peak in the figure,

occurring in the 1890s, represents a rise in articles questioning the reality and danger of sewer gas, as discussed later.

The trends in Figure One prompt an investigation into the rise and fall of sewer gas. How and why did sewer gas fears come about in America? Were they put in motion by scientific discoveries and/or broader social developments? What exactly did sewer gas represent for Americans in the 1870s and 1880s? How and why did it disappear from professional and popular literature in the twentieth century after investigations in the mid-1890s?

To be sure, sewer gas makes no sense today; it is not recognized by professionals — and is not feared by the lay public — as being the cause of specific diseases. Although the gases of sewers may cause dizziness and internal discomfort when inhaled, they do not contain significant numbers of microorganisms capable of causing specific diseases. Moreover, the true causes of contagious disease, it is now believed, are pathogenic microorganisms that do not and cannot float around at a great distance in emanations from organic matter. From the start of the twentieth century onwards, specific contagious diseases were no longer attributed to diffuse airborne entities but to specific microbes traveling in liquids and solids or in coughed or sneezed droplets. From today’s perspective, sewer gas epitomizes the social construction of a convenient but irrational scapegoat for the spread of disease, a myth that lasted from roughly 1870 to 1910.

But for the American city dweller in the 1880s, sewer gas was as real as many other sources of diseases for his descendants a century later. Today an excess of apples can be carcinogenic, bare-footed children can cause illness at preschools, and public telephones carry and serve to disseminate millions of different microbes, conclusions largely corroborated by scientific experiments. Thus, the “sewer gas



**Figure 1. Sewer gas literature, 1870-1909.**

phenomenon” still exists in society today, although in different guises. This is not to say that present-day etiologies are faulty and will, sooner or later, be disproved, but rather that deep-seated sociocultural anxieties encourage the construction of certain kinds of disease threats. For example, the fear of germs on public pay phones is rooted in a deep-seated disgust for contact with bodies of unknown origin. One can only speculate whether a particular phone has been used by someone with a contagious disease. In the same way, late-nineteenth-century Americans were weary of sewer gas, which had the capability of traveling through the city from filthy, disease-ridden homes to clean, sanitary ones. These putative means of transmission — sewer gas and public telephones — undergo investigation and scrutiny in the form of personal experiences and scientific experimentation, at which point their legitimacy is either strengthened or undercut.

In 1997, CBS investigated the ubiquitous presence of bacteria on common surfaces such as ATM keypads, handrails, and public pay phones. Reporter John Roberts, with the aid of microbiologist Carl Batt of Cornell University, found that half of all

surfaces tested in New York City had at least one form of pathogenic bacteria on them. Such discoveries were repeated in San Francisco and in the less-crowded city of Lincoln, Nebraska. The conclusion was that touching that which had been touched by untold numbers of strangers posed serious risks to health: “It’s possible, very possible, to get sick from a pay phone,” said Batt [6].

While public pay phones, then, are far from being denied as a source of disease, they are akin to sewer gas in that contemporary frameworks for disease etiology corroborate their relation to disease. The present framework for disease causation dictates that the presence of harmful microbes (determined by laboratory science) is equated with disease. Moreover, public telephones and sewer gas both serve as links, potentially connecting the healthy to the sick. A radically different framework in the future, in theory, may deem public pay phones completely harmless, but the distaste for contact with the unknown will remain and be transferred elsewhere.

### **BUILDING UP TO SEWER GAS: THE PROBLEM OF WASTE MANAGEMENT AND DRAINAGE IN URBAN AMERICA**

The fear of sewer gas can be traced to the urbanization of the United States in the mid-1800s. As cities across America rapidly grew in size, often tripling in population within a few decades, public waste management developed under the auspices of municipal governments and public health boards. Privately-managed waste systems were deemed hazardous, by the Philadelphia Board of Health, for example, because of the inefficiency with which urban dwellers removed solid and liquid wastes from residences [7]. This was less of a problem in rural settings where privately-owned cesspools, located tens of meters from the home, did not emanate foul smells that could be detected by nearby persons. In cities, however, cesspools located directly beneath tenement housing generated foul odors and gases easily detected by city dwellers in the vicinity.

Recognizing the health hazards associated with moist, swampy land, the public worked with municipal officials in order to induce better drainage in the city. This took the form of erecting simple ditches, open-air wooden troughs along roads, and pipes underground, which carried excess liquid material outside of the city. For example, in 1840 in Charleston, South Carolina, officials mandated that many of the city's roads be reworked into a convex shape so that runoff (mud and rainwater) would travel from the center of streets into wooden troughs found on the sides and into larger sewer drains. In Manchester, New Hampshire, city officials required private drains to be built of stone, brick, iron, or "sound plank" at least two inches in diameter so as not to allow leakage of runoff into streets and residential areas [8].

Such arrangements, however, led to the private use of public drains in order to remove private cesspool waste. As a result,

cities such as Springfield, Illinois created laws against such practices, issuing fifty-dollar fines for depositing private wastes, especially water closet waste, into public sewers.

The establishment of drainage systems and laws against mixing private and public waste in sewers in mid-nineteenth-century American cities indicates a larger underlying fear: the fear of contact with stagnant waste. Fecal and liquid wastes were intolerable and deemed serious health hazards that had to be whisked away, especially in places where waste build-up was rapid in densely-populated areas. Such fears are evidenced in New York City where city officials deplored "a jumble of ill-constructed sewer lines, built at different times for the purpose of draining off storm water, [which] could not adequately bear the burden of waste removal." One doctor in 1849 cited the unhealthy living conditions of Manhattan created by "these thirty thousand cesspools studding it up and down, and filling the atmosphere with nauseous gases" [9].

To collect waste in a systematic way was an essential practice, but to transport it elsewhere so that its emanations could not reach human populations was even more important. As such, sewer projects were massively undertaken across American cities from the 1840s through to the end of the century. Chicago's first sanitation system, built in 1855 under the direction of Ellis Sylvester Chesbrough, provides one case study revealing the practical implications of the fear of stagnant waste: sewers.

### **SEWERING CHICAGO: ERASING OLD PROBLEMS AND CREATING NEW ONES**

Chicagoans had long recognized the unfavorable natural topography of the city: its flat, non-porous terrain did not

allow for natural runoff of storm water or absorption. Instead, in rainy weather, runoff built up on the surface of the land, forming swamps and overflowing cesspools across the city. These observations, along with the advent of a succession of cholera and dysentery epidemics in the early 1850s, prompted officials to act immediately. The Illinois legislature created the Chicago Board of Sewerage Commission on February 14, 1855, to help sewer the city in its entirety with the purpose of effectively removing waste. The Sewerage Commission selected Chesbrough, the commissioner of Boston's water works, to head the project.

After resigning from his position in Boston, Chesbrough came to Chicago and soon thereafter produced a report to the Sewerage Commission on his plans for the sewerage of Chicago. The 1855 report represents the first comprehensive sewerage system undertaken by any major city in the United States [10].

Chesbrough made his goals clear at the beginning of the report:

As the main object of the sewers is to improve and preserve the health of the city, it is very obvious that all substances should be received into them which would have a contrary effect, if not drained off. As a consequence, all stagnant water, all liquids from kitchens and manufactories, and the contents of all privies, should be admitted into them.

Chesbrough stated that sewers were the answer to the problem of stagnant water, liquid waste, and fecal waste. He recommended they be constructed in Chicago for the expressed purpose of improving and preserving the "health of the city." He estimated that their construction would cost roughly three million dollars. The actual cost of the project, executed through the 1860s, far exceeded such estimates, although exact figures are unknown. Louis P. Cain notes that the mere raising of brick buildings in Chicago above previous levels (in order to make

room for the construction of sewers) cost ten million dollars.

Whatever the precise monetary cost of such an endeavor, the price that the city of Chicago was willing to pay for its sewerage indicates the far-reaching consequences of the fear of emanations produced by stagnant wastes. However, these fears were not entirely erased with the construction of massive sewer systems. Americans soon discovered that their solutions to such fears in themselves became locales for the production of something they called sewer gas. Chesbrough ingeniously foresaw such developments, encouraging the ventilation of Chicago's sewers in order to prevent sewer gas explosions in the city. He proposed that catch basins be constructed in order to collect sand and other heavy substances that would otherwise clog city sewers. Chesbrough feared that clogged sewers would lead to pressure-driven gas exhalations from the sewers. In Chesbrough's words, catch basins "are so constructed as to prevent offensive gasses [sic] from escaping into the streets" [12].

Chesbrough's concern represented a larger problem that accompanied the construction of sewers across America: the problem of sewer gas. Sewer gas was problematic because, just like the emanations from stagnant waste matter, it gave off an offensive odor. If this odor could have been completely contained within the pipes of sewer systems, the fear of sewer gas might never have arisen. However, the connection of sewer pipes to individual homes and apartments created circumstances that fed pre-existing fears of noxious gases and communicable diseases. With the development of sewer systems, then, fears of wastes did not subside; instead, they were reconstructed to fit the framework of civil engineering and waste disposal. The construction of sewers during the urbanization of America paved the way for the construction of sewer gas,

underneath which lay old-aged fears of offensive odors emitted by stagnant liquid and fecal matter.

### **CONSTRUCTING SEWER GAS: SOCIAL ANXIETIES AND HOUSEHOLD HEALTH**

In addition to the sewer's contribution to the development of the notion of sewer gas, social anxieties heightened awareness and fears of such ubiquitous gases. Sewers, noted the affluent and the relatively healthy, connected the havens of the upper class to the poisonous dwellings of the lower class. Previously erected as independent complexes, houses and apartments across cities were directly or indirectly connected to one another by way of drain pipes and sewer canals underground beginning in the 1850s. Such sewer systems, in effect, made possible the movement of stagnant wastes and noxious emanations from complex to complex or, more specifically, from disease-ridden homes of the lower classes to clean homes of the wealthy. This realization heightened fears of sewer gas, because unseen connections via pipes enabled even the most sanitary home to be invaded by sickness and disease. Indeed, the sewer — created to be the savior of the city — brought trouble to urbanites by connecting homes and buildings with one another, making sewer gas nearly impossible to avoid.

Dr. Fordyce Barker, President of the New York Academy of Medicine in 1882, discussed sewer gas's effect on the rich and the poor, noting that "The special poisons to which I now refer are the gases resulting from defective plumbing, to which all classes — the poor occupants of tenement — houses, those who are able to command the necessaries and many of the luxuries of life, and those who live in the most expensive houses, and whose riches can buy everything but health-care exposed" [13]. James E. Serrell, New

York's chief city engineer, in the late 1870s, regarded sewer gas to be "more deadly than the midnight assassin" because of the "deadly effects claimed to be produced by the sewer gases passing into the dwellings of our citizens of all classes" [14].

In an environment in which the home powerfully represented the individual's safeguard and well-being and served as both a status symbol and social marker, it is not surprising that class tension was linked to domestic sanitation. According to historian Nancy Tomes, "Affluent Americans were a peculiarly house-proud people, for whom owning a home, furnishing it tastefully, and running it efficiently were badges of respectability" [15]. One aspect of respectability was the health of not only the family, but the home itself, which was a reflection of one's personal hygiene and, thus, social status. Immaculate personal hygiene, during the second half of the 1800s, was less a matter of tradition and habit and more a reflection of enlightenment and self-discipline. The idea that one's clean, respectable, sanitary home might be undone by emanations from filthy slums made sewer gas fearsome and despicable.

### **CONSTRUCTING SEWER GAS: EPIDEMICS AND SPECIFIC DISEASES**

The threat of epidemic diseases in the late-nineteenth century increased the perceived danger of sewer gas. While sewers were an "irritating reminder that the poor and marginal, by way of sewers, could still impart their ordure to the noses of the upper classes," the sewer gas inside them only became fully culpable for disease when epidemic outbreaks prompted epidemiological and etiological inquiry [16]. In an atmosphere of frequent epidemics, widespread belief in the miasmatic theory of disease, and an obsession with sanita-

tion and hygiene, one concrete culprit was sought for all diseases so that future epidemics could be avoided. That culprit was sewer gas: "There have been of late so many deaths from diphtheria, typhus fever and other fatal disease caused by poisonous sewer and other gases penetrating both the homes of the wealthy and the poor" [17]. Class fears were substantiated by medical evidence that sewer gas caused an array of specific diseases.

Diphtheria and typhoid fever were more closely linked to the presence of sewer gas by doctors, engineers, and plumbers in the last three decades of the nineteenth century than any other diseases. In New York City, diphtheria was the fourth-leading killer and typhoid the eighth-leading killer of city dwellers from 1868 to 1872 [18]. Diarrhea (ranked second) and scarlet fever (ranked third) were also associated with sewer gas by experts.

A typhoid fever epidemic at the Maplewood Institute in Pittsfield, Massachusetts served to heighten awareness of a precursor of sewer gas: foul gases from stagnant waste. In the summer of 1864, 66 of 74 resident students at the Maplewood Institute for girls complained of dizziness or some other physical anomaly. Fifty-one of the 66 were diagnosed with typhoid fever, a rate of 69 percent with regard to the entire school population. The surrounding town of Pittsfield, with a population of 8,000, reported just eight typhoid fever cases the same summer. The discovery of swampy land next to the school building and stagnant waste in a nearby barn led to conclusions that noxious emanations had killed thirteen of the students at Maplewood. George E. Waring, Jr., the most widely acclaimed sanitarian in the country, concluded, "The injurious influence of decomposing azotized matter, in either predisposing to or exciting severe disease, and particularly typhoid fever, is universally admitted among high medical authorities."

Waring cited the Maplewood incident in 1870 to emphasize the reality of "sewage and cess-pool diseases." By linking foul waste matter with actual epidemics and known diseases, Waring both affirmed and promoted sewer gas fears. In the same treatise, Waring reminded his readers of President Buchanan's near encounter with "intestinal or enteric fever" in 1857 brought about by sewer gas. In that instance, several guests attending Buchanan's inauguration fell ill suddenly at the National Hotel in Washington, D.C. Investigators at first suspected food or drink poisoning to be the cause of the incident, but later concluded that sewer gas had infiltrated the hotel and sickened the guests there. Waring writes,

Poison was suspected, but a rigorous investigation brought the committee appointed for the purpose, and all the medical attendants upon cases, to the belief that the disease was due to sewer-gases. The drain of the privy was found to be obstructed; and the foul emanations were driven back, poisoning many who inhaled them. On removing the obstructions, the effluvia and the cause of the disease disappeared [19].

Waring's account demonstrates the perceived link between epidemics and sewer gas. The correlation between sewer gas and known, specific diseases, by 1870, allowed sewer gas to develop into a concrete entity.

Interestingly, such forces were set in motion before the precise nature of sewer gas was even studied. The vagueness with which sewer gas was described is striking, especially in contrast with the boldness with which the effects of sewer gas were portrayed. For example, in 1882, Dr. Frank Hamilton struggled to define sewer gas:

What is "sewer-gas"? This term has been employed a long time by chemists, sanitarians, plumbers, and others, to indicate the ordinary emanations from sewers; but recently certain gentlemen have taken exceptions to the term, denying that there is any such thing as sewer-gas "having a peculiar and definite

composition.” This is undoubtedly true, and it is probably that no intelligent man or educated physician ever thought otherwise [20].

After having failed to clearly identify the nature of sewer gas, Hamilton emphatically cited it for causing typhoid fever and diphtheria: “... sewer-gas causes more typhoid fever than all other causes combined.... Diphtheria must be classed among the diseases which in all probability are, in many cases, caused or conveyed by sewer-gas.”

How could the effects of sewer gas be so clear yet the perpetrator unidentifiable? Hardly the exception, such a pattern often shapes the methodology of scientific discovery: experience and observation prompt etiological inquiry whose initial answers are constructed to fit pre-existing forces. In retrospect, erroneous models appear foolish, yet they can be contextualized within a larger social framework.

The case of sewer gas was, as such, as social forces worked to formulate an entity perfectly suited to meet their immediate needs. A natural abhorrence for foul odors emitted by waste matter — especially in light of their relation to disease — led to the necessary construction of sewers because of the rise of waste in densely-populated areas. However, this measure produced other complications as sewers themselves, products of technological prowess and genius from the days of the Roman Empire, concentrated noxious gases and propagated them underground throughout urban landscapes and residential networks. The possibility that these fatal odors could enter one’s home through sewer pipes confirmed and exacerbated pre-existing fears of noxious odors produced by stagnant wastes outdoors and in cesspools. The production of a network of excremental waste transport led to the creation of sewer gas.

Another way to understand the construction of sewer gas is to perceive it as a scapegoat, by 1870, onto which broader

social and cultural anxieties were transferred. A historical example of fears transferring from one agent to another lies in the work of Theobald Smith, who “transferred the fear of an important group of diseases to a fear of their intermediate insect hosts” [21]. Smith discovered in 1889 that ticks carried the microbe that caused Texas cattle fever, effectively contributing to the transfer of fear of the disease itself to its vector. Similarly, the fear of smallpox was transferred to an acute fear of the Chinese population of San Francisco during smallpox epidemics there in 1868, 1876, 1881, and 1887 [22]. White San Franciscans directed their fear of smallpox toward visible Chinese populations, unjustifiably quarantining the Chinese.

In a similar fashion, anxieties concerning contagious diseases and relatively lower, “dirtier” classes were transferred to sewer gas. The dread of epidemic diseases and a disdain for the unhygienic poor turned into an additional fear of sewer gas. That it was housed in sewers and propagated throughout cities in a network made its role as potential killer complete. In conclusion, sewer gas was an entity known not by its precise nature, but by the convenience with which it provided an answer for a wide range of anxieties in the second half of the nineteenth century.

## **SEWER GAS AND THE WHITE HOUSE**

President James A. Garfield’s fatal illness in 1881 epitomizes the fearful and suspicious public attention devoted to sewer gas in late-nineteenth-century America. On July 2, 1881, President Garfield was shot by Charles Guiteau, a Stalwart. The Stalwarts were anti-reform, conservative Republicans, including spoilsmen with whom Garfield was at odds. They desired Vice-President Chester A. Arthur to be President.



Garfield sustained a grazed arm and a bullet wound to the back near his spine. With the wounds cleaned with alcohol and temporary dressings applied, Garfield was transported to the White House where he would remain through the summer, bedridden. Physicians decided not to remove the bullet because their prognosis was exceedingly pessimistic: he was going to die at any moment. But in fact, Garfield survived for at least two more months, his condition wavering between relative comfort and excruciating pain and numbness. He remained a patient in the White House.

During this time the air surrounding the Potomac flats was thought to cause malaria. Moreover, the White House itself was closely scrutinized for the possibility that its allegedly faulty construction and plumbing would worsen the President's already dire condition. "Rotten timbers in its basement and green, slimy brickwork were vividly described in Congress. A distinguished engineer came to look at the venerable plumbing" [23].

The engineer was George E. Waring, Jr., called in mid-August to ascertain whether sewer gas was infiltrating the White House because of the mansion's antiquated plumbing. His name was introduced by Attorney General Wayne MacVeigh and approved by Colonel Almon F. Rockwell, both a doctor and engineer, in charge of coordinating the President's recovery. Waring was invited not only in response to the President's condition, but also in response to First Lady Lucretia Garfield's developing fever, purportedly caused by the air of the Potomac Flats and the defective plumbing of the White House. Recent allegations of the White House's unsanitary condition, made in the late 1870s, further made Waring's visit imperative. In 1879, the officer in charge of the White House building and grounds noted the defective nature of the mansion's plumbing and convinced Congress to provide funding for new

plumbing devices. Newly-developed water traps to exclude sewer gas and water closets were among the several devices installed, yet suspicions of the White House's cleanliness remained.

After a week's investigation of the premises, Waring issued a preliminary report to Rockwell on August 23, 1881. The report dramatically described the White House's sanitary problems at length. For example, the basement kitchen sink contained a filthy water trap so large that it was itself a cesspool. Upstairs, traps were improperly installed and the bathrooms were unventilated. In addition, the room adjacent the President's chambers contained a bathroom that utilized an antiquated pan closet. Pan closets possessed no water-flushing mechanisms and instead comprised a pan like trough into which urine and excrement were dumped. The pan was then manually tilted to allow the waste to slide, by gravity, into a larger container connected to the soil pipe. The soil pipe ran through the entire complex. Waring found it to be unventilated.

Although no public report was made immediately and White House officials did not acknowledge the role of sewer gas in causing the President harm, Waring's report encouraged Garfield to move from his current residence to the outdoors. Garfield thus begged for a change of scene, and, the Garfields being believers in the therapeutic effects of sea air, moved to Elberon, New Jersey, to a summer house along the beach. On September 6, the President was carried on a stretcher from his room to a wagon to the local railroad station where he took a train to Elberon. The move proved wise at first — his condition seemed to improve — but soon thereafter Garfield vomited uncontrollably and developed chills and high fever. Garfield died two weeks after moving out of the White House, on September 19, 1881. The autopsy reported that his death was caused by an aneurysm of the splenet-

ic artery, most likely linked to the bullet never removed.

However, rumors soon spread that the President had died because of the infiltration of sewer gas into the White House. President Arthur, Garfield's successor, refused to live in the mansion until the plumbing was redone. Waring's report to Rockwell was published in the *New York Times* in October 1881 [24], and immediate measures were taken to begin reconstruction. During both the Garfield and Arthur administrations, over \$110,000 was spent on White House maintenance, a figure larger than any other since the White House's destruction by the British during the War of 1812.

Even the President of the United States in his luxurious mansion could die of defective plumbing and sewer gas poisoning. By the early 1880s sewer gas's effects were widely recognized, especially among doctors and sanitary experts. The role of sewer gas as a concrete entity able to cause disease had finally been realized, a product of fear of disease and a repulsion and anxiety toward contact with bodily waste and with the filthy masses.

### **THE BATHROOM AS A BATTLEFRONT: FROM FIGHTING SEWER GAS TO FIGHTING GERMS**

The architectural revolution of the private bathroom in late-nineteenth-century America demonstrates the practical impact of sewer gas fears on the household level. The American bathroom — the toilet, sink, bathtub, accessories, and tiled floors and walls — serves as a case study in order to unveil the private response to sewer gas threats in urban America. It is also in the bathroom that the sewer gas framework began to break down in favor of a newly-understood microbial framework due to, primarily, laboratory experimentation. One concerned "Layman" of Philadelphia wrote in 1887,

The nature of sewer gas, the way in which it is generated, how it enters our homes, and its effect on the human system are now so well understood that it is unnecessary to enlarge upon that topic. The ingenuity of Anglo-Saxon mechanics has easily met the requirements of the scientists and provided the means to prevent sewer gas from entering our homes.

But there is another source of pollution present in almost every house which has not yet received the general recognition it deserves ... bacteria [25].

Was "Layman" right to boast of humankind's understanding of sewer gas? What were some of the "Anglo-Saxon mechanics" that allegedly defeated it? And how did a preoccupation with germs come into conflict with and overtake America's thirty-year-old preoccupation with sewer gas? While the enemy in the bathroom was sewer gas alone for many years, beginning in the 1880s both sewer gas and germs were targeted for exclusion and eradication. By 1910, only the latter would oppose the American householder in the bathroom, although bathroom hygiene and cleanliness were rooted in sanitary practices stemming from earlier sewer gas fears. The bathroom provides a concrete locale where sewer gas fears were highly evident, acted upon, and then replaced by fears of germs.

In 1870 one could enter an upper-middle class bathroom to find a room not much different from a lavishly-furnished master bedroom: ornate furniture, stylish mirrors, lush carpets, and toilets and bathtubs in wooden boxes, presented in such a way to mimic living room furniture. Bathrooms of the middle and lower classes contained simpler furniture but the overall look mirrored any other room in the home [26].

The development of public water systems and sewers enabled the bathroom to come from outside (as privies) and into private homes beginning in the middle of

the nineteenth century. However, one major problem confronted architects and engineers: the problem of unhealthful and unpleasant odors. While convenience propelled the development of the indoor bathroom, a certain distaste for and fear of excremental odors marked the only side effect for these technological advances. As a result, engineers and sanitarians worked together to remedy these side effects. In sum, “Hundreds of designs for water closets and flushing devices were patented in the 1870s and 1880s; the 1884 catalogue of the Meyer-Sniffen Company presented no less than thirty-three different versions of the sanitary water closet, from the simplest to the most elaborate” [27].

Initial efforts focused on the water closet and its structure. A prevalent early model was the pan closet which comprised a dry, pan-like structure situated to collect excrement. By pushing a lever one tilted the pan so that its contents slid into a small pool of water below. This pool of excrement and water would remain so until manually removed either daily or weekly, rendering the pan closet unsanitary: “The pan closet was very commonly used but universally condemned by sanitarians because the lower waste receptacle retained hidden filth and the moveable pan arrangement permitted escape of impure air” [28]. The model was popular because it was cheap and easily installed; it was, however, short-lived because it failed to keep unpleasant odors out of the bathroom. Fecal air could rise when the pan was momentarily tilted. Waring fiercely opposed the pan closet, colorfully stating,

[The pan closet] probably is not, but it certainly might be, the invention of the devil.... Immediately below the copper pan there is a chamber of horrors known to the trade as the “container,” and a container indeed it is! It contains what it pretends to remove, until no other utensil of human economy is one-half so foul.... When the pan is thrown down, after use, the pent-up gases escape through the seat with a stifling whiff familiar to all

who have been subjected to it — as who in a modern city has not been [29]?

The hopper closet served as an improvement over the pan closet by the 1870s. In place of a dry pan that required frequent dumping the hopper closet possessed a water seal, that is, a constant volume of water that served as a buffer between the atmosphere and pipes where wastes were being collected. This seal excluded sewer gas from entering the home and effectively buried foul-smelling excrement [30].

Mechanical valves aided water seals to further block sewer gas from entering the home through toilets. The Washburn & Moore Manufacturing Company, in an 1884 advertisement titled “No More Sickness and Death from Sewer-Gas,” marketed the C Valve with the following words: “We plug out sewer-gas with a solid brass valve at top of trap.... C represents a solid brass valve ground to the outlet, perfectly tight, preventing the escape into the room of any gases from the sewer-pipe, and making it impossible for water either to syphon or evaporate from the trap” [31].

An additional development that achieved the goal of excluding unpleasant odors was siphonic action, a powerful flushing mechanism in which atmospheric pressure forced liquid to flow from one level to another by way of circular currents. Waring and George Jennings discovered siphonic action in the 1880s. It quickly replaced the wash-out flushing mechanisms of hopper closets in which “flushing” merely entailed the pushing of waste into drain pipes by pouring water into the toilet. The wash-out flush did not thoroughly remove waste and contaminated water while water was being poured into the bowl, resulting in incompletely disposed contents. Siphonic action mechanisms were popular for their whisking away of any and all waste, although the cost of their implementation and use was

considerably higher than that of manual flushing devices.

**SEWER GAS EXCLUSION,  
MICROBIAL ERADICATION, AND  
THE SANITARY-  
BACTERIOLOGICAL SYNTHESIS**

Siphonic action not only excluded sewer gas from the bathroom: it also removed dirt, grime, and germs. Bacteriology and the germ theory provided a new vocabulary with which previous health practices could be discussed and older fears could be reformulated in what amounted to a “sanitary-bacteriological synthesis.” More generally, the “sanitary-bacteriological synthesis” was negotiated during the mid-to-late-nineteenth century among doctors, scientists, engineers, government officials, and the general public. It served as “... a new way of understanding, explaining, and combating the problem of disease in modern society ... in which the overriding concern of the early and mid-nineteenth-century sanitary movement with filth, contamination, cleanliness, and behavior was integrated through the language of bacteriology into a new set of perceptions and practices” [32]. Such developments occurred “alongside a new germ-centered focus on the danger of contact with sick or suspect bodies ... and substances associated with them, as well as on the possibility of control through interventions derived from laboratory science.” Siphonic action and the language with which it was described catered both to previous fears of sewer gas and developing fears of germs, allowing for the transition from sewer gas to germ theory. Water seals in toilets, for example, first developed to block unpleasant odors and sewer gas, were later reinforced in practice in order to exclude bacteria from entering the home.

The Potteries Selling Company of Trenton, New Jersey, drew its audience’s

attention to both sewer gas and germs as late as 1910 in order to market the “Sy-Clo” Toilet. The toilet possessed a water seal that covered the pipe connecting the bowl to underground waste pipes. This water seal protected the homeowner from both sewer gas and airborne microbes: “If the outlet is not covered, poisonous gases and disease germs must sooner or later escape into the house and sickness is certain to follow; it may simply mean that you are going to feel miserable, or it may be some serious disease” [23].

On the following page of the Potteries Selling Company’s pamphlet the water seal was advertised as such: “Its seal, that is to say the body of water which prevents the sewer gas from escaping, is deep, broad, and always in plain sight, and cannot be broken under any circumstances.” This quotation reveals the seal’s usefulness against sewer gas. On another page the seal was claimed to protect against microbes: “These microbes get into houses through pipes of imperfect closet bowls, but it is absolutely impossible for them to work their way through the water seals of a Sy-Clo Closet.” Clearly, then, the Potteries Selling Company played on public fears of both sewer gas and germs. One could combat both enemies at the same time simply by purchasing its bathroom fixture. Practices formerly developed to combat sewer gas-like water seal installation-were used to combat germs as well.

“Layman” similarly targeted both sewer gas and germs but felt that the latter was receiving too little attention by the mid-1880s. Water seals were not enough, he claimed, to eradicate germs in the bathroom, although they effectively prevented sewer gas leakage. His treatise represents a growing divergence between sewer gas and germ warfare. The former had been handled appropriately through 1884; the latter, however, required new measures unique to its character.

“Layman” highlighted the evasive nature of germs, their ability to stick to bathroom fixtures and become lodged in cracks and crevices. Accordingly, “Layman” called for two developments in bathroom fixtures and appliances: non-corrosive material and open structures. The interest in improving the quality of the material used in bathroom architecture stemmed from prior attempts to use stronger material in the construction of sewer pipes. The call for open structures as opposed to enclosed bathtubs and toilets, however, was unique to the sanitarian’s war against germs.

In a manner consistent with the “sanitary-bacteriological synthesis,” preoccupation with sewer gas paved the way for the battle against germs in the bathroom. Just as sanitarians called for iron soil pipes in houses instead of lead or copper pipes in order to prevent sewer gas leakage, porcelain, marble, and vitreous china entered the scene in bathrooms in order to eradicate germs. Calls for white, nonporous surfaces that could be scoured until gleaming mirrored terrifying demonstrations that “the densest stone walls are easily penetrated by [sewer] gases” [35].

Tiled floors and porcelain-enameled toilets, tubs, and sinks appeared in the bathroom out of a fear that previously-used materials would harbor the growth of germs. Wooden cabinets, metal bathtubs and the like were thought to be easily cracked or corroded, allowing for the hidden development of bacterial colonies. As a result, commercial industries like Kohler produced porcelain-enameled bathroom appliances, claiming their sturdiness and resistance to corrosion and erosion: “[The] enameled tub — when produced in 1911 as a single, ‘sanitary’ piece, without crevices, joints, or seams — turned the Kohler Company into a nationally recognized producer of plumbing fixtures” [36]. Other companies like the Potteries Selling Company turned to the use of china-sup-

posedly stronger than cast iron appliances enameled with porcelain-in their products:

We use china for our tableware because no other substance can be kept so pure, sweet and wholesome. It might be said by some that enameled iron ware is stronger than china, but a moment’s thought will show that this is a fallacy. Its enamel will easily chip off and leave a rusting place which will create an odor and afford a lodging place for disease germs.... No closet bowl should be allowed in the house which is not made of china, because no other material is or can be so clean and sanitary [37].

The Potteries Selling Company marketed its china toilet upon the public’s fears of germs growing in the crevices of damaged bathroom fixtures.

Bathtubs were especially marketed in the 1890s by manufacturing companies’ touting their sturdiness. The Stewart Ceramic Company of New York stated in *Scribner’s Magazine* in 1893, “Get the best. Do not risk your health by using materials that will leak, absorb, decay, and become malodorous and infectious” [38]. Their tubs were “imperishable, well-glazed, non-porous, and as easily cleansed as a dinner plate.” Likewise, the Standard Manufacturing Company of Pittsburgh guaranteed the quality of their porcelain-lined bathtubs in 1896, a product “unmixed with guess-work” [39].

Porcelain and china were appealing not only for their sturdiness, but also for their whiteness. Advertisers claimed that this whiteness could make dirt more easily visible — visible for cleaning, that is: “Not only did this style [of free-standing, porcelain or china toilets] eliminate the dangers of hidden work inside the [wooden] cabinet areas; it also provided bathroom surfaces that could be scoured more effectively” [40]. Even outside the bathroom, manufacturing companies advertised the use of porcelain-enamel for these reasons:

[Regarding refrigerators:] White, everlasting porcelain, moulded into one piece, lines every food compartment. The whiteness makes every corner light as day, so you can see anything spilled there. The glaze enables you to wipe it up with a cloth. That's about all the cleaning ever necessary. Healthful because they are never uncleanly. The only refrigerators that are absolutely odorless. Durable because the porcelain never breaks. Nothing can [g]raze, crack nor peel [41].

This example demonstrates the fluidity with which theories permeated different health practices. Ideas on sewer gas exclusion could be transformed to keep dirt and germs from lodging in cracks in bathroom fixtures, as well as keep odors out of refrigerators in the kitchen. In another advertisement, from McClure's Magazine, an enamel pantry provided "a germ-proof, easily cleaned surface. Wiping with a damp cloth is all that is necessary.... Anyone can do it" [42].

### **ERADICATING GERMS IN THE BATHROOM AND THE EARLY WANING OF SEWER GAS**

The fascination with nonporous materials in the bathroom did not, however, merely remain as an offshoot of sewer gas exclusion practice. This interest took unique turns on its own, evolving into practices that no longer combated sewer gas. For example, the widespread disappearance of carpets in bathrooms had little to do with sewer gas fears but wholly with microbial fears. One advertisement for hardwood floors (that they should replace carpets) claimed, "Good health, not less than good taste, demands the elimination of carpets from our homes. These garner and disseminate poisonous germs of many kinds, and fill the room with minute particles of dust which are constantly respired" [43].

An anonymous physician wrote to the *Herald of Health* to clarify the relationship between carpets and disease:

The truth is that they [carpets], more than any article of furniture, more even than the walls of the room, gather and retain dust; and this dust, though chiefly inorganic, and comparatively harmless, contains organic germs, which only need to be raised into the air and taken into the human economy, to develop the active disease; creating, under favorable circumstances, an epidemic [44].

The decorative features of mid-nineteenth-century bathrooms, like carpets and draperies, gave way to the modern bathroom at the turn of the century "as an overtly industrial ensemble of porcelain-enameled equipment, with white, washable surfaces that reflected contemporary theories of hygiene" [45].

The bathroom revolution included not only changes in building materials but also, as "Layman" discussed, changes in overall structure from enclosed fixtures to free-standing tubs and toilets. This shift was a response not to sewer gas fears but to microbial fears. For example, the open toilet rose to ascendancy over the toilet enclosed by wooden cabinetry. "Layman" stated, "The usual manner of inclosing the ordinary water-closet in wood, very frequently combining it with a washstand and bathing-tub, converts the inclosure into a kind of open sewer, almost as dangerous to health as the old-time connections that have long been discarded" [46]. As a result, enclosed toilets encouraged the growth of bacteria:

The necessary conditions for the development of bacteria are known to be: foul emanations, warmth, and absence of light; and all these conditions are present in such inclosures, even those which are most carefully guarded against sewer gas. The organisms escaping with the feces are carried by the gases into contact with the surfaces surrounding water-closets and may there germinate and decompose, loading the atmosphere with the deadly agents which we have been at so much pains and expense to exclude.

As was the case with sewers, a piece of technology which itself developed the potential to house poisons, enclosed toilets built for one's convenience in the home developed the potential to house bacterial colonies. The Sanitary Association claimed that bacteria from feces and stagnant waste grew easily in enclosed toilets because of the lack of light and the entrapment of warm air and foul odors. Hence, the organization and "Layman" believed that open toilets inhibited the growth of bacteria. Growing acceptance of the germ theory taught Americans that bacteria were often pathogenic. Their growth in homes was synonymous with an invitation for disease.

The free-standing bathtub and toilet also grew popular because such arrangements allowed for the exposure of washable surfaces. Prior to 1880, the aesthetics of bathroom architecture dictated that the goal of the designer was to hide all fixtures as much as possible. However, in the next decade, encasements gradually disappeared, bathtubs were lifted off of the ground and supported by small claw-feet at the corners, and toilets were erected to expose all parts for cleaning, especially the sides and back. Elevating the bathtub off of the ground allowed homeowners to clean the floor underneath it; bathtubs were also moved away from corners in order to make them accessible for cleaning [47].

In conclusion, the bathroom changed from a bedroom-like chamber to a "hospital-within-the-home" [48] beginning in the 1880s due to fears of both sewer gas and microbes. Mechanical valves and hopper closets were developed in order to more effectively exclude sewer gas from entering the bathroom. Manufacturing companies feverishly built newer models of traps, toilets, and bathtubs that both encouraged and satisfied public demand. Practices to exclude sewer gas leakage into the home also made sense in light of the germ theory, leading to the develop-

ment of stronger, nonporous materials with which bathtubs, sinks, bathroom floors and walls (tiles), and toilets were built. Iron, originally introduced to construct stronger pipes to prevent sewer gas leakage, had evolved into porcelain and china to prevent germs from lodging in cracks.

The adoption of free-standing fixtures with exposed surfaces that allowed for scouring catered to fears of germs alone. In fact, beginning in the 1890s, when the germ theory took a firmer foothold in the United States, bathroom developments reflected a stronger obsession with germs than with sewer gas. From the standpoint of most observers in the 1890s, the vague threat of sewer gas paled in comparison to recent discoveries that linked specific germs to specific contagious diseases. "Layman," in 1887, while cautioning the householder against the threat of sewer gas, more strongly warned against the threat of pathogenic microbes: "But there is another source of pollution [in addition to sewer gas] present in almost every house which has not yet received the general recognition it deserves" [49]. The new threat eventually sounded the death knell of sewer gas.

### **SEWER GAS: A MERE GENERAL VAGUE IMPRESSION**

On May 30, 1894, Dr. Abraham Jacobi announced, in front of fellow physicians and scientists across the country, "There is a general vague impression among the public [regarding sewer gas], but I never saw a case or could prove one" [50]. By the mid-1890s clinicians followed Jacobi and began to question the veracity of the sewer gas theory, wondering if fears of sewer gas were grounded in contemporary scientific principles. In order to explore such possibilities, a nation-wide conference was organized by the Congress of American Physicians and

Surgeons in Mutzerott's Music Hall in New York City, where Jacobi, the nation's most renowned pediatrician and professor of medicine at the College of Physicians and Surgeons, made the case against sewer gas.

His arguments were little concerned with malodorous influences found in the bathroom, nor did they address the creation of poisonous, encased environments where sewer gas could accumulate alongside collections of germs. Instead, Jacobi turned his medical audience not to what could be detected by crude smell or sight, but to the world of microorganisms and their nature — that which required microscopes and laboratory testing for visualization and understanding. Bacteriology provided the tools for Jacobi's arguments. He showed by experiment that the content of the air from sewers contained fewer microorganisms than atmospheric air and concluded that "specific germs are destroyed by the process of putrefaction in the sewers," thus rendering the air from sewers harmless [51]. Henceforth, the truth of disease threats was to be found in laboratory methods and in the quantitative measurement of microbes.

What caused this shift in ideas regarding sewer gas? How did the sewer gas framework for disease etiology slowly crumble at the turn of the century? In the first blow to the sewer gas framework, beginning in 1876, several scientists began to consider sewer gas a harmless medium by which the real perpetrator, germs, traveled. Such beliefs constituted a "germs in sewer gas framework," an intermediate theory that both acknowledged sewer gas as a distinct entity and encouraged the practice of sewer gas exclusion from the home. The germs in sewer gas framework lasted into the 1890s.

A second development that threatened the legitimacy of sewer gas (and broke down the compromising germs in sewer gas framework) was the rise of bacterio-

logical contagionism and the New Public Health. Bacteriological contagionism emphasized the person infected with pathogenic microbes — not spaces — as disseminator of disease. The New Public Health, similarly, was concerned with the surveillance of specific microbes in populations, not sewer gas. Jacobi led the assault against aerial and spatial notions of disease transmission beginning in 1888, while Charles V. Chapin, the nation's leading public health figure at the turn of the century, shaped laws and health practices to mirror heavily contagionist beliefs from the 1890s onwards.

Bacteriologist and public health pioneer C.-E.A. Winslow initiated a third development — the final, fatal blow that completed the dismantling of sewer gas by the first decade of the twentieth century. In 1907, Winslow carried out laboratory experiments that revealed that bacteria did not hover in volumes of air. He demonstrated that not only were bacteria absent in sewer gas; their nature also prevented them from being flung into a suspended state in the air. The effect was that the threat of sewer gas dissipated after 1910. In sewer gas's place stood germs.

### **A TEMPORARY SOLUTION: THE "GERMS IN SEWER GAS FRAMEWORK"**

As early as 1876 the finding that there were no significant deviations in the chemical composition of sewer gas compared to atmospheric air was made by Professor William H. Brewer of Yale University. Tens of reports both in the United States and in Britain confirmed such findings, leading to scientific debates whether sewer gas was dangerous. Was sewer gas dangerous or merely a vessel for the transport of dangerous germs?

William Paul Gerhard, a pupil of Waring and sanitary engineer in New York, outlined the conflict between sewer



gas theory and germ theory in his writings. He was aware that many scientists and plumbers like Waring believed that sewer gas itself — which was largely organic vapor, or gases given off by decomposing waste and fecal matter — could produce any one of the so-called “filth diseases” such as nausea, headache, or vomiting. However, he was convinced that sewer gas served to contain “microscopic spores or germs which live and feed upon such organic vapor and are capable of reproduction under favorable conditions, such as presence of putrefying filth, excess of moisture, heat, lack of oxygen, etc.” [53]. The belief that sewer gas houses harmful germs and mediates their movement is what this author calls the “germs in sewer gas framework.”

This subtle but important transition was apparent in an article by Dr. J. Soyka of the University of Munich, translated and printed for an American audience in 1882. Soyka lamented “the tendency [in Germany] being greatly to exaggerate the danger [of sewer gas]” [54]. Soyka’s lament was founded in a belief in disease specificity, one significant implication of the germ theory. Soyka, like Jacobi, cited the need for a one-to-one unique relationship between microbes and different diseases. Sewer gas did not fulfill such a criterion:

In considering the subject, all cases of sudden death or illness caused by inhaling [sewer gas] may be left out of the question, for what is now to be dealt with is not sewer poisoning, but the spread of certain diseases ... which arise in consequence of the reception into the system of an organism. ... It is not pretended that the foul gas in sewers can give birth to the germs of typhus, diphtheria, etc., but only that such gases serve as the medium in which these organisms are suspended and conveyed to the patient.

Soyka concluded that “positive proof of a connection between sewer gases and

the spread of epidemic disease is wanting.”

The germs in sewer gas framework adequately satisfied fears of both sewer gas and germs, resulting in its long tenure from roughly the mid-1870s through the 1890s. Although sewer gas was no longer blamed for directly causing a variety of diseases in this framework, it was still associated with aiding and abetting the work of harmful microbes. Dr. Job Lewis Smith, an influential American pediatrician alongside Jacobi, subscribed to this idea, stating in 1886, “The atmosphere in which the child lives should be free from noxious gases and organic matter in which micro-organisms are developed and thrive” [55].

The Philadelphia Board of Health in 1882 likewise described the problem of sewer gas in the language of the germ theory: “With the presence of filth of every description, a sluggish current, moisture, heat, germs of disease, and the absence of circulation of fresh air, nothing more seems to be required for calling into activity those processes which give to sewer air its poisonous qualities” [56].

### **A MILIEU HOSTILE TO SEWER GAS: DISEASE SPECIFICITY AND BACTERIOLOGICAL CONTAGIONISM**

This happy medium, however — the framework of sewer gas plus germ theory — started to break in 1888 because of growing belief in disease specificity, contagionism, and the New Public Health. In 1888 Jacobi published an article questioning the sewer gas theory on grounds that sewer gas was not disease specific. Jacobi raised the question, “Can these foul exhalations produce alike diphtheria, typhoid, and dysentery” [57]? Dr. Louis Fischer of the New York Medical School similarly claimed, “Now, do micro-organisms develop different diseases under different

conditions, i.e., does a germ sometimes develop typhoid, the same germ diphtheria, or scarlatina, or measles? My answer is, Not any more than we should expect to have potatoes grow from pumpkin seeds” [58]. Notions of disease specificity triggered closer examination of the nature of germs — how they spread and where they were most prevalent.

That sewer gas might serve as a medium in which the bacterium for diphtheria grew and was disseminated was largely ignored by Jacobi, who lamented what he believed to be an even larger threat to health — those infected with diphtheria itself. As such, Jacobi’s objection to sewer gas not only was grounded in theory but also held practical ramifications. He wrote in 1888, based on clinical experiences, “... I have often found a professional both inspecting traps and cellar floors, while the rest of the children of a family were permitted to play in the rooms and about the beds of those affected with the malady” [59].

Jacobi’s emphasis on the carriers of disease and the infected brings to light one camp of scientists and physicians at the turn of the century: the bacteriological contagionists. Most bacteriological contagionists, like Providence Superintendent of Health Charles V. Chapin and bacteriologist C.-E.A. Winslow, likewise objected to the harmfulness of sewer gas and instead indicted individuals infected with pathogenic microbes for spreading disease. In the other camp could be found the anticontagionists (or filth theorists) who focused on the presence of disease-causing microbes everywhere. Sewer gas was one locale where the presence of microbes should not be ignored, according to them.

However, such distinctions between contagionists and filth theorists are relatively artificial and grew more of a function of how scientists at the turn of the century aligned themselves in professional journals. In fact, at the turn of the century,

both contagionists and latter-day anticontagionists believed that on a basic level germs caused (or could cause) disease. They also held that specific microbes caused specific diseases. How they differed, then, lay in their emphasis — objects versus people — which was a function of their slightly different ideas on the nature of germs. Did germs fly? How did they travel from one location to another? Could a person infected with diphtheria transmit the disease to another by simply touching him or her?

Anticontagionists such as Waring believed that harmful germs were omnipresent. This stemmed from associations of germs with air. Indeed, for anticontagionists, germs were like air particles — found everywhere, floating, and resting in and about objects — and they were poisonous to the body. Fumigation and sewer gas exclusion practices, then, made sense in light of such an understanding of the nature of germs. Infected persons did not pose a threat to anticontagionists except for the expired air that they exhaled. The association of germs with air stemmed from earlier beliefs in miasmas and was therefore easy to make.

Bacteriological contagionists, on the other hand, did not conceive of any inherent likeness between air particles and germs. For them, the germ theory was truly opposed to the miasmatic theory of disease. Germs, unlike air particles, aggregated in certain areas, especially in sick individuals. Sewer gas was only relevant so far as it hindered the individual’s immune response — its resistance — to invading microbes. Jacobi wrote in 1894, “The impossibility or great improbability of specific diseases rising from sewers into our houses ... must, however, not lull our citizens and authorities into indolence and carelessness. For the general health is suffering from chemical exhalations, and the vitality of cell life and the power of resistance are undermined by them” [60]. But

this warning against sewer gas exposure paled in comparison to warnings about exposure to persons infected with contagious diseases. The infected person served as a concentrated locale for swarming germs.

### **EPIDEMIOLOGY AND THE CONVERSION OF CHARLES V. CHAPIN**

Charles V. Chapin provided the foundations of the public health movement in the twentieth century and was thus the most influential public health officer in the United States at the turn of the century. He fiercely fought the contagionist battle by directing his efforts at isolating individuals carrying infectious microbes. He spearheaded the beginnings of the New Public Health, a term used by historians of medicine to describe a largely laboratory-based public health in the early-twentieth century that focused on the surveillance and control of pathogenic microbes (often masked in healthy bodies) in populations. The New Public Health was interested in tracking harmful microbes and less concerned with sanitizing the environment.

Ironically, Chapin believed in the dangers of sewer gas early in his career as a physician and as Providence's Superintendent of Public Health, a title that he held from 1884 until 1932. His public health records demonstrate a belief in the relationship between sewer gas, disease, and household health. He kept all records of typhoid fever, diphtheria, and scarlet fever cases in Providence from the 1870s through the first decade of the twentieth century. Each record contained two sections: a biographical sketch of the afflicted and a description of the "condition of the premises [of the sick]" [61]. In this section of the report were inspectors' comments on "foul odors" and the "source of foul odors." In one reported case of typhoid fever, Bessie Cashman of 47 Bates

Street, Providence, lived in a home where the privy vault was "partly full and very offensive and not properly covered." Sanitary Inspector John S. Rogers, under the authority of Chapin, further noted that there were no traps in the house and that the kitchen sink, where sewer gas leakage could occur, was offensive by smell.

The medical records of physicians additionally indicates the relationship between disease and the home under Chapin. He had doctors fill out five-by-seven-inch cards for every diagnosed case of typhoid fever in Providence from 1895 to 1905. On the front side of the card was the patient's name, age, date of diagnosis, and school or work affiliation. On the back side of the card in 1895 were blanks to be filled out by the sanitary inspector regarding the patient's residence: the condition of the bathrooms, the pipes and drains in the house, traps, plumbing fixtures like toilets, sinks, and bathtubs, and cesspools. Such inquiries illuminate the public health belief that typhoid fever was a problem of the home and of sewer emanations.

However, in 1905, these cards had changed significantly, reflecting an epidemiology that no longer indicted sewer gas for causing disease. By 1905, such cards, rather than noting information concerning household architecture and plumbing, contained detailed information regarding sources of water, ice, milk, seafood, vegetables, and fruit. Fears of sewer gas had subsided by the first decade of the twentieth century as fears of water and food contaminated by bacteria predominated the etiological scene [62].

Chapin epitomizes the radical shift from sewer gas theory to a germ theory framework that could no longer consider sewer gas a serious threat to health. In 1889, in conjunction with his belief in the germ theory of disease, he believed that "there are three ways in which the typhoid organisms can gain access to the body: in the inspired air, in the drink, and in the

food” [63]. Thus, said Chapin, “a case is reported where three young ladies, guests in a large hotel, who slept close by a privy containing typhoid stools, were attacked [with typhoid fever], although their food and drink were above suspicion.”

Ten years later, in 1899, Chapin no longer regarded aerial infection as a significant means by which typhoid fever spread within a population. Instead, he cited drinking water, milk, the house fly, and direct contact with infected persons as being the means by which the disease could be contracted [64]. Specific mention of sewer gas does not occur in either of these alleged etiologies of typhoid fever, although that the 1889 account implies modes of disease transmission consistent with sewer gas (and does not discuss infected persons) and the 1899 account excludes such references (and additionally includes infected persons) is telling of Chapin’s shift in beliefs.

How and why did Chapin change his views on modes of infection between 1889 and 1899? Why did public health records and note cards change in content between 1895 and 1905? Careful observations of epidemiological patterns in Providence caused Chapin’s change of heart. Meticulous record-keeping in the form of Chapin’s index cards, for example, and stronger demands for tighter correlation between agents of disease and disease occurrence allowed for a gradual shift in belief from anticontagionism to contagionism.

Jacobi and Chapin, two medical giants in America, boldly challenged the compromising germs in sewer gas framework from 1888 through the 1890s. This theory, they claimed, did not hold against the evidence for an increased emphasis on infected bodies as opposed to infected spaces. Interestingly, this evidence came not in the form of laboratory experimental results but from close examination of disease occurrence. Jacobi’s observational

position as a clinician and Chapin’s as a public health officer allowed the two men to conclude that disease etiology was not only microbial but also non-aerial. Such beliefs are embodied in bacteriological contagionism and the New Public Health.

### **DEBUNKING SEWER GAS: THE LABORATORY EVIDENCE AND C.-E.A. WINSLOW**

If one development in the late-nineteenth century were to be singled out as the most significant influence on the fall of sewer gas, it would be the rise of the laboratory and microbiology. A shift from the crudely perceivable to the microscopically visible was made possible by laboratory testing and experimentation. No longer did imagination (of germs and their activity) and foul smells (of fecal odors and waste) determine understanding. No longer, even, did a sick-looking or healthy-feeling person determine the wellness of an individual. Instead, determination of wellness and hazards to health lay increasingly in the hands of the bacteriologist in the laboratory. As such, the nature of germs as discovered by experts behind the microscope was brought to the forefront of disease etiology.

In addition to discovering that sewer gas did not contain significant numbers of bacteria, scientists explored the way bacteria traveled from one place or person to another. This could not have been explored without the laboratory. C.-E.A. Winslow, regarded “nationally and internationally as the elder statesman of the public health movement” [65] in his time, conducted remarkable laboratory research that would definitively debunk the sewer gas theory.

Born in 1877 and raised in Boston, Charles-Edward Amory Winslow earned both bachelor and master of science degrees from the Massachusetts Institute of Technology and thereafter, from 1902 to 1910, served on the faculty of M.I.T.,

teaching sanitary biology and serving as head of the Sanitary Laboratory. His research centered chiefly on proper sewage disposal and water purity, relatively new fields at the turn of the century [66]. From early on in his career, then, Winslow utilized the laboratory in order to observe, identify, and isolate foreign particles such as bacteria.

One heated debate that cultivated Winslow's interest in sewer gas was whether bacteria could travel in the air of sewers. At the turn of the century, several scientists performed experiments to show that bursting bubbles and turbulent currents led to the flinging of bacteria in sewerage into the air. Sir Edward Frankland of England and Raphael Pumpelly and A. C. Abbott of the United States, as a result, argued that sewer gas was dangerous [67]. Other experimenters who closely examined the air of sewers arrived at different conclusions. Scientists from Germany, England, and the United States showed that sewer air was similar in composition to atmospheric air, containing no more or less bacteria as well. This discrepancy, then, prompted further investigation which Winslow undertook by request of the National Association of Master Plumbers.

In 1907, Winslow set up fifteen-foot pipes vertically, at the bottom of which lay 1.5 liters of sewage. Air was then drawn by an exhaust fan at the top, creating an air flow of 620 feet per minute. This setup effectively simulated soil-pipe conditions in most homes. Winslow then measured the density of airborne bacteria in the pipe at different heights using laboratory technology. He found exactly eighteen bacteria per liter of air two feet from the bottom, fourteen bacteria per liter seven feet from the bottom, and five bacteria per liter twelve feet from the bottom of the pipe. The normal number of bacteria per liter of air in sewage pipes without air currents was one or two, according to Winslow. Hence, due to the air current, the number

of bacteria in sewer gas had risen from one or two to five at a distance of twelve feet from the bottom of the pipe where the sewage lay.

Such findings indicated the relatively harmless nature of sewer gas. The normal rate of one or two bacteria per liter of sewer air (motionless sewer air, that is) was already virtually sterile in the minds of most scientists. What was debated here, then, was the possibility of millions of bacteria known to exist in the sewage itself flying up into the air of sewers in order to render it contaminated. Winslow created currents of 490 feet per minute, 620 feet per minute, and 790 feet per minute in order to variably test this possibility. He found, however, that "when air was drawn at various rates over the surface of one liter of sewage ... no increase of bacteria could be demonstrated in the air."

The significance of Winslow's experiments and results lay in his interpretation of the facts and use of controls. Prior experience with the purity of tap water in New York taught Winslow that bacteria there were found in numbers twice that of sewer air. And even then, the chance of bacterial infection was quite low. Hence, using quantitative figures, Winslow staunchly held that sewer air was relatively safe, that gases from sewers were better for breathing than water from household sinks for drinking. Winslow wrote,

Sanitation in order to be intelligent must however be quantitative. It should deal, not with theoretical possibilities but with practical probabilities — measured as closely as possible in regard to their quantitative importance. I have shown in my experiments that even under the most extreme conditions the number of bacteria which get into the air from infected liquid is small.... In drinking New York water, twice as many colon bacilli are ingested every day, for 1000 cubic centimeters is a small amount for daily consumption. So there would be less danger of contracting disease from continuously breathing the air of a vent pipe or of a soil pipe, above where liq-

uid is splashing, than from drinking New York water.

That bacteria from liquids did not and could not readily leap into the air was a novel finding in the early-1900s. Quantitative laboratory techniques like that employed by Winslow allowed for such conclusions to be reached. They disproved earlier conclusions that the mere identification of pathogenic microbes in sewage implied that sewer gases were lethal. Intuitive assessments of the existence of bacteria in sewage (without exact knowledge of the numbers of bacteria in the air) — which heightened sewer gas fears—were upended by quantitative experiments that deemed sewer gases more safe to breathe than it was to drink tap water. About sewer gas Winslow also stated, “The modern knowledge of bacteriology will not . . . permit us to accept such a point of view. Typhoid fever, and in most cases diarrhea as well, are caused by minute organisms adapted to a semi-aquatic life, which could by no possible means escape from a broken drain or a moist rubbish heap and fly through the air in pursuit of victims” [68].

Such powerful arguments grounded in laboratory experiments had, by 1910, definitively marked the fall of sewer gas. After 1910 references to it were rare excepting truthful observations that inhaling sewer gases induced dizziness and headaches. In one comprehensive health guide published in 1910 entitled *What May Be Done To Improve the Hygiene of the City Dweller*, the author warned against breathing impure air: “The next equally important matter is how to give to the city dweller the purest air” [69]. Sewer gas was not included in possible sources of impure air, although it would have held a prominent and dependable place just twenty years earlier. Even Waring, a once staunch believer in sewer gas, made no mention of it as a threat in a commencement address at Yale University in 1896

about the proper disposal of sewage. In this speech he further yielded authority on such matters to the bacteriologist: “I am not a bacteriologist, nor have I been able to keep pace even in a general way with the rapid developments of the new science” [70].

Exploration of the nature of sewer gas, as described earlier, reached new standards and expectations in the bacteriological laboratory by the twentieth century. Winslow, using quantitative methods in order to count the number of bacteria in sewer gas, demonstrated the relative harmlessness of sewer gas. What allowed this expert analysis not only to proceed but also to debunk sewer gas as a cause of disease was a changing atmosphere in the medical world. By the 1890s, not only did scientists assume that germs, not gases or odors, caused disease. They also extended the germ theory to authoritatively state that specific disease had specific causes in specific microbes.

Disease specificity, bacteriological contagionism, the strategies and preoccupations of the New Public Health, and laboratory science together constituted a hostile milieu that led to the decline of sewer gas as a cause of disease. In 1876, sewer gas began descending from its status as cause of disease (the sewer gas framework) to vessel for pathogenic bacteria (the germs in sewer gas framework). The dismantling of sewer gas, however, went beyond the recognition that it served as an inert medium for microbes. After 1910, under the influential direction of Jacobi, Chapin, and Winslow, the germs in sewer gas framework had given way to the germ theory framework, whereby sewer gas was no longer relevant to occurrences of disease. Such developments furthermore threatened the legitimacy of sewer gas as a real entity. In sewer gas’s place rose the germ and the understanding that its aggregation in infected persons and milk and water supplies was to be feared. Moreover,

the notion of a ubiquitous airborne poison — otherwise known as “miasmaticism” — disappeared in America for the first time, and in its place traceable, detectable, measurable microbes were feared across the country.

### **CONCLUSION: THE RISE AND FALL OF SEWER GAS, 1870 TO 1910**

The rise and fall of sewer gas in America reveals anxiety — anxiety in a population willing to go to great lengths to preserve its health. Sewer gas’s construction as a real and urgent threat was rooted in anxieties surrounding overcrowding and stagnant waste, which led to the massive building of sewers like those systems in Chicago and in Memphis. Ironically, these very sewers, meant to be bastions of human creativity and technological genius, became themselves bastions of death, housing sewer gases and propagating them through the urban landscape. Both the rich and the poor, the clean and the unclean, were defenseless against sewer gas.

In response, engineers and plumbers like George E. Waring, Jr. devised scores of fixtures, appliances, and building schemes in order to exclude sewer gas from the private home. Traps, valves, toilet designs, and building blueprints were developed according to theoretical models concerning the nature of sewer gas: what it was and how it moved through sewers. From the very first, moreover, there was just as much variety in the practical solutions invented or developed as there were theoretical descriptions of the nature of sewer gas. Throughout the 1870s and 1880s, all the while, sewer gas maintained its grip on the minds of Americans, claiming (according to most authority) the lives of thousands across the country — even the President.

Sewer gas reached its height from 1878 to 1883. It was ubiquitous, finding its way into every American home unless one possessed perfectly-installed valves, soil pipes, traps, and bathroom fixtures. Proper ventilation to dilute sewer gas was further necessary in the event that it penetrated these defenses. In these six years, “sewer gas” or “sewer air” was included in book and journal titles 120 times, or at a steady rate of about once every eighteen days. Advertisers bombarded consumers with hundreds of different plumbing contraptions, claiming that without such devices one could experience sewer gas poisoning and thus die of diphtheria, typhoid fever, diarrhea, scarlet fever, or any of a number of frightening diseases.

The rise of the germ theory in these six years did little to mitigate the gravity with which Americans perceived sewer gas, whose diverse theoretical grounding (considering the lack of agreement concerning its nature and prevention) could be remodeled to fit the framework of germs and disease specificity. From 1878, scientists, plumbers, and manufacturing companies alike warned the public against allowing sewer gas and germs into the home, especially via the bathroom. The bathroom was still a new room in the American home in the late-nineteenth century, just as extensive sewer systems were new developments in the mid-nineteenth century. Their susceptibility to contamination and filth was well-known, making their upkeep vital in order to prevent disease in the home. Whether sewer gas provided an environment in which bacteria could thrive, or was pathogenic in and of itself, the message was clear, intuitive, and challenging: keep both sewer gas and germs out of the bathroom if you want to prevent your family from succumbing to contagious diseases. Construct sound toilets, bathtubs, and sinks and remove those filthy carpets if you want to keep disease out. This was the prevailing orthodoxy

during the heyday of sewer gas, from 1878 to 1883. Remnants of such feelings persisted, to be sure, into the 1890s.

The pervasiveness of the germ theory, accompanied by the preeminence of bacteriology, laboratory science, and the New Public Health, provided an environment beginning in the 1880s in which the nature of sewer gas and of bacterial growth and movement was explored by scientists. No longer did the crudely visible and the inferred suffice in order to establish disease etiology. Instead, chemical and biological analysis that made visible what could not have been seen before helped scientists to understand disease etiology on a microscopic level. These new, higher standards of disease causation made sewer gas theory untenable by the early years of the twentieth century. Sewer air was similar to atmospheric air, and Winslow demonstrated in 1907 that bacteria did not leap up from the medium of liquid to the medium of air. In sewer gas's place, equally feared by Americans, were lethal germs swarming in human bodies and in food, water, and milk.

By 1910, the germ theory framework better fit existing notions of disease etiology: that disease was caused by microbes unable to fly through the air and most dangerous when clustered in infected individuals. Sewer gas was eventually undone by germ theory; one can see the physical evidence, for example, as early as 1887 in the development of free-standing, open structures in the bathroom which had nothing to do with sewer gas fears. The conversion was made complete by Winslow's experiments in 1907. In the years after his demonstrations, the idea that sewer gas as either a direct cause of disease or agent by which microbes flew through the air quickly declined. Quite naturally, germs, already pervasive in American culture, took their place as a cause of disease. The germ theory, disease specificity, and laboratory science made relatively quick work of a once-

fearsome enemy, relegating deadly sewer gas to the realm of myth, superstition, and the dim recesses of history.

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