

“How John Snow’s Investigation of the 1854 Broad Street Pump Cholera Outbreak laid the foundation for modern day epidemiology and public health policy.”

It is August 1854 and London is a city of scavengers. Each morning a menagerie of 100,000 bone-pickers, rag gatherers, pure-finders, dredgers, night soil men, mudlarks, sewer hunters and night soil men make merry when faced with their bounty of the decaying organic waste of London. To stroll along the Thames at this time one would see the toshers wading through the muck of low tide, dressed in flowing velveteen coats, their oversized pockets filled with stray bits of copper recovered from the water’s edge, bearing an eight foot pole to test the ground in front of them and pull themselves out of the quagmire when necessary, whilst emanating a murky predawn glow from the lanterns fastened around their chests. Beside them fluttered the *mud-larks, often children dressed in tatters, content to scavenge the waste that the toshers rejected as below their standards: gathering mostly lumps of coal, old wood and scraps of rope. Above the river in the streets of the city, the pure-finders made a living by collecting dog-faeces, while the bone pickers foraged for carcasses of any stripe. Below ground in the growing network of tunnels beneath London's streets, the sewer hunters* slogged through the flowing waste of the metropolis. Every few months, an unusually dense pocket of methane would be ignited by one of their kerosene lamps and the hapless soul would be incinerated twenty feet below ground in a river of raw sewage and effluent.

The scavengers in other words lived in a world of excrement and death. *Dickens began his last great novel, *Our mutual Friend* with a father-daughter team of toshers stumbling across a corpse floating in the Thames whose coins they solemnly pocket. When chided by a fellow Tosher for his actions the father responds with the rhetorical question “To What world does a dead man belong to? To another world. To what world does money belong to. To this world.” In writing this Dickens offers an unspoken social commentary on how the two worlds, the dead and the living, have begun to coexist in these marginal spaces on the fringes of society. With the bustling commerce of the great city conjuring up its opposite, a ghost class that somehow mimics the status markers and value calculations of the material world of its maker, as outlined in Henry Mayhew’s pioneering 1884 work, *London Labour and the London Poor**, where he outlines the jarring precision of the bone pickers daily routine. *

It usually takes the bone-picker from seven to nine hours to go over his rounds, during which time he travels from 20 to 30 miles with a quarter to a half hundredweight on his back. In the summer he usually reaches home about eleven of the day, and in the winter about one or two. On his return home he proceeds to sort the contents of his bag. He separates the rags from the bones, and these again from the old metal (if he be lucky enough to have found any). He divides the rags into various lots, according as they are white or coloured; and if he have picked up any pieces of canvas or sacking, he makes these also into a separate parcel. When he has finished the sorting he takes his several lots to the rag-shop or the marine-store dealer, and realises upon them whatever they may be worth.

Whilst these actions served as a necessary means for survival by the underclasses of London they ultimately arose as a result of the fact that London in 1854 was a *Victorian Metropolis attempting to make do with Elizabethan Public Infrastructure. The city was vast even by metrics of today with two and a half million people crammed into a region, 30 miles in circumference. However the majority of techniques used to manage that kind of population density such as recycling centres, public health departments and sewage systems simply were not implemented on a wide scale contributing to the rampant spread of communicable diseases such as Cholera. Consequently the city itself improvised a response to deal with the challenges facing it, a response that would only prove to further exacerbate

the matter in the future but one that would meet the waste recycling needs of the people at that moment. Whilst we are naturally inclined to consider these scavengers as tragic figures and to vehemently protest against a system that allowed so many thousand to eke out a living foraging through human waste which I must admit is the correct response, and certainly was the stance taken by Mayhew and Dickens, such social outrage should be accompanied by a measure of wonder and respect, however begrudging. Without any central planner coordinating their actions, nor any education at all, the itinerant underclass managed to conjure up an entire system for processing and sorting the waste generated by two million people when their very government failed to do so. One of the many praises lauded upon Mayhew's London Labour is simply his willingness to see and record the details of these impoverished lives. However, just as valuable was the insight that came out of that bookkeeping. Once he had run the numbers, Mayhew discovered that far from being self-serving rogues, these people were actually performing an essential function for their community, writing "The removal of the refuse of a large town is perhaps one of the most important of social operations." And as such is it any wonder that once this precariously organised system broke down that the greatest wave of death and disease observed in London in the previous century unfolded.

Waste recycling is often perceived to be an invention of the environmental movement. After all, how often do we hear the familiar phrase reduce, reuse, recycle but the truth is contrary with recycling being an ancient art, one on which each and every community of living organisms is dependent upon for survival. Composting pits were used by the citizens of *Knossos in Crete four thousand years ago, Much of *medieval Rome was built by pilfering the remains of the crumbling ruins of the imperial city with the Colosseum serving as a quarry prior to its rise to popular tourist attraction. But most critically in the case of the Broad Street pump cholera outbreak of 1854, waste recycling in the form of composting and manure spreading played a crucial role in the *explosive growth of medieval European towns.

From a practical approach the matter becomes quite simple. High-density collections of human beings require significant energy inputs to be sustainable beginning with most fundamentally, a reliable source of food. With the resources of Middle age towns confined to their locality their population size was limited by the prosperity and fertility of the land on which the town was built. If the town could grow enough food to support 5,000 people then the population ceiling became 5000. However by ploughing the organic waste produced by the town back into the soil, the town increased the soil's productivity, thus raising the population ceiling, thereby creating more waste and by consequence increasingly fertile land capable of supporting an increasingly larger population to the nth degree. This feedback loop transformed the boggy expanses of the low countries which historically were incapable of sustaining any life more complex than isolated bands of fishermen into some of the most productive soils in all of Europe. The Netherlands named Pays - Bas in French translating directly to Low Country to this day remains one of the most densely populated countries in europe. A similar effect was observed in the growth of London. As London grew in size and population its population exceeded the capacity of the sewage system to fulfil the waste recycling needs of the city. Typically without intervention this would lead to the growth of the city stabilising or declining to more comfortably accommodate the population.

However the interventions of the underworld proletariat in picking up the slack in the need for waste recycling enabled the population to far exceed what the carrying capacity of the city otherwise would be. Thus by the 8th of August 1854 the stage was set for the whole system to come crashing down .

Just like the society which it occurred as a result of London's underground Market of Scavenging had its own system of Rank and Privilege and at the top were the *night soil men. The night soil men worked as independent contractors at the very edge of the legitimate economy and were employed by city landlords to remove the night soil from the overflowing cesspools of their tenant buildings. The role of night soil men had existed beginning in Medieval Times when they were called "rakers and gong fermors", and they played a vital role in the waste recycling system that helped London grow into a true metropolis. By selling the waste they collected to farmers outside the city walls they increased the productivity of surrounding lands supporting population growth and stimulated the local economy. Although the work was foul the pay was good, too good as it happened. Due to its geographic protection from invasion, London had become the most sprawling of European cities, expanding far beyond its Roman Walls*. The Urban sprawl that mid 19th Century London faced was so severe that Paris, the other great metropolis of the Era possessed an equal population in approximately half the land mass. However this was not the insignificant triviality it may appear to be to the modern observer. For the Night soil men, that sprawl meant longer transport times with open farmland now often located over 10 miles away, driving the price of removing the waste upwards, an increase in price which was inherited by the consumer. By the beginning of the Victorian Era, the night soil men were charging a shilling a cesspool, wages that were at least twice that of the average skilled labourer and for many Londoners, the financial cost of removing waste exceeded the environmental cost of just letting the excrement accumulate - particularly for the landlords, who often didn't live on top of these overflowing cesspools. Sights like this one reported by a civil engineer hired to survey two houses under repair in the 1840s became more and more commonplace: "I found whole areas of the cellars of both houses were full of night soil to the depth of three feet, which had been permitted for years to accumulate from the overflow of the cesspools... Upon passing through the passage of the first house I found the yard covered in night soil from the overflowing privy to the depth of nearly six inches and bricks were placed to enable the inmates to get across dry shod." In fact it was in this manner exactly that the Broad street cholera outbreak of 1854 began, with a soiled cloth tossed into an overflowing cesspool in close proximity to a shallow well emanating its poison into the local water supply. Another account describes a dustheap in Spitalfields in the heart of the East End "a heap of dung the size of a tolerably large house, and an artificial pond into which the contents of the cesspits are thrown. The contents are allowed to desiccate in the open air, and they are frequently stirred for that purpose."

In the aftermath of the Cholera outbreak of 1849, following a social investigation into the Cholera district of Bermondsey, Mayhew described the grotesque scene in an article published in the London Morning Chronicle which provides us with a clear indication of how this mismanagement of waste products likely led to the outbreak experienced that year. "We then journeyed on to London-Street... In No.1 of this street the cholera first appeared seventeen years ago, and spread up with fearful virulence; but this year it appeared at the opposite end, and ran down it with like severity. As we passed along the reeking banks of the sewer the sun shone upon a narrow slip of the water. In the bright light it appeared the colour of strong green tea, and positively looked as solid as black marble in the shadow - indeed it was more like watery mud than muddy water; and yet we were assured this was the only water the wretched inhabitants had to drink. As we gazed in horror at it, we saw drains and sewers emptying their filthy contents into it; we saw a whole tier of doorless privies in the open road, common to men and women, built over it; we heard bucket after bucket of filth splash into it, and the limbs of the vagrant boys bathing in it seemed, by pure force of contrast, white as Parian marble. And yet, as we stood doubting the fearful statement, we saw a little child, from one of the galleries opposite, lower a tin can with a rope to fill a large bucket that stood beside her. In each of the balconies that hung over the stream the self-same tub was to be seen in which the inhabitants put the

mucky liquid to stand, so that they may, after it has rested for a day or two, skim the fluid from the solid particles of filth, pollution, and disease. As the little thing dangled her tin cup as gently as possible into the stream, a bucket of night-soil was poured down from the next gallery.”

Whilst Victorian London certainly had its postcard wonders such as the *Crystal Palace, *Trafalgar Square and the new addition of *Westminster Palace, it also had wonders of a different magnitude and no less remarkable such as the artificial ponds of raw sewage, dung heaps the size of houses and the runaway success of the Water Closet*, more colloquially known as the flushing toilet. The elevated wage of night soil men was not the sole contributor to the rising levels of human waste in the city or the increased occurrence of cholera but was aided in its endeavours by the invention of the water closet. Although a preliminary version was developed in the Late 16th century, the device didn't take off until the late 1700s, when a watchmaker Alexander Cummings and a Cabinetmaker Joseph Bramah* filed for two separate patents on an improved version of the original. Bramah built a profitable business installing water closets in the homes of the well to do with the number of water closet installations increasing tenfold between 1824 and 1844. Popularity surged once again following manufacturer George Jennings installation of water closets for public use at Hyde Park* during the great Exhibition of 1851. With an estimated 827,000 visitors using them many were astonished by using a functioning toilet. The water closet led to a massive leap forward in quality of life but had disastrous effect on the city's sewage problem. Without a functioning sewer system to connect to, most WCs simply flushed their contents into existing cesspools, greatly increasing their tendency to overflow. The change was so great that the average London Household water usage of 160 gallons a day in 1850 had grown to 244 by 1856 greatly increasing the volume of cesspools.

With this in mind the single most important factor driving London's population growth* was not the runaway success of the water closet or increased rate paid to night soil men, but rather a matter of simple demography. The number of people generating waste had almost tripled in the space of fifty years with London according to the 1851 census being the most populous city in the world with a population of 2.4 million up from approximately 1 million at the turn of the century. Even with a modern civic infrastructure, two million people suddenly forced to share ninety square miles of space wasn't just a disaster waiting to happen, it was a kind of permanent rolling disaster. A vast organism destroying itself by laying waste to its habitat. Slowly but surely London was drowning in its own filth.

Now we venture to the site of our 1854 Cholera Outbreak the ever evolving district of Soho. In the middle of the Great Plague of 1665, the Earl of Craven* purchased a parcel of land in a semirural area to the west of central London called Soho Field. He built thirty six small houses “for the reception of poor and miserable objects, suffering from the plague” with the rest of the land being used as a mass grave*. With over four thousand plague infested bodies buried there, residents gave it the appropriately macabre name “Earl of Craven's pest field ” with no one daring to erect a foundation in the land for over two generations . Eventually the city's inexorable drive for shelter won out over its fear of disease with the pesthouse fields becoming the fashionable district of the Golden Square*, the centre of John Snow's investigation. In the decades after the plague Soho became one of the most fashionable districts in London home to almost a hundred titled families in the 1690s.* However by the middle of the 18th century the aristocracy continued its march westward building even grander estates and townhouses in the new neighbourhood of Mayfair*. By 1740 there were only 20 titled residents left with a new kind of Soho native beginning to appear, an individual defined by a mix of artistic vision and entrepreneurial spirit that would be associated with the area for several generations. As the city became increasingly industrial, and as the aristocracy emptied out, this artistic flair was

exchanged for a rugged hardness* with the neighbourhood becoming grittier and more informal with landlords breaking up the old townhouses into separate tenement flats; courtyards between buildings filled with impromptu stables and junkyards, with Dickens description in *Nicholas Nickleby** outlining the new state of Soho. "In that quarter of London in which Golden Square is situated, there is a bygone, faded, tumble-down street, with two irregular rows of tall meagre houses, which seem to have stared each other out of countenance years ago. The very chimneys appear to have grown dismal and melancholy, from having had nothing better to look at than the chimneys over the way. To judge from the size of the houses, they have been, at one time, tenanted by persons of better condition than their present occupants; but they are now let off, by the week, in floors or rooms, and every door has almost as many plates or bell-handles as there are apartments within. The windows are, for the same reason, sufficiently diversified in appearance, being ornamented with every variety of common blind and curtain that can easily be imagined; while every doorway is blocked up, and rendered nearly impassable, by a motley collection of children and porter pots of all sizes, from the baby in arms and the half-pint pot, to the full-grown girl and half-gallon can."

By 1851 the sub district of Berwick Street on the westside of Soho was the most densely populated of all 135 sub districts that made up greater London with 432 people to the acre. But despite the increasingly crowded and unsanitary conditions, the neighbourhood was a hotbed of creativity with the list of poets, musicians sculptors and philosophers who lived in Soho during this period including Edmund Burke*, Fanny Burney*, Percy Shelley*, William Hogarth*, Franz Liszt*, Richard Wagner* a Young Mozart* and Karl Marx. Jane Jacobs "New Ideas need old buildings " applies perfectly to Soho around the dawn of the Industrial age, made up of a class of visionaries , eccentrics and radicals living in the disintegrating shells that had been abandoned a century prior by the well to do and as such is it any surprise that one of the greatest advancements in modern public health policy was sprung from an investigation performed in this ragtag hub of innovation and creativity. As time progressed the neighbourhood had become a classic mixed-use economically diverse neighbourhood, with the odd slaughterhouse, manufacturing plant and tripe boiler. The neighbourhood's residents were a mix of the working poor and the entrepreneurial middle class and as such, Soho became something of an anomaly in the west end of the city, an Island of working poverty and foul smelling industry surrounded by the opulent townhouses of Mayfair and Kensington. This economic discontinuity was manifested physically in the very layout of the streets around Soho with the hustle and bustle of Regent Street* almost imperceptible from the smaller lanes and alleys of Soho*. Walking around the city it feels almost as if a barricade has been erected, keeping you from reaching the prominent avenue of Regent Street only a few feet away. And indeed, the street layout was explicitly designed to serve as a barricade. When John Nash designed Regent street to connect Marylebone park with the prince regent's new home at Carlton House, He planned the thoroughfare as a kind of Cordon Sanitaire separating the well to do of Mayfair from the growing working class community of Soho. Nash's explicit intention was to create " a complete separation between the streets occupied by the Nobility and the Gentry, and the narrower streets and meaner houses occupied by mechanics and the trading part of the community.... "My purpose was that the new street should cross the eastern entrance to all the streets occupied by the higher classes and to leave out to the east all the bad streets"

This social topography would play a pivotal role in the events that unfolded in the late summer of 1854, when a terrible scourge, cholera, struck Soho but left the surrounding neighbourhoods utterly unharmed reinforcing any and all elitist stereotypes with this quick moving plague attacking the debauched and destitute while passing over the better sort that lived only blocks away. Whilst this was the bleak reality facing the people of Soho by 1854, those on the wrong side of the avenue still

managed to get by. Behind the barricade Soho was a veritable engine of local commerce, with almost every residence housing some kind of small business. Sometime in the late 1840s, a London policeman named Thomas Lewis and his wife moved into 40 Broad Street*, one door up from the pub. It was an eleven room house that had originally been designed to hold a single family and a handful of servants. Now it contains twenty inhabitants. Thomas and Sarah Lewis lived in the parlour at 40 Broad, first with their little boy, a sickly child who died at ten months and then a girl born in march of 1854, who possessed from the beginning a more promising constitution than her brother, suffering a few bouts of illness in her second month but relatively healthy for most of the summer. We do not know her name. We do not know what series of events led to her contracting cholera in late August of 1854 at not even 6 months old with the last cholera outbreak in the Golden Square taking place in 1849. But on the 28th of August 1854 all that changed. At around six a.m while the rest of the city struggled for a few final minutes of sleep at the end of an oppressively hot summer night, the Lewis infant began vomiting and emitting watery green stools that carried a pungent smell. Sarah Lewis sent for the local doctor, William Rogers who maintained a practice a few blocks away, on Berners Street. As she waited for the doctor's arrival, Sarah soaked the soiled cloth diapers in a bucket of tepid water. As her infant slept, Sarah Lewis crept down to the cellar at 40 Broad and tossed the fouled water into the cesspool that lay at the front of the house. That is how it began.*

As modern observers we often have a tendency to view advancements in scientific discovery as radical out of the blue euureka moments which in reality is rarely the case. For the most part these discoveries fall within a wider trend of questioning, awareness and discovery with decades of prior investigation laying the foundation for the problem. By the time that those who are marked in the annals of history arrive, their discoveries are typically the next logical conclusion and given mere weeks in some cases would be exemplified by a contemporary. Thus to gain a full understanding of the weight of these discoveries we must look beyond their pinnacles, the flashy discoveries that we laud today but rather examine the wider trends that contributed to this discovery taking place. In doing so we can gain a greater understanding of just how substantial these discoveries are, as although all logical evidence may point towards the conclusion drawn by figures such as Snow there is often an aspect of their character that makes it so that defying all reason, the discovery could only have been made by them.

Snow's 1854 Broad Street Pump cholera investigation fell within a wider trend beginning in the mid 18th century driven by the desire to understand health in populations. Beginning in 1750 Britain and the wider empire underwent a major social transformation experiencing the growth of impirealistic energy and colonialism, the rise of the slave trade and fighting of a number of wars such as the American Civil War and the Crimean war of the 1850s. This concentration of valuable finitely available persons on the edge of the known world at the time led to an increased desire to understand health in populations so as to maintain the health of these human commodities. Similarly at home as the proletariat vital to the smooth running of the Industrialist empire* died in their swathes, an increased effort to study the spread of epidemics began to manifest within British Medical Societies. One such study to examine this trend of death in the underclasses of london titled "General Report on the Sanitary Condition of the Labouring Population of Great Britain" was performed by Edwin Chadwick* a longstanding contemporary of Snow in 1842, and was described as "the fundamental document of modern public health" by 20th Century physician, public health administrator and medical historian George Rosen. In this text Chadwick advocates that government intervention is necessary to provide the city with clean water, argues in favour of the implementation of improved drainage systems and champions that local councils should be enabled to clear refuse from the

crowded homes and streets of their towns. If any one of these actions had been taken it is likely that the horrors of the 1854 cholera outbreak never would have had the chance to manifest with the ideal conditions for the growth and spread of cholera vibrios and by extension cholera lacking. The rise of professionalisation in medicine also facilitated this change in the perception of disease and patient health with professional networks such as the Royal College of Surgeons of England* established in 1843, societies such as the Royal Epidemiological Society* which Snow was a founding member of founded in 1850 and journals such as the Lancet* founded in 1823 eliminating this outdated notion of the isolated rural community doctor. These spaces acted as forums of scientific discovery offering a place for medical collaboration and learning for doctors across the country enabling the effective study of patient populations. In addition to this the traditions of Colonialism, the Slave Trade and War from which this motive to understand how health occurred in populations sprung from, distinctly moulded the way in which epidemiological investigation took place. The advanced and intricate record keeping* of Colonial Britain led to a tradition of numerical investigation in epidemiology with statistics and mathematics acting as a rational response to what appeared to be an irrational problem, the spread of disease with no known vector. This reliance on numerics led to the growth of the field of nosology which focused on the classification of diseases so as to establish trends when viewed in comparison with quantitative case data. Imperial endeavours also led to a tradition of mapping* a hallmark of Snow's investigation who ultimately concluded that the source of the 1854 Soho outbreak was the Broad Street pump, as a result of his construction of a dot map. With each dot representing a case of Cholera, Snow noted that the highest concentrations of cholera were observed in the regions in closest proximity to the water pump, ultimately solving the puzzle of the outbreak. Furthermore, investigative methods applied in epidemic outbreaks in the colonies set a precedent for the way in which epidemiological investigations took place, with a Doctor in Cape Verde performing one of the earliest known cases of contact tracing during a yellow fever outbreak in the early 19th Century. By consulting with the washerwomen who dealt with the "dirty linen" and thus noticed any and all changes in bodily output, he was able to work backwards and establish a timeline, ultimately arriving at his conclusion. This event displayed the utility of narrative medicine in epidemiological investigation demonstrating how solutions could arise from the ailed population itself.

By Sunday September 3rd the city held its breath. The usual chaos of the street sellers had disappeared with most of the neighbourhood's population evacuated to the surrounding regions or suffering behind their doors. The most common sight on the streets were the priests and doctors making their frantic rounds. Word of the outbreak in Golden Square had swept across the city with 70 deaths in a town not uncommon but normally it took months for such a figure to be reached. The Broad Street outbreak had achieved this in but a single day. While the disease for the most part was confined to a region of roughly five square blocks, the rest of Soho was on high alert with many shuttering their windows or leaving to the countryside. However one Soho regular had been following the case closely from his residence on Sackville Street on the southwestern edge of the neighbourhood. Setting out at dusk he travelled directly into the heart of the outbreak. When he reached 40 Broad he stopped and examined the pump for a few minutes in the fading light. He drew a bottle of water from the well, briefly examined it then turned and made his way back to Sackville Street.

John Snow now aged 42 had experienced a remarkable streak of professional success beginning in his early thirties, notably for his contributions to the anaesthetic movement of the mid 19th Century. Unlike most members of the medical establishment or the sanitary reform movement, Snow had been born into a family of modest means and at the age of fourteen apprenticed to a surgeon in Newcastle on Tyne. As an apprentice, Snow witnessed firsthand the ravages of cholera when the disease struck in late 1831. He treated the survivors of a particularly brutal outbreak in a local mine,

the Killingworth Colliery. The young Snow observed that the sanitary conditions in the mine were dreadful with the workers offered no separate quarters to relieve themselves, thus forcing them to eat and defecate in the same dark and stifling caverns. The idea that the cholera outbreak was shaped by the social conditions of these impoverished workers and not in any innate susceptibility to disease stayed with Snow as the cholera ran its course informing his later theories on the communication of cholera. In London, Snow settled in Soho and enrolled in the Hunterian School of Medicine*. Within two years he had received an apothecary and surgeon's licence and established a general practice at 54 Frith Street London* approximately 5 minutes away from the Golden square. Setting up shop those days required an entrepreneurial spirit with the competition intense among the new medical middle class. Despite the proximity of so many rivals with 4 other surgeons located in the vicinity, Snow quickly established a successful practice. Despite his taciturn and emotionally flat bedside manner he was a superb, quick witted doctor with an exceptional memory for past cases. Snow was as free from superstition and dogma as it was possible to be in those days although admittedly he was limited by the conceptual dead ends of early Victorian Medicine. The idea of microscopic germs spreading disease outlined in early germ theory was implausible to the majority of anti-contagionist theorists with laudanum an opioid regularly prescribed for almost any ailment. Lacking any real social life, Snow spent his time away from patients working on side projects that grew from his surgeon's practice but hinted towards the ultimate range of his medical ambition. He began writing in local medical journals opining on medical and public health issues of the day. His first published paper, addressing the use of arsenic in cadavers, appeared in the Lancet in 1839. He went on to publish over 50 articles in the following decade on a wide array of topics with his many critiques of sloppy science published in the Lancet earning him a scolding from the editor who wrote "Mr Snow might better employ himself in producing something, than in criticising the production of others."

Seeking to increase his credibility and ultimately produce something of his own, Snow turned towards advanced education*. In 1843 he earned a bachelor of medicine degree from the university of London and a year later passed his M.D. exams. Now officially Dr. Snow he was invited to Westminster Medical Society *where he quickly became a respected and active member. The vast majority of Physicians would have settled into that realm tending to increasingly well to do clientele and boosting their own social prestige concurrently. But not Snow. What drove him more than anything were problems that needed solutions, filling in the blind spots in the medical establishment's view of the world. Snow would continue to work as a practising physician for the rest of his life but his eventual fame would come from exploits out of the consulting room. Snow did not aim low in his investigations, playing a defining role in the battle against the era's most relentless killer. But before he could tackle cholera, John Snow set his sights on the most outwardly apparent deficiency of Victorian Medicine. Pain management.

Snow's Mastery of Ether and Chloroform* previously unreliable anaesthetics raised him to a new echelon in the London Medical world. He became the most sought after anaesthesiologist in London assisting with hundreds of operations a year. Snow's research into anaesthesia had elevated him from a surgeon of humble origins to the apogee of Victorian London. But in a way the most impressive thing about his research was not the levels of social class which he successfully traversed but rather the intellectual strata, the different scales of experience that his mind crossed so effortlessly. Snow was truly a consilient thinker in the sense of the term as it was originally formulated by the Cambridge philosopher William Whewell in the 1840s, who wrote "The Consilience of Inductions 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 behaviour 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 blood stream, 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 anaesthetics. Snow was not interested in individual isolated phenomena; he was interested in chains and networks, in the movement from scale to scale. And yet there was a ceiling to his intellectual pursuit of ether and chloroform: **his research stopped at the scale of the individual subject**. With the next step up the chain - the larger, connected world of cities and societies*, of groups, not individuals - not factoring into his anaesthesia investigations. He may have been called to administer to the Queen but the body politic remained outside of the mastery of Snow. Cholera would change that.

It was Snow's ability to think consiliently* which enabled him to be the one to make the breakthrough in the question of cholera. What set Snow apart from the many who dipped from the well of the Cholera Question previous to him was not any great discovery or novel insight, in fact much of the breakthroughs of Snow were reliant upon the insights offered by the discoveries of those who opposed his theories. However, what enabled Snow to determine the source and mode of transmission of Cholera while his opponents failed to reach the correct conclusion with the very answer in their hands, lay in the way in which he viewed cholera.

At the time of John Snow there were two prevailing theories on how exactly infectious diseases spread. The more widely accepted model of Miasma Theory supported by the Registrar General for health William Farr*, the Board of Health and the Committee on Scientific Inquiries, as well as the sanitation commissioner Edwin Chadwick* and the majority of the scientific community argued that cholera was caused by foul smelling* putrid particles in the air named miasmata. The alternate line of thought, germ theory* supported by a minority of physicians including Snow known as the contagionists argued that cholera was transmitted by germ cells with Snow theorising that this germ was transmitted from person to person by ingesting contaminated water. I don't believe that I need to spell out just who was right. However, one obstacle lay in the way of Snow and that was that in 1854 germ theory remained a speculative hypothesis formed by attempting to fill in the blanks of the spread of disease. The Cholera-causing bacterium *Vibrio cholerae* was not successfully identified until late 1854* in Florence Italy by Fabio Paccini and not successfully verified again until 1883 by Robert Koch in India. Further to this germ theory was not comprehensively outlined or accepted as a valid argument on the communication of diseases until Louis Pasteur* published his 1861 work titled "The germ theory". Although contagion theory experienced some early popularity when the disease first reached British shores in the early 1830s with the Lancet's editor opining "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. In short, one that makes mankind the chief agent for its dissemination" most physicians and scientists believed that cholera was disease spread via poisoned atmosphere*, not personal contact. In fact one survey of published statements from U.S physicians during the period found that less than five per cent believed the disease was primarily contagious. In addition to miasma theory's prestigious following it also had folklore and superstition on its side with the foul inner city air widely believed to be the source of most disease.

As such just as was the case in his study of ether and chloroform Snow had to undergo a hypothetico-deductive investigation centred around the now wide held epidemiological principles of coherence and specificity with a firm rooting in the pathophysiology of cholera to reach a conclusion acceptable to the scientific community.

Remarkably with all the discourse that had taken place since the arrival of cholera in 1832 no one, the contagionists included, suggested that the disease may be transmitted by means of contaminated water.* Snow's detective work in cholera began when he noticed a telling detail in the published accounts of the 1848 epidemic. Asiatic cholera had been absent from Britain for over a decade by this stage but had recently broken out in the Continent, with the city of Hamburg* included. In September of that year, the German Steamer Elbe docked in London having left port at Hamburg a few days earlier. A crewman named John Harnold checked into a lodging house in Horsley-down and fell ill with cholera on the 22 September. He was dead before the day was out. A few days later, a man named Blenkin-sopp took over the room; he was seized by the disease on September 30. Within a week, the cholera began to spread through the Neighbourhood and ultimately the nation. By the time the epidemic ground to a halt, 2 years later 50000 people were dead.

Snow recognized immediately that this sequence of events posed a severe challenge to the opponents of the contagion model with the coincidence simply too great* for anti-contagionists to bear. Two cases of cholera in a single room in the space of a week may be plausible in the miasma model but to argue that the room suddenly became plagued with these noxious vapours the very day a sailor travelling from a city known to contain active cases of cholera arrived was a leap at best. As such Snow wrote "Who can doubt that the case of John Harnold, the seaman from Hamburg, was the true malady of in Blekinsopp, who came and lodged and slept, in the only room in all London in which there had been a case of true Asiatic Cholera for a number of years? And if cholera be communicated in some instances, is there not the strongest probability that it is so in the others?" But Snow also recognised the weakness of the contagionist argument. The same doctor attended to both Harnold and Blekinssopp spending multiple hours in the room with them during the rice-water stool phase of the disease. Clearly the cholera was not communicated by sheer proximity, in fact the most puzzling element of the disease was that it seemed capable of travelling across city blocks, skipping entire houses in the process as the remaining members of the neighbourhood succumbed to the disease. In this very case, the subsequent cases in Horsleydown erupted a few doors down from Harold's original lodging house. You could be in the same room with a patient near death and emerge unscathed but somehow you could avoid direct contact altogether with the infected person and yet still be seized with cholera, simply because you lived in the same neighbourhood. Snow was astute enough to realise that solving the mystery of cholera would lie in reconciling these two seemingly contradictory facts. Emboldened by this opportunity to find a meaningful solution and bolstered by his observations tending to the dying miners in Killingworth, Snow was confident that an explanation lay within further investigation. In the weeks after the Horsley-down outbreak, as the cholera began its fatal march through the city and beyond, Snow embarked on an unrelenting stretch of inquiry: consulting with chemists who had studied the rice water stools of cholera victims, mailing requests for information from the water and sewer authorities in Horsleydown and devouring accounts of the great epidemic of 1832. And thus by 1849 Snow felt confident enough to go public with his theory.* Cholera, Snow argued, was caused by some unidentified agent that the victim ingested, either through direct contact with the waste matter of other sufferers or more likely and explaining why the mode of transmission went undetected for as long as it did, through drinking water that had been contaminated with that waste matter. Cholera was contagious, yes, but not in the outwardly apparent way that smallpox was contagious. As such sanitary conditions were crucial to fighting the disease and in regions where such measures weren't up to scratch the disease ravaged populations unmitigated. Foul air had nothing to do with cholera, it wasn't something you inhaled, it was something you swallowed.

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 Horselydown.* Snow made an exhaustive investigation of the site and found ample evidence to support his developing theory. All twelve victims lived in a row of cottages called the Surrey building, which shared a single well in the courtyard they faced. A drainage channel of 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 in this environment could quickly spread through the entire Surrey building. The layout of the collection of these Thomas Street flats, provided Snow with the perfect control study for his inquiry. The Surrey building backed onto a set of houses that faced another courtyard known as Truscott's Court containing a set of abodes every degree as decrepit and squalid as the Surrey building, and home to 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 was responsible for the outbreak, why would one squalid impoverished group suffer ten times the loss of 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 birds 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: Londoners living south of the Thames were significantly more likely to drink water that had originated in from the river as it passed through Central London. Whereas Londoners living North of the river drank from a variety of sources: with some companies piping in water from the Thames above Hammersmith, far from the urban core and some drew from the 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 river where most of the city's sewers emptied, and thus anything that was multiplying in the city's intestinal tracts was likely to find its way into the drinking water of South London.* If Snow's theory was accurate Londoners living below the Thames should have significantly higher rates of cholera than those living above. Snow then surveyed the tables of cholera death that had been compiled by William Farr, London's registrar General, with his findings following the pattern that the water supply routes predicted.

* Of the 7, 446 deaths in the metropolitan area during the 1848 to 1849 epidemic, 4001 were located south of the Thames. That meant that the per capita casualty rate measured to approximately 8 per thousand - three times that of the central city. In the growing suburbs of West and North London, the death rate was comparatively just over one per thousand. Whether you looked at the evidence on the scale of an urban courtyard or that of an entire city neighbourhood the same pattern repeated itself: the cholera seemed to distribute itself around shared water supplies. If the miasma theory was right why would such arbitrary distinctions be drawn? Why would cholera devastate one building and leave the next one unscathed? Why would one slum suffer twice the losses as a slum with arguably worse sanitary conditions? This insight stayed with Snow for 5 long years where his investigation of the rates of infection associated with different waterworks companies in 1854 ultimately lead to the formation of the Board of Works in 1855* and passing of the water Act of 1856 forcing the South London Water Works companies of Southwark and Vauxhall to increase their sanitation standards, and preventing them from drawing water below Teddington.

Snow introduced his theory of cholera in two forms in the second half of 1849: first as a self published monograph "On the Mode of Communication of Cholera" intended for the medical community and then as a medical article in the London Medical Gazette. * The reaction to Snow's argument was positive but sceptical with a reviewer in the London Medical Gazette writing "Dr. Snow deserves the thanks of the profession for endeavouring to solve the mystery of the communication of cholera," with Snow's case studies not convincing the public due to the premise that correlation does not equate to causation with the reviewer commenting "they furnish no proof whatever of the correctness of his views." And in all honesty the reviewer was correct. Snow had convincingly demonstrated that the South London neighbourhoods were at greater risk for cholera than the rest of the city, but it did not necessarily follow that the water in these neighbourhoods was responsible for the disparity, true though it may be. Perhaps cholera was contagious and thus the cluster of cases in south London reflected the chain of infection thus far, if the initial cases had unfolded differently, perhaps the East End would have been attacked more heavily, and South London left relatively unscathed. There was a relationship between water supply and cholera, that much Snow had convincingly proved but he had not yet established a cause. However the Gazette did suggest one scenario that might settle the matter outlining the framework for Snow's hypothetico deductive model of investigation that would deliver him the answers. "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 the next 5 years. As his anaesthesia 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. When word arrived of a terrible outbreak in Golden Square, within walking distance of his Sackville street offices he was ready. With so many casualties in such a short stretch of time it pointed towards a central contaminated water source used by a large number of people.* And thus Snow needed to get samples quickly while the epidemic was in full stride, however Snow was left confounded by the fact that he expected that contaminated water would have a cloudiness to it that was visible to the naked eye. But his initial glance at the Broad Street water surprised him; it was almost entirely clear. He drew samples from the other pumps in the area: Warwick Street, Vigo Street, Brandle Land and Little Marlborough street, all of which were murkier than Broad Street water. The Little Marlborough Street sample was worst of all. As he drew the water there, a handful of local residents on the street remarked that the pump water was notoriously poor, so poor that many of them had taken to walking the extra distance to Broad Street for their drinking water. As Snow returned home on Sackville Street, he turned over the clues in his mind. Perhaps the Broad Street pump was not the culprit after all, given the lack of particles in the water. Perhaps one of the other pumps was the culprit? Or perhaps some other force was at work here. He knew that an outbreak of this magnitude was sure to hold the final piece to validate his argument. It was just a matter of finding the right evidence. Snow didn't realise it at the time but as he walked home that night the basic pattern of the experimentum crucis suggested five years before in the London medical gazette was beginning to unfold, miles from Broad Street in the greenery of Hampstead*. Susannah Ealy had fallen ill earlier in the week after drinking her regular supply of Broad Street Water, shipped to her by her children living in Soho. By Saturday she was dead, followed by her niece on Sunday who had returned to her home in Islington after visiting her Aunt. As Snow Reviewed the pump-water samples in his microscope, Susannah Eley's servant, who had also consumed a glass of Broad Street water, remained locked in a life or death struggle with the disease. Not one other case of Cholera would be recorded in Hampstead for weeks. Snow's theory was validated.*