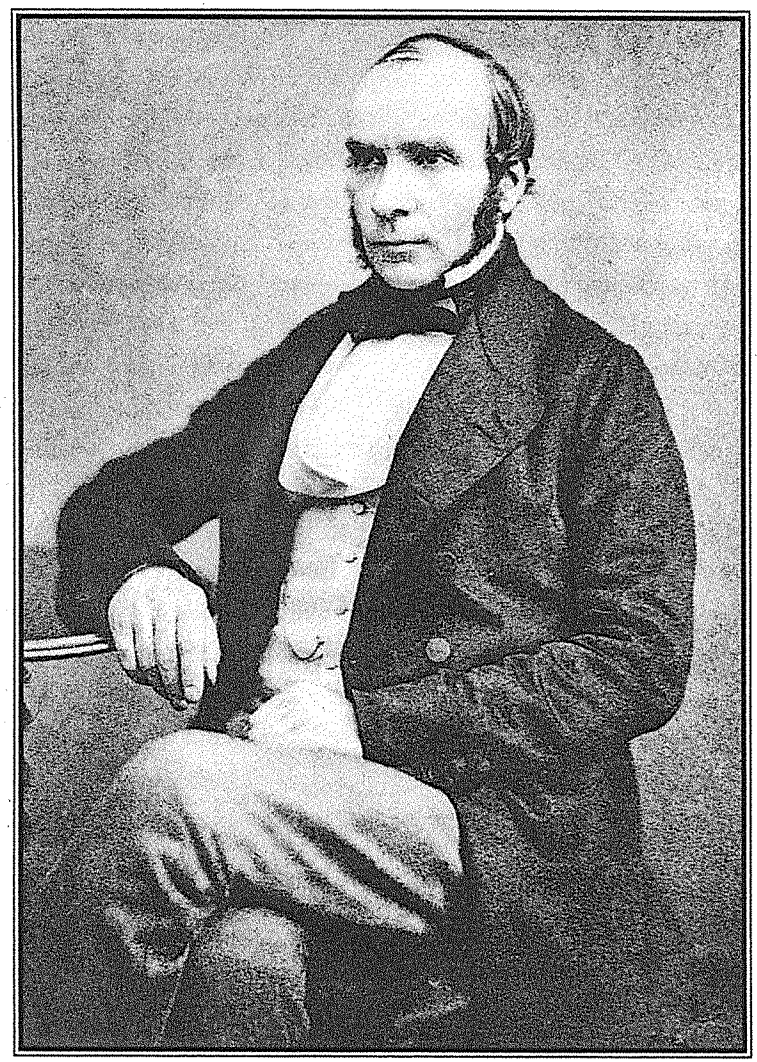


JOHN SNOW

Sunday, September 3

THE INVESTIGATOR

BY SUNDAY MORNING, A STRANGE QUIET HAD OVERTAKEN

SNOW'S MASTERY OF ETHER AND CHLOROFORM RAISED HIM to a new echelon in the London medical world. He became the most sought-after anesthesiologist in the city, assisting with hundreds of operations a year. By the 1850s, a growing number of doctors were recommending chloroform as a palliative for the discomfort of childbirth. As the birth of her eighth child approached in the spring of 1853, Queen Victoria decided to give chloroform a try, encouraged by the scientifically astute Prince Albert. Her choice of an anesthesiologist was an obvious one. Snow gave the episode a few more words than usual in his casebooks, though his tone did not betray the magnitude of the professional honor that had been bestowed upon him:

> Thursday 7 April: Administered Chloroform to the Queen in her confinement. Slight pains had been experienced since Sunday. Dr. Locock was sent for about nine o'clock this morning, stronger pains having commenced, and he found the os uteri had commenced to dilate a very little. I received a note from Sir James Clark a little after ten asking me to go to the Palace. I remained in an apartment near that of the Queen, along with Sir J. Clark, Dr. Ferguson and (for the most part of the time) Dr. Locock till a little a [*sic*] twelve. At a twenty minutes past twelve by a clock in the Queen's apartment I commenced to give a little chloroform with each pain, by pouring about 15 minims [0.9 ml] by measure on a folded handkerchief. The first stage of labour was nearly over when the chloroform was commenced. Her Majesty expressed great relief from the application, the pains being very trifling during the uterine contractions, and whilst between the periods of contraction there was complete ease. The effect of the chloroform was not at any time carried to the extent of quite removing consciousness. Dr. Locock thought that the chloroform prolonged the intervals between the pains, and retarded the labour somewhat. The infant was born at 13 minutes past one by the clock in the room (which was 3 minutes before the right time); consequently the chloroform was inhaled for 53 minutes. The placenta was expelled in a very few minutes, and the Queen appeared very cheerful and well, expressing herself much gratified with the effect of the chloroform.

Snow's research into anesthesia had elevated him from a surgeon of humble origins to the very apogee of Victorian London. But, in a way, the most impressive thing about his research was not the levels of social class that he traversed but rather the intellectual strata, the different scales of experience that his mind crossed so effortlessly. Snow was a truly *consilient* thinker, in the sense of the term as it was originally formulated by the Cambridge philosopher William Whewell in the 1840s (and recently popularized by the Harvard biologist E. O. Wilson). "The Consilience of Inductions," Whewell wrote, "takes place when an Induction, obtained from one class of facts, coincides with an Induction obtained from another different class. Thus Consilience is a test of the truth of the Theory in which it occurs." Snow's work was constantly building bridges between different disciplines, some of which barely existed as functional sciences in his day, using data on one scale of investigation to make predictions about behavior on other scales. In studying ether and chloroform, he had moved from the molecular properties of the gas itself, to its interactions with the cells of the lungs and the bloodstream, to the circulation of those properties through the body's overall system, to the psychological effects produced by these biological changes. He

even ventured beyond the natural world into the design of technology that would best reflect our understanding of the anesthetics. Snow was not interested in individual, isolated phenomena; he was interested in chains and networks, in the movement from scale to scale. His mind tripped happily from molecules to cells to brains to machines, and it was precisely that consilient study that helped Snow uncover so much about this nascent field in such a shockingly short amount of time.

And yet, there was a ceiling to his intellectual pursuit of ether and chloroform: his research stopped at the scale of the individual subject. The next step up the chain—the larger, connected world of cities and societies, of groups, not individuals—did not factor into his anesthesia investigations. He might have attended on the queen's body, but the body politic remained outside Snow's frame of reference.

Cholera would change all that.

WE DON'T KNOW EXACTLY WHAT SEQUENCE OF EVENTS turned John Snow's interest toward cholera in the late 1840s. For this working physician and researcher, of course, the disease would have been a constant presence in his life. There may in fact have been a direct link to his practice as an anesthesiologist, since chloroform had been (wrongly) championed as a potential cure for cholera by some early adopters who were less rigorous in their empiricism than Snow. Certainly, the outbreak of 1848–1849, the most severe British outbreak in more than a decade, made cholera one of the most urgent medical riddles of its time. For a man like Snow, obsessed with both the practice of medicine and the intellectual challenge of science, cholera would have been the ultimate quarry.

There were practically as many theories about cholera as there

were cases of the disease. But in 1848, the dispute was largely divided between two camps: the contagionists and the miasmatists. Either cholera was some kind of agent that passed from person to person, like the flu, or it somehow lingered in the "miasma" of unsanitary spaces. The contagion theory had attracted some followers when the disease first reached British soil in the early 1830s. "We can only suppose the existence of a poison which progresses independently of the wind, of the soil, of all conditions of the air, and of the barrier of the sea," *The Lancet* editorialized in 1831. "In short, one that makes mankind the chief agent for its dissemination." But most physicians and scientists believed that cholera was disease spread via poisoned atmosphere, not personal contact. One survey of published statements from U.S. physicians during the period found that less than five percent believed the disease was primarily contagious.

By the late 1840s the miasma theory had established a far more prestigious following: the sanitation commissioner, Edwin Chadwick; the city's main demographer, William Farr; along with many other public officials and members of Parliament. Folklore and superstition were also on the side of the miasmatists: the foul inner-city air was widely believed to be the source of most disease. While no clear orthodoxy existed regarding the question of cholera's transmission, the miasma theory had far more adherents than any other explanatory model. Remarkably, in all the discussion of cholera that had percolated through the popular and scientific press since the disease had arrived on British soil in 1832, almost no one suggested that the disease might be transmitted by means of contaminated water. Even the contagionists—who embraced the idea that the disease was transmitted from person to person—failed to see merit in the waterborne scenario.

Snow built his argument for the waterborne theory around two primary studies, both of which showcased talents that would prove to be crucial five years later, during the Broad Street outbreak. In late July of 1849, an outbreak of cholera killed about twelve people living in slum conditions on Thomas Street in Horsleydown. Snow made an exhaustive inspection of the site and found ample evidence to support his developing theory. All twelve lived in a row of connected cottages called the Surrey building, which shared a single well in the courtyard they faced. A drainage channel for dirty water ran alongside the front of the houses, connecting to an open sewer at the end of the courtyard. Several large cracks in the drain allowed water to flow directly into the well, and during summer storms, the entire courtyard would flood with fetid water. And so a single case of cholera would quickly spread through the entire Surrey building population.

The layout of the Thomas Street flats provided Snow with an ingenious control study for his inquiry. The Surrey building backed onto a set of houses that faced another courtyard known as Truscott's Court. These abodes were every bit as squalid as the Surrey building, with the exact same demographic makeup of poor working families living within them. For all intents and purposes, they shared the same environment, save one crucial difference: they got their water from different sources. During the two-week period that saw the deaths of a dozen residents in the Surrey building, only one person

perished in Truscott's Court, despite the fact that both groups lived within yards of each other. If the miasma were responsible for the outbreak, why would one squalid, impoverished group suffer ten times the loss of the one living next door?

The Thomas Street outbreak showcased Snow's on-the-ground investigative skills, his eye for the details of transmission patterns, sanitary habits, even architecture. But Snow also surveyed the outbreak from the bird's-eye view of citywide statistics. During his research, Snow had amassed an archive of information about the various companies that supplied water to the city, and that study had revealed a striking fact: that Londoners living south of the Thames were far more likely to drink water that had originated in the river as it passed through Central London. Londoners living north of the river drank from a variety of sources: some companies piped in water from the Thames above Hammersmith, far from the urban core; some drew from the New River in Hertfordshire to the north; others from the River Lea. But the South London Water Works drew its supply from the very stretch of the river where most of the city's sewers emptied. Anything that was multiplying in the city's intestinal tracts would be more likely to find its way into the drinking water of South London. If Snow's theory of cholera was on the mark, Londoners living below the Thames should have been significantly more prone to the disease than those living above.

Snow next surveyed the tables of cholera death that had been compiled by William Farr, London's registrar-general. What he found there followed the pattern that the water-supply routes predicted: of the 7,466 deaths in the metropolitan area during the 1848–1849 epidemic, 4,001 were located south of the Thames. That meant that the per capita casualty rate was near eight per thousand—three times that of the central city. In the growing suburbs of West and North

London, the death rate was just above one per thousand. For the miasmatists, who were inclined to blame those death rates on the foul air of the working-class neighborhoods south of the river, Snow could point to the neighborhoods of the East End, which were probably the most destitute and overcrowded of any in the city. And yet their death rate was exactly half that of the area south of the Thames.

Whether you looked at the evidence on the scale of an urban courtyard or on the scale of entire city neighborhoods, the same pattern repeated itself: the cholera seemed to segment itself around shared water supplies. If the miasma theory were right, why would it draw such arbitrary distinctions? Why would the cholera devastate one building but leave the one next door unscathed? Why would one slum suffer twice the losses as a slum with arguably worse sanitary conditions?

Snow introduced his theory of cholera in two forms during the second half of 1849: first as a self-published thirty-one-page monograph, *On the Mode and Communication of Cholera,* intended for his immediate peers in the medical community, and then as an article in the *London Medical Gazette,* targeted at a slightly wider audience. Shortly after the publication, a country doctor named William Budd published an essay that came to similar conclusions about cholera's waterborne transmission, though Budd left open the possibility that some cases of cholera might be transmitted through the atmosphere, and he claimed, erroneously, to have identified the cholera agent in the form of a fungus growing in contaminated water supplies. Budd would later make an observation regarding the waterborne transmission of typhoid, for which he is now best known. But Snow's cholera theory had beaten Budd's to the presses by a month, and it did not include the false lead of fungal agents or of atmospheric transmission.

The reaction to Snow's argument was positive but skeptical. "Dr. Snow deserves the thanks of the profession for endeavouring to solve the mystery of the communication of cholera," a reviewer wrote in the *London Medical Gazette.* But Snow's case studies had not convinced: "[They] furnish no proof whatever of the correctness of his views." He had convincingly demonstrated that the South London neighborhoods were more at risk for cholera than the rest of the city, but it did not necessarily follow that the water in those neighborhoods was responsible for the disparity. Perhaps there was special toxicity to the air in those zones of the city that was absent in the slums to the north. Perhaps cholera was contagious, and thus the cluster of cases in South London simply reflected the chain of infection thus far; if the initial cases had unfolded differently, perhaps the East End would have been attacked more grievously, and South London left relatively unscathed. There was a correlation between water supply and cholera—that much Snow had convincingly proved. But he had not yet established a cause.

The *Gazette* did suggest one scenario that might settle the matter convincingly:

> The *experimentum crucis* would be, that the water conveyed to a distant locality, where cholera had been hitherto unknown, produced the disease in all who used it, while those who did not use it, escaped.

That passing suggestion stayed with Snow for five long years. As his anesthesia practice expanded, and his prominence grew, he continued to follow the details of each cholera outbreak, looking for a scenario that might help prove his theory. He probed, and studied, and waited. When word arrived of a terrible outbreak in Golden Square, not ten blocks from his new offices on Sackville Street, he was ready.

So the macro-growth of the urban superorganism and the microscopic subtleties of the bacterium are both essential to the events of September 1854. In some cases, the chains of cause and effect are obvious ones. Without the population densities and the global connectivity of industrialization, cholera might not have been as devastating in England, and thus might not have attracted Snow's investigative skills in the first place. But in other places, the causal chains are more subtle, though no less important to the story. The bird's-eye view of the city, the sense of the urban universe as a system, as a mass phenomenon—this *imaginative* breakthrough is as crucial to the eventual outcome of the Broad Street epidemic as any other factor. To solve the riddle of cholera you had to zoom out, look for broader patterns in the disease's itinerary through the city. When health matters are at stake, we now call this wide view epidemiology, and we have entire university departments devoted to it. But for the Victorians, the perspective was an elusive one; it was a way of thinking about patterns of social behavior that they had trouble intuitively grasping. The London Epidemiological Society had been formed only four years before, with Snow as a founding member. The basic technique of population statistics—measuring the incidence of a given phenomenon (disease, crime, poverty) as a percentage of overall population size—had entered the mainstream of scientific and medical thought only in the previous two decades. Epidemiology as a science was still in its infancy, and many of its basic principles had yet to be established.

At the same time, the scientific method rarely intersected with the development and testing of new treatments and medicines. When you read through that endless stream of quack cholera cures published in the daily papers, what strikes you most is not that they are all, almost without exception, based on anecdotal evidence. What's

striking is that they never apologize for this shortcoming. They never pause to say, "Of course, this is all based on anecdotal evidence, but hear me out." There's no *shame* in these letters, no awareness of the imperfection of the method, precisely because it seemed eminently reasonable that local observation of a handful of cases might serve up the cure for cholera, if you looked hard enough.

But cholera couldn't be studied in isolation. It was as much a product of the urban explosion as the newspapers and coffeehouses where it was so uselessly anatomized. To understand the beast, you needed to think on the scale of the city, from the bird's-eye view. You needed to look at the problem from the perspective of Henry Mayhew's balloon. And you needed a way to persuade others to join you there.

THAT WIDER PERSPECTIVE IS WHAT JOHN SNOW FOUND himself searching for by noon on Monday. He had reexamined his samples from the Soho wells in the light of day and found nothing suspicious in the Broad Street water. As he delivered chloroform to a patient of a nearby dentist who was performing a tooth extraction, he pondered the outbreak still raging a few blocks away. The more he thought about it, the more convinced he became that the water supply must have been contaminated somehow. But how to prove it? The water alone might not be sufficient, since he didn't even know what he was looking for. He had a theory about cholera's routes of transmission and its effects on the body. But he had no idea what the agent that caused cholera was exactly, much less how to identify it.

Ironically, just a few days before Snow had unsuccessfully attempted to see any telltale signs of cholera in the water, an Italian scientist at the University of Florence had discovered a small,

comma-shaped organism in the intestinal mucosa of a cholera victim. It was the first recorded sighting of *Vibrio cholerae,* and Filippo Pacini published a paper that year describing his findings, under the title "Microscopical Observations and Pathological Deductions on Cholera." But it was the wrong time for such a discovery: the germ theory of disease had not yet entered mainstream scientific thought, and cholera itself was largely assumed by the miasmatists to be some kind of atmospheric pollution, not a living creature. Pacini's paper was ignored, and *V. cholerae* retreated back into the invisible kingdom of microbes for another thirty years. John Snow would go to his grave never learning that the cholera agent he had spent so many years pursuing had been identified during his lifetime.

The fact that Snow had no idea what cholera looked like under the microscope didn't stop him from doing further tests on the water. After his appointment with the dentist, he returned to draw more samples from the Broad Street pump. This time he saw small white particles in the water. Back in his lab, he ran a quick chemistry experiment, which reported an unusually high presence of chlorides. Encouraged, he took the sample to a colleague, Dr. Arthur Hassall, whose skill with the microscope Snow had long admired. Hassall reported that the particles had no "organized structure," which led him to believe they were the remnants of decomposed organic matter. He also saw a host of oval-shaped life-forms—Hassall called them "animalculae"—presumably feeding on the organic substances.

So the Broad Street water was not as pure as he had originally thought. But still, there was nothing in Hassall's analysis that pointed definitively to the presence of cholera. If he was going to crack this case, the solution wouldn't be found under the microscope, on the scale of particles and animalculae. He needed to approach the problem from the bird's-eye view, on the scale of neighborhoods. He

would try to find the killer through an indirect route: by looking at patterns of lives and deaths on the streets of Golden Square.

The scientific establishment was equally anchored in the miasma theory. In September 1849, the *Times* ran a series of articles that surveyed the existing theories about cholera: "How is the cholera generated?—how spread? what is its modus operandi on the human frame? These questions are in every mouth," the paper observed, before taking a decidedly pessimistic stance on the question of whether they would ever be answered:

> These problems are, and will probably ever remain, among the inscrutable secrets of nature. They belong to a class of questions radically inaccessible to the human intelligence. What the forces are which generate phenomena we cannot tell. We know as little of the vital force itself as of the poison-forces which have the power to disturb or suppress it.

Despite this bleak forecast, the *Times* went on to survey the prevailing theories: a "telluric theory that supposes the poison to be an emanation from the earth"; an "electric theory" based on atmopheric conditions; the ozonic theory that attributed outbreaks to a deficiency of ozone in the air; a theory that blamed cholera on "putrescent yeast, emanations of sewers, graveyards, etc." The paper also mentioned a theory that maintained that the disease was spread by microscopic animalcules or fungi, though it downplayed its viability, claiming that the theory "failed to include all the observed phenomena."

The diversity of views is striking here—ozone, sewer emanations, electricity—but just as striking is the underlying commonality: all but one of the theories assume that the cholera is somehow being transmitted through the atmosphere. (Snow's waterborne theory, already a matter of public record, goes completely unmentioned.) The air was the key to the riddle of cholera, and indeed to most known diseases. Nowhere is the philosophy more pronounced than in the writings of the Victorian age's most beloved and influential medical figure, Florence Nightingale. Consider this passage from the beginning of her groundbreaking 1857 work *Notes on Nursing*:

> The very first canon of nursing, the first and the last thing upon which a nurse's attention must be fixed, the first essential to a patient, without which all the rest you can do for him is as nothing, with which I had almost said you may leave all the rest alone, is this: TO KEEP THE AIR HE BREATHES AS PURE AS THE EXTERNAL AIR, WITHOUT CHILLING HIM. Yet what is so little attended to? Even where it is thought of at all, the most extraordinary misconceptions reign about it. Even in admitting air into the patient's room or ward, few people ever think, where that air comes from. It may come from a corridor into which other wards are ventilated, from a hall, always unaired, always full of the fumes of gas, dinner, of various kinds of mustiness; from an underground kitchen, sink, washhouse, water-closet, or even, as I myself have had

sorrowful experience, from open sewers loaded with filth; and with this the patient's room or ward is aired, as it is called—poisoned, it should rather be said.

With Nightingale, the problem is one of emphasis; there's obviously nothing wrong with ensuring that hospital rooms have fresh air in them. The problem arises when supplying clean air becomes the single most important task for the doctor or nurse, when the air is assumed to be a "poison" that has caused the patient's illness in the first place. Nightingale believed that cholera, smallpox, measles, and scarlet fever were all miasmatic in nature, and she recommended that schools, homes, and hospitals use a certain "air test," devised by the chemist Angus Smith, that detected organic materials in the air:

> If the tell-tale air test were to exhibit in the morning, both to nurses and patients, and to the superior officer going round, what the atmosphere has been during the night, I question if any greater security could be afforded against a recurrence of the misdemeanor.
>
> And oh, the crowded national school! where so many children's epidemics have their origin, what a tale its air-test would tell! We should have parents saying, and saying rightly, "I will not send my child to that school, the air-test stands at 'Horrid.'" And the dormitories of our great boarding schools! Scarlet fever would be no more ascribed to contagion, but to its right cause, the air-test standing at "Foul."
>
> We should hear no longer of "Mysterious Dispensations," and of "Plague and Pestilence," being "in God's hands," when, so far as we know, He has put them into our own. The little air-test would both betray the cause of these "mysterious pestilences," and call upon us to remedy it.

So often what is lacking in many of these explanations and prescriptions is some measure of humility, some sense that the theory being put forward is still unproven. It's not just that the authorities of the day were wrong about miasma; it's the tenacious, unquestioning way they went about being wrong. An investigator looking for holes in the theory could find them everywhere, even in the writings of the miasmatists themselves. The canary in the miasma coal mine should have been the sewer-hunters, who spent their waking hours exposed to the most noxious—sometimes even explosive—air imaginable. And yet, bizarrely, the canary seemed to be doing just fine, and Mayhew admits as much in one slightly puzzled passage in *London Labour and the London Poor*:

> It might be supposed that the sewer-hunters (passing much of their time in the midst of the noisome vapours generated by the sewers, the odour of which, escaping upwards from the gratings in the streets, is dreaded and shunned by all as something pestilential) would exhibit in their pallid faces the unmistakable evidence of their unhealthy employment. But this is far from the fact. Strange to say, the sewer-hunters are strong, robust, and healthy men, generally florid in their complexion, while many of them know illness only by name. Some of the elder men, who head the gangs when exploring the sewers, are between 60 and 80 years of age, and have followed the employment during their whole lives.

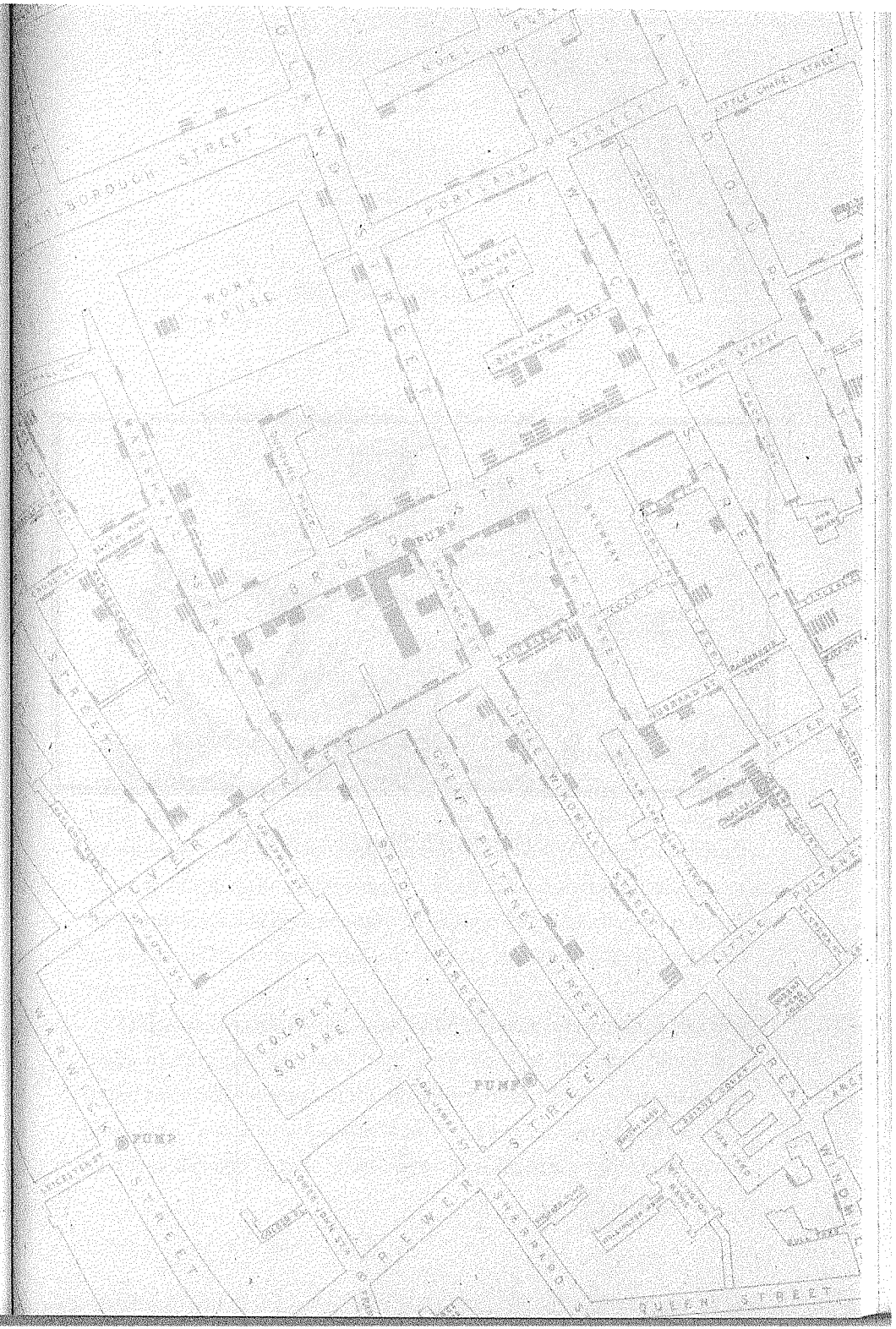
As Snow observed many times in his writings during the period, there were countless cases of groups sharing the exact same living environment, breathing the exact same air, who seemed to have entirely opposing responses to the allegedly poisonous vapors. If the

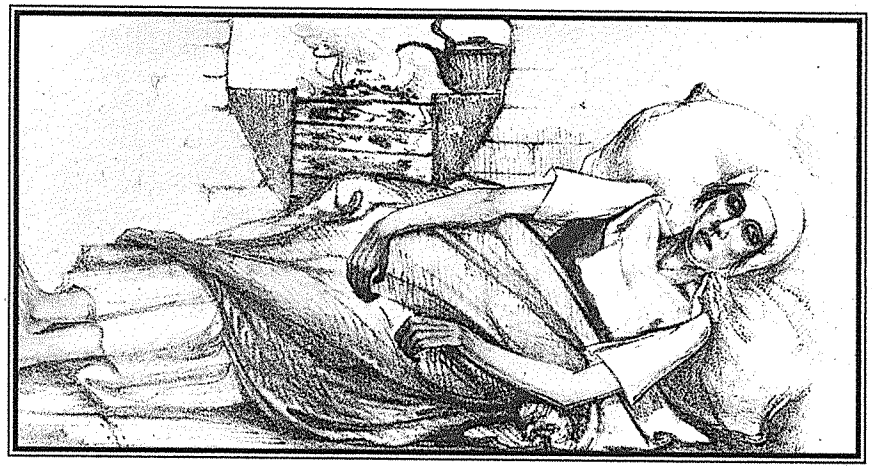
miasma was truly killing off Londoners, it seemed to choose its victims in an entirely arbitrary fashion. And despite the fact that Chadwick and his commissions had made immense progress in eliminating the city's population of cesspools, the cholera had nonetheless come roaring back to devastate the city in 1853.

JOHN SNOW SPENT MOST OF TUESDAY SEARCHING FOR patterns. In the morning he was knocking on doors, interrogating strangers in the street, asking anyone he encountered for anecdotal

evidence about the outbreak and its victims. The clues he found were tantalizing, but too many doors went unanswered, and the dead couldn't report on their recent drinking habits. Personal testimony would not take him far in an evacuation zone. And so at midday he paid a visit to the Registrar-General's Office, where Farr gave him an early look at the numbers being calculated for the week. Eighty-three deaths had been reported in Soho between Thursday and Saturday. Snow asked for a complete list, including addresses, and returned to Broad Street to continue his sleuthing. He stood at the base of the pump, and ran through the addresses on the list. From time to time, he gazed out at the empty streets around him, imagining the paths the residents might take to find their way to water.

It was going to take more than body counts to prove that the pump was the culprit behind the Broad Street epidemic. Snow was going to need footprints, too.





"BLUE STAGE OF THE SPASMODIC CHOLERA"

Wednesday, September 6

BUILDING THE CASE

A HUNDRED YARDS WEST OF THE BROAD STREET PUMP, IN the dark alley of Cross Street, a tailor lived in a single room at number 10, sharing the space with his five children, two of whom were fully grown. On warm summer nights the heat in their cramped living space could be unbearable, and the father would often wake after midnight and send one of the boys out to fetch some cool well water to combat the sweltering air. They lived only two blocks from the pump at Little Marlborough Street, but that water had such an offensive smell that they regularly walked the extra block to Broad Street.

The tailor and his twelve-year-old boy had been struck in the first hours of the outbreak, and both were dead by Saturday. Snow had found their address listed in the inventory of deaths that Farr had supplied him. Several other deaths were recorded on Cross Street as well. The location had caught Snow's eye when he first arrived back at the

pump to survey the surrounding streets, armed with the addresses of the dead. Almost half the deaths Farr had recorded were linked to addresses within his line of sight; and half the remaining ones came from residences that were only a matter of steps from Broad Street itself. The Cross Street deaths were unusual, though: to make it to the Broad Street pump from there, you had to wind your way through two small side streets, then take a right onto Marshall Street, then another left, and then walk a long block down Broad Street. To get to the Little Marlborough pump, though, you simply strolled down the alley, walked two short blocks north, and you were there. It was within your line of sight if you stood at the very end of Cross Street.

Snow had noticed another element while scanning Farr's records: the deaths on Cross Street were much less evenly distributed than the ones in the immediate vicinity of the pump. Almost every house along Broad Street had suffered a loss, but there were only a handful of isolated cases on Cross Street. This is what Snow was looking for now. He could see at a glance that he'd be able to demonstrate that the outbreak was clustered around the pump, yet he knew from experience that that kind of evidence, on its own, would not satisfy a miasmatist. The cluster could just as easily reflect some pocket of poisoned air that had settled over that part of Soho, something emanating from the gulley holes or cesspools—or perhaps even from the pump itself. Snow knew that the case would be made in the exceptions to the rule. What he needed now were aberrations, deviations from the norm. Pockets of life where you would expect death, pockets of death where you would expect life. Cross Street was closer to Little Marlborough, and thus should have been spared in the outbreak, according to Snow's theory. And indeed, it had largely been spared, but for the four cases Farr had reported. Could those cases have some connection to Broad Street?

Sadly, by the time Snow arrived at 10 Cross to interview the tailor's surviving children, he was too late. He learned from a neighbor that the entire family—five children and their father—had died in the space of four days. Their late-night thirst for Broad Street water had destroyed them all.

IN HIS MIND SNOW WAS ALREADY DRAWING MAPS. HE'D imagined an overview of the Golden Square neighborhood, with a boundary line running an erratic circle around the Broad Street pump. Every person inside that border lived closer to the poisoned well; everyone outside would have had reason to draw water from a different source. Snow's survey of the neighborhood, based on Farr's initial data, revealed ten deaths that lay outside the boundary line. Two of them were the tailor and his son on Cross Street. After a few hours of conversation, Snow determined that three others were children who went to school near Broad Street; their grieving parents reported that the children had often drunk from the pump on their way to and from school. Relatives confirmed that three other casualties had maintained a regular habit of drawing water from Broad Street, despite living closer to another source. That left two remaining deaths outside the border with no connection to Broad Street, but Snow knew that two cholera deaths over a weekend was well within the average for a London neighborhood at that time. They might easily have contracted the disease from a different source altogether.

Snow knew that his case would also revolve around the inverse situation: residents who lived near the pump who survived, because, for one reason or another, they had opted not to drink from the poisoned well. He reviewed Farr's list again, looking this time for

telltale absences. There were a handful of deaths reported at 50 Poland Street. On its own, this was a predictable number: Poland Street lay immediately to the north of the pump, well within Snow's imagined border. But in scanning the list, Snow realized that the number was strikingly low, because 50 Poland Street was the address of the St. James Workhouse, home to 535 people. Two deaths was routine for a household of ten living off of Broad Street. A population of five hundred living close to the pump should have seen dozens of death. As Whitehead had already learned from his daily rounds, the workhouse—despite its destitute and morally suspect inmates—had been something of a sanctuary from the outbreak. When Snow interrogated the workhouse directors, an explanation immediately jumped out at him: the workhouse had a private supply from the Grand Junction Water Works, which Snow knew from his earlier research to be one of the more reliable sources of piped water. The workhouse also had its own well on the premises. They had no reason to venture out to the Broad Street pump for water, even though it lay not fifty yards from their front door.

Snow noticed another telling absence on Farr's list. With seventy workers, the Lion Brewery at 50 Broad was the second-largest employer in the immediate vicinity. Yet not a single death was recorded for that address in Farr's list. It was possible, of course, that the workers had gone home to die, and so Snow paid a visit to the Lion's proprietors, Edward and John Huggins, who reported with some bafflement that the plague had passed over their establishment. Two workers had reported mild cases of diarrhea, but not a single one had shown severe symptoms. When Snow inquired about the water supply on the premises, the Hugginses replied that, like the workhouse, the brewery had both a private pipeline and a well. But, they explained

for the benefit of the teetotaling doctor, they rarely saw their men drink water at all. Their daily rations of malt liquor usually satisfied their thirst.

Later, Snow would visit the Eley Brothers factory, where he found the situation much more dire. The proprietors reported that dozens of their employees had fallen ill, many of them dying in their own homes over the first few days of the epidemic. When Snow noticed the two large tubs of water that the brothers kept on premises for their employees to drink from, he scarcely needed to ask where the water had originated.

Snow had heard through the grapevine that the Eley brothers' mother and their cousin had recently perished of cholera as well, both of them far removed from Golden Square. The coincidence must have immediately struck Snow; perhaps he even thought back to the *experimentum crucis* gauntlet thrown down by the *London Medical Gazette* so many years before. No doubt, considering Snow's discretion, he posed the question delicately: Had Susannah Eley by any chance consumed some of the water from the Broad Street pump? It must have been an anguished moment for Snow: how to extract the information he needed without revealing that the brothers' thoughtfulness had been the agent of their mother's demise. Snow's taciturn demeanor would have helped him as the brothers described their regular deliveries of pump water to Hampstead; a more volatile investigator might have responded to the revelation of that crucial clue with more emotion. But whatever emotion he showed the Eley brothers, when he stepped out of the factory into the bright light of Broad Street, he must have thought to himself with some satisfaction that the case was coming together quite nicely indeed. The miasmatists might finally have met their match.

Snow's observational talents extended beyond the human body. The sad irony of his argument for the waterborne theory of cholera is that he had all the primary medical explanations in place by the winter of 1848–1849, and yet they fell on deaf ears for almost a decade. The tide eventually turned not because of his skills as a doctor or scientist. It wasn't lab research that would ultimately persuade the authorities; it wasn't direct observation of *V. cholerae* itself. It was Snow's faithful, probing observation of urban life and its everyday patterns: the malt-liquor drinkers at the Lion Brewery; the late-night

trips for cold water on hot summer nights; the tangled web of private water supplies in South London. Snow's breakthroughs in anesthesia had revolved around his polymath skills as a physician, researcher, and inventor. But his cholera theory would ultimately depend on his skills as a sociologist.

Equally important was the social connection Snow had to the subjects he observed. It is not an accident that of the dozens and dozens of cholera outbreaks that he analyzed in his career, the one for which he is most famous erupted six blocks from his residence. Like Henry Whitehead, Snow brought genuine local knowledge to the Broad Street case. When Benjamin Hall and his public-health committee made their triumphant appearance on the streets of Soho, they were little more than tourists, goggling at all the despair and death, and then retreating back to the safety of Westminster or Kensington. But Snow was a true native. That gave him both an awareness of how the neighborhood actually worked, and it gave him a credibility with the residents, on whose intimate knowledge of the outbreak Snow's inquiry depended.

Snow shared more than geography with the working poor of Golden Square, of course. While he had long since elevated himself in social status, his roots as the son of a rural laborer colored his perception of the world throughout his life—primarily in the sense of blocking out certain dominant ideas. Nowhere in Snow's writings on disease does one ever encounter the idea of a moral component to illness. Equally absent is the premise that the poor are somehow more vulnerable to disease thanks to some defect in their inner constitution. Ever since he observed the Killingsworth mining outbreak as a young apprentice, Snow had long known that epidemics tended to afflict the lower orders of society. For whatever reason—probably some mix of rational observation and his own social awareness—that

disparity led Snow to seek external causes, not internal ones. The poor were dying in disproportionate numbers not because they suffered from moral failings. They were dying because they were being poisoned.

Snow's resistance to the miasma theory was methodological as well. The strength of his model derived from its ability to use observed phenomena on one scale to make predictions about behavior on other scales up and down the chain. Observed failure of certain organ systems of the body could predict behavior of the whole person, which could in turn predict behavior in the social body en masse. If the symptoms of the cholera concentrated around the small intestine, then there must be some telltale characteristic in the eating and drinking habits of cholera victims. If cholera was waterborne, then the patterns of infection must correlate with the patterns of water distribution in London's neighborhoods. Snow's theory was like a ladder; each individual rung was impressive enough, but the power of it lay in ascending from bottom to top, from the membrane of the small intestine all the way up to the city itself.

And so Snow's immunity to the miasma theory was as overdetermined as the theory itself. Partly it was an accident of professional interest; partly it was a reflection of his social consciousness; partly it was his consilient, polymath way of making sense of the world. He was brilliant, no doubt, but one needed only to look to William Farr to see how easily brilliant minds could be drawn into error by orthodoxy and prejudice. Like all those ill-fated souls dying on Broad Street, Snow's insight lay at the intersection point of a series of social and historical vectors. However brilliant Snow was, he would never have proved his theory—and might well have failed to concoct it in the first place—without the population densities of industrial London, or Farr's numerical rigor, or his own working-class up-

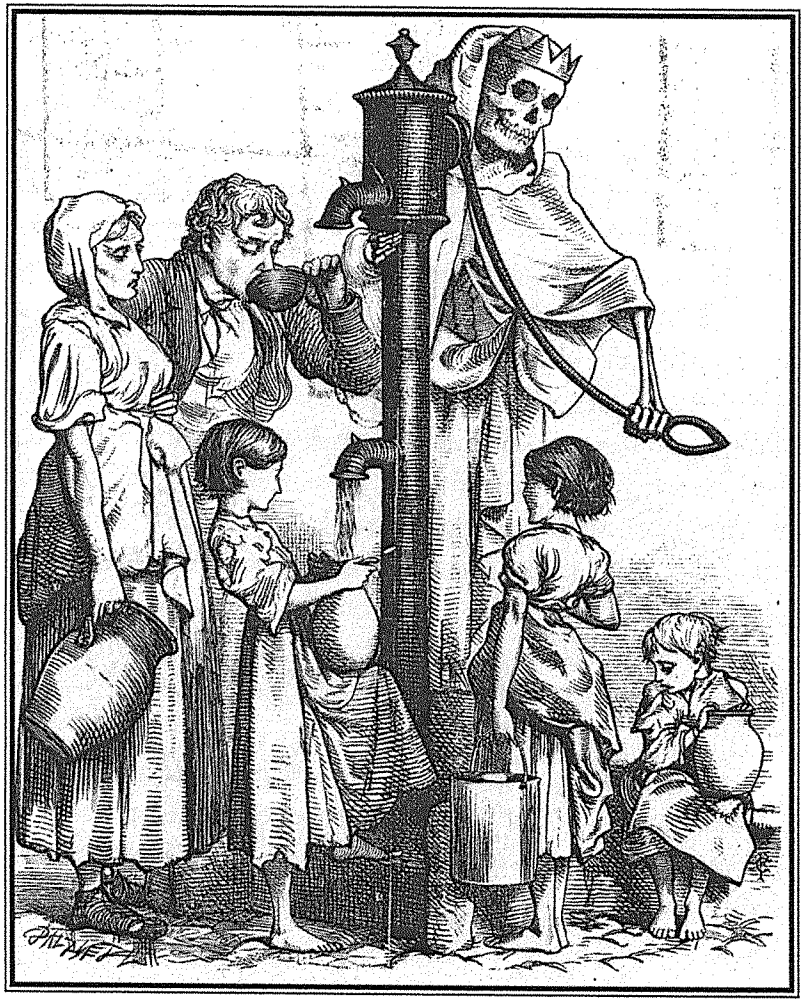
bringing. This is how great intellectual breakthroughs usually happen in practice. It is rarely the isolated genius having a eureka moment alone in the lab. Nor is it merely a question of building on precedent, of standing on the shoulders of giants, in Newton's famous phrase. Great breakthroughs are closer to what happens in a flood plain: a dozen separate tributaries converge, and the rising waters lift the genius high enough that he or she can see around the conceptual obstructions of the age.

You can see the convergence of all these forces in Snow's regimen that Wednesday. In the midst of the most important investigation of his life, he was still a working physician, managing the diffusion of gases. He delivered chloroform to two patients: one having hemorrhoids removed, the other having a tooth extracted. He spent the rest of the day in the streets of his neighborhood, probing, questioning, listening. Yet each conversation, however intimate, was shaped by the impersonal calculations of Farr's statistics. He drew lines of connection between individual pathology and the wider neighborhood; he shifted perspective seamlessly from doctor to sociologist to statistician. He drew maps in his head, looking for patterns, looking for clues.

BY THE END OF THE DAY, SNOW HAD BUILT A CONVINCING statistical case against the pump. Of the eighty-three deaths recorded on Farr's list, seventy-three were in houses that were closer to the Broad Street pump than to any other public water source. Of those seventy-three, Snow had learned, sixty-one were habitual drinkers of Broad Street water. Only six of the dead were definitively not Broad Street drinkers. The final six remained mysteries, "owing to the death or departure of every one connected with the deceased individuals," as Snow would later write. The ten cases that fell outside the imagined boundary line surrounding the Broad Street pump were equally telling: eight appeared to have a connection to Broad Street. Snow had established new causal chains back to the pump water, beyond the list of Farr's addresses: the proprietor of the coffeehouse who often sold sherbet mixed with Broad Street water told Snow that nine of her customers had died since the outbreak began. He had drawn the telling contrast between the Lion Brewery and the Eley Brothers factory; he had documented the unlikely safe haven of the Poland Street Workhouse. He even had his *experimentum crucis* in Hampstead.

It was, on the face of it, a staggering display of investigative work, given the manic condition of the neighborhood itself. In the twenty-four hours since he'd received Farr's early numbers, Snow had tracked down intimate details of behavior from the surviving family and neighbors of more than seventy people. The fearlessness of the act still astonishes: as the neighborhood emptied in terror from

the most savage outbreak in the city's history, Snow spent hour after hour visiting the houses that had suffered the worst—houses that were, in fact, still under assault. His friend and biographer Benjamin Ward Richardson later recalled: "No one but those who knew him intimately can conceive how he laboured, at what cost, and at what risk. Wherever cholera was visitant, there was he in the midst."



"DEATH'S DISPENSARY"

Friday, September 8

THE PUMP HANDLE

ON THURSDAY NIGHT, THE BOARD OF GOVERNORS OF ST. James Parish had held an emergency meeting to discuss the ongoing outbreak and the neighborhood's response. Halfway into the meeting, they received notice that a gentleman wished to address them. It was John Snow, armed with his survey of the past week's devastation. He stood before them, and in his odd, husky voice told them that he knew the cause of the outbreak, and could prove convincingly that the great majority of cases in the neighborhood could be traced to its original source. It is unlikely that Snow went into the intricacies of his broader case against the miasma theory—better to go straight to the telling patterns of death and life, leave the philosophizing for another day. He explained the dismal ratios of survival among the people living near the pump, and the unusual exemptions granted to people who had not drunk the water. He told the Board of Governors of deaths that had transpired far from Golden Square,

connected to the area only by the consumption of Broad Street water. He may have told them of the brewery of the workhouse on Poland Street. Death after death after death had been linked to the water at the base of the Broad Street well. And yet the pump remained in active use.

The members of the Board were skeptical. They knew as well as any other locals how highly regarded the Broad Street water was—particularly as compared to the other nearby pumps. But they also knew firsthand the smells and noxious fumes that were rampant in the neighborhood; surely these were more responsible for the outbreak than the reliable Broad Street water. Yet Snow's argument was persuasive—and, besides, they had few other options. If Snow was wrong, the neighborhood might go thirsty for a few weeks. If he was right, who knew how many lives they might save? And so, after a quick internal consultation, the Board voted that the Broad Street well should be closed down.

The following morning, Friday, September 8, exactly a week after the outbreak had first begun its awful rampage through Soho, the pump handle was removed. Whatever menace lay at the bottom of the well would stay there for the time being.

The deaths in Soho would continue for still another week, and the final reckoning of the assault of the Broad Street well on the neighborhood would not be calculated for months. The removal of the pump handle was generally ignored by the newspapers. On Friday, the *Globe* had published an upbeat—and typically miasmatic—account of the present state of the neighborhood: "Owing to the favourable change in the weather, the pestilence which has raged with such frightful severity in this district has abated, and it may be hoped that the inhabitants have seen the worst of the visitation. Yesterday there were very few deaths, and this morning no new cases

were reported." On the following day, however, the news appeared to be less encouraging:

> We regret to announce that after the account was written which appeared in The Globe of yesterday, there were several severe and fatal cases of cholera, and that seven or eight were reported on Saturday morning, although the wisest precautions were adopted to arrest the progress of the disease. The neighbourhood of Golden-square presented . . . a most melancholy and heart-rending appearance. There was scarcely a street free from hearses and mourning coaches, and the inhabitants of the district, appalled by the calamity which has visited them, crowded the streets to witness the last sorrowing act of duty towards their neighbours and friends. A vast number of the tradespeople left their shops and fled from the place, the closed shutters bearing the announcement that business had been suspended for a few days. Messers Huggins, the brewers, with praiseworthy forethought, have issued an announcement that the poor . . . may obtain any quantity of hot water for cleansing their dwellings, or other purposes, at any hour of the day or night, an act of humanity and kindness of which a large number have availed themselves.

Dozens would die over the next week, but clearly the worst was over. When the final numbers were tallied, the severity of the outbreak shocked even those who had lived through it. Nearly seven hundred people living within 250 yards of the Broad Street pump had died in a period of less than two weeks. Broad Street's population had literally been decimated: ninety out of 896 residents had perished. Among the forty-five houses extending in all directions from the intersection of Broad and Cambridge streets, only four managed to survive the epidemic without losing a single inhabitant. "Such a mortality in so

short a time is almost unparalleled in this country," the *Observer* noted. Past epidemics had produced higher body counts citywide, but none had killed so many in such a small area with such devastating speed.

THE REMOVAL OF THE PUMP HANDLE WAS A HISTORICAL turning point, and not just because it marked the end of London's most explosive outbreak. History has its epic thresholds where the world is transformed in a matter of minutes—a leader is assassinated, a volcano erupts, a constitution is ratified. But there are other, smaller, turning points that are no less important. A hundred disparate historical trends converge on a single, modest act—some unknown person unscrews the handle of a pump on a side street in a bustling city—and in the years and decades that follow, a thousand changes ripple out from that simple act. It's not that the world is changed instantly; the change itself takes many years to become visible. But the change is no less momentous for its quiet evolution.

And so it was with the Broad Street well that the *decision* to remove the pump handle turned out to be more significant than the short-term effects of that decision. Yes, the Broad Street outbreak would burn itself out over the next few days, as the last victims died off and other, more fortunate, cases recovered. Yes, the neighborhood would slowly return to normalcy in the weeks and months that followed. These were real achievements that arose from that pump handle being removed, even if the water in the well had potentially been purged of *V. cholerae* by the time Snow made his case to the Board of Governors. But the pump handle stands for more than that local redemption. It marks a turning point in the battle between urban man and *Vibrio cholerae,* because for the first time a public institution had made an informed intervention into a cholera outbreak

based on a scientifically sound theory of the disease. The decision to remove the handle was not based on meteorological charts or social prejudice or watered-down medieval humorology; it was based on a methodical survey of the actual social patterns of the epidemic, confirming predictions put forward by an underlying theory of the disease's effect on the human body. It was based on information that the city's own organization had made visible. For the first time, the *V. cholerae*'s growing dominion over the city would be challenged by reason, not superstition.