

## Unfeeling statistics

### 1.1 Snow on cholera

Mathematics is, at least in part, the science of abstraction. Mathematicians look at the rich complexity of the real world and replace it with a simple system which, at best, palely reflects one or two aspects of it. Roads become lines, towns become points, weather becomes a series of numbers (temperature, wind-speed, pressure, ... ) and human beings become units. The object of the first part of this book is to show how useful such abstraction can be.

In 1818 Europe became aware of a terrifying epidemic raging in parts of India. The disease, previously unknown to European science, struck suddenly, manifesting itself in violent diarrhoea and vomiting followed by agonising muscular cramps. An early description tells how

The eyes surrounded by a dark circle are completely sunk in the sockets, the skin is livid ... the surface [of the skin] is now generally covered with cold sweat, the nails are blue, the skin of the hands and feet are corrugated as if they had been long steeped in water.

Often the skin turned blue or black and sometimes the convulsions were so severe that the body was contracted into a ball which could not be straightened out after death. The disease was named 'Cholera Morbus' and killed perhaps half its victims.

Most probably cholera had always existed in India but the movement of armies and the increase in long-distance trade brought about by the expansion of the British and Russian empires now allowed it to spread. In Russia infected villages were surrounded by troops with orders to shoot anyone trying to leave. Spain made it a capital offence to leave an infected town. In spite of all efforts to contain the disease, it swept through Europe in the years 1830–2 killing one citizen in 20 in Russia, one in 30 in Poland and Austria and many in every European country

before 'burning itself out'. In 1848 it returned and there were epidemic outbreaks in Britain in most of the years up to 1855.

What was the cholera, how was it spread, how could it be prevented and how cured? It was a disease of the poor which also killed the rich — but that was and is true of most epidemic diseases. Many people, particularly reformers, felt sure that it was associated with dirt, poor sanitation, bad water, bad air, bad diet and crowded living conditions. Beyond that there was no agreement. Was it contagious? If so, how could it evade all attempts at quarantine and why were doctors and clergymen who attended the sick so often spared? Was it caused by a poisonous miasma created by some process of fermentation in the presence of bad drains or stagnant water? That would help explain why it was a summer disease — except in Scotland where the outbreaks occurred in winter. Was the miasma, which some experts claimed to have seen, electrical or was it something to do with ozone?

In 1849 Dr John Snow published yet another theory. Snow had worked his way up from fairly humble beginnings to the top of the medical profession, becoming one of the founding fathers of anaesthesia. (In 1853 he was the doctor chosen to give chloroform to Queen Victoria in childbirth.) He was a shy, diffident man, wholly immersed in his work† and devoted to the relief of suffering. Snow, as an expert on respiration, rejected the miasmatic theory. If the disease were due to a 'miasma', surely the lungs would be affected first. Since cholera was primarily a disease of the alimentary canal, the cholera producing material must be swallowed 'and the increase of the ... cholera poison must take place in the interior of the stomach and the bowels'. Unless strict cleanliness was observed, the cholera poison, once excreted, would be transferred to hands and thence to food and drink ready to infect further victims.

If the cholera had no other means of communication than those which we have been considering, it would be constrained to confine itself to the crowded dwellings of the poor, and would be continually liable to die out accidentally in a place, for want of opportunity to reach fresh victims; but there is often a way open for it to extend itself more widely, and to reach the well-to-do classes of the community; I allude to the mixture of the cholera evacuations with the water used for drinking and culinary purposes, either by permeating the ground, and getting into wells, or by running along channels and sewers into the rivers from which entire towns are supplied with water.

Snow showed that his theory was in accordance with most of what was known about the disease although he could only speculate about the

†Though, according to his biographer, 'in the last few years of his life he so far threw off restraint as to visit the opera occasionally.'

nature of the cholera poison which 'having the property of reproducing its own kind, must necessarily have some sort of structure, most likely that of a cell'. However, in the last 200 years legions of clever doctors had produced ingenious theories about this or that disease each in accordance with most known facts but, in the end, contributing no permanent knowledge of cause, prevention or cure.

Snow was not just an ordinary clever doctor. In the words of his sonorous Victorian biographer:

During subsequent years, but specially during the great epidemic outbreak of the disease in London in 1854, intent to follow out his grand idea, he went systematically to work. He laboured personally with untiring zeal. 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. For the time he laid aside as much as possible of the emoluments of practice; and when even, by early rising and late taking rest, he found that all that might be learned was not, from the physical labour implied, within the grasp of one man, he paid for qualified labour.

Part of his time he spent in the traditional way, listening to the arguments of his opponents and collecting information about particular cases but most of his effort went into collecting statistics — that is counting large numbers of cases†. Moreover, rather than just collecting statistics, as many of his contemporaries did, in the hope that something might emerge, he sought statistical evidence for or against his particular theory of cholera.

At the time, London was supplied by various private water companies which drew their water from different sources and supplied different districts. His first statistical analysis tabulated the number of deaths per thousand in the various districts supplied by each water company for the epidemics of 1832 and 1848. The results for the 1848 epidemic are shown in Figure 1.1.

At first sight the results seem conclusive evidence in favour of a waterborne source for cholera. All the districts which suffered worst were supplied wholly or partly by the Southwark and Vauxhall water company. However, the districts supplied by the Southwark and Vauxhall company have other features in common. William Farr, of the Registrar-General's office, who was responsible for the collection of the statistics on which the table was based had also analysed them and found a strong correlation between height above sea level and deaths from cholera. (Taking the epidemics of 1849 and 1853–4 together he found that the mortality in the lowest parts of London was 15 times

†The idea of applying statistics to practical problems was of course very much in the air, so much so that some modern historians feel that Snow was merely part of the 'Spirit of the Age'. However, Snow did the work and it seems unfair that the 'Spirit of the Age' should get the credit.

the mortality in the highest.) For Farr the Southwark and Vauxhall company districts were distinguished by their low-lying nature rather than their water supplier.

The interpretation of the table is made still harder by the fact that some districts have more than one water supplier. Thus, for example, a commercial war broke out between the (predecessor of the) Southwark and Vauxhall and the Lambeth water companies with the result that many districts were supplied by pipes of both water companies. (Eventually peace was restored and the companies celebrated their reconciliation by raising their rates by 25%.) However, Snow realised that

Figure 1.1: Snow's table of cholera deaths and water supply for London, 1849.

District.	Population in the middle of 1849.	Deaths from Cholera.	Deaths by Cholera to 10,000 inhabits.	Annual value of House & Shop room to each person in £.	Water Supply.
Rotherhithe . . . . .	17,208	352	205	4.238	Southwark and Vauxhall Water Works, Kent Water Works, and Tidal Ditches.
St. Olave, Southwark . . . . .	19,278	349	181	4.559	Southwark and Vauxhall.
St. George, Southwark . . . . .	50,900	836	164	3.518	Southwark and Vauxhall, Lambeth.
Bermondsey . . . . .	45,500	734	161	3.077	Southwark and Vauxhall.
St. Saviour, Southwark . . . . .	35,227	539	153	5.291	Southwark and Vauxhall.
Newington . . . . .	63,074	907	144	3.788	Southwark and Vauxhall, Lambeth.
Lambeth . . . . .	134,768	1618	120	4.389	Southwark and Vauxhall, Lambeth.
Wandsworth . . . . .	48,446	484	100	4.839	{ Pump-wells, Southwark and Vauxhall, river Wandle.
Camberwell . . . . .	51,714	504	97	4.508	Southwark and Vauxhall, Lambeth.
West London . . . . .	28,829	429	96	7.454	New River.
Bethnal Green . . . . .	87,263	789	90	1.480	East London.
Shoreditch . . . . .	104,122	789	76	3.103	New River, East London.
Greenwich . . . . .	95,954	718	75	3.379	Kent.
Poplar . . . . .	44,103	313	71	7.360	East London.
Westminster . . . . .	64,109	437	68	4.189	Chelsea.
Whitechapel . . . . .	78,590	506	64	3.388	East London.
St. Giles . . . . .	54,062	285	53	5.635	New River.
Stepney . . . . .	106,988	501	47	3.319	East London.
Chelsea . . . . .	53,379	247	46	4.210	Chelsea.
East London . . . . .	43,495	182	45	4.823	New River.
St. George's, East . . . . .	47,334	199	42	4.753	East London.
London City . . . . .	55,816	207	38	17.676	New River.
St. Martin . . . . .	24,557	91	37	11.844	New River.
Strand . . . . .	44,254	156	35	7.374	New River.
Holborn . . . . .	46,134	161	35	5.883	New River.
St. Luke . . . . .	53,234	183	34	3.731	New River.
Kensington (except Padding- ton) . . . . .	110,491	260	33	5.070	West Middlesex, Chelsea, Grand Junction.
Lewisham . . . . .	32,299	96	30	4.824	Kent.
Belgrave . . . . .	37,918	105	28	8.875	Chelsea.
Hackney . . . . .	55,152	139	25	4.397	New River, East London.
Islington . . . . .	87,761	187	22	5.494	New River.
St. Pancras . . . . .	160,122	360	22	4.871	{ New River, Hampstead, West Middlesex.
Clerkenwell . . . . .	63,499	121	19	4.138	New River.
Marylebone . . . . .	153,960	261	17	7.586	West Middlesex.
St. James, Westminster . . . . .	36,426	87	16	12.669	Grand Junction, New River.
Paddington . . . . .	41,267	35	8	9.349	Grand Junction.
Hampstead . . . . .	11,572	9	8	5.804	Hampstead, West Middlesex.
Hanover Square & May Fair . . . . .	33,196	26	8	16.754	Grand Junction.
London . . . . .	2,280,282	14137	62	—	

this intermingling represented not a problem but an opportunity when, in 1852, the Lambeth company moved their water works up river clear of the London sewage whilst the Southwark and Vauxhall continued to draw its water downstream. Snow wrote that this

... admitted of the subject being sifted in such a way as to yield the most incontrovertible proof on one side or the other. In the sub-districts enumerated in [Figure 1.2] as being supplied by both Companies the mixing of the supply is of the most intimate kind. The pipes of each company go down all the streets, and into nearly all the courts and alleys. A few houses are supplied by one company and a few by the other, according to the decision of the owner or occupier at the time. ... Each company supplies both rich and poor, both large houses and small; there is no difference either in the condition or occupation of the persons receiving the water of the different companies ...

The experiment, too was on the grandest scale. No fewer than three hundred thousand people of both sexes, of every rank and station, from gentlefolks down to the very poor, were divided into two groups without their choice, and, in most cases without their knowledge; one group being supplied with water containing the sewage of London, and, amongst it whatever might have come from cholera patients, the other group having water quite free from such impurity.

When cholera returned to London in 1854 Snow determined to visit every house in these districts where a cholera death occurred and record the name of the supplying company. As he remarks 'The enquiry was necessarily attended with a good deal of trouble' and in many cases it proved impossible to find anyone who knew the name of the water supplier. Fortunately a simple chemical test based on the high salt content of the Southwark and Vauxhall company's water ('part of that' he wrote 'which has passed through the kidneys ... of two millions and a quarter of the inhabitants of London') enabled him to deal with these cases as well. He communicated his initial findings to Farr 'who was much struck with the result' and arranged official assistance for the last three weeks of the investigation. Snow summarised his results in Figure 1.2. (A star \* indicates that the apportionment of deaths among water sources within the sub-district involved a small amount of estimation.)

It is a maxim among practical statisticians that 'The data you need are not the data you have, the data you have are not the data you want and the data you want are not the data you need.' Although the total number of houses supplied by each company was known, this total was not broken down by district. The simplicity of Snow's 'grand experiment' was thus marred by the fact that he could not directly

separate those districts supplied by both companies from those supplied by only one or the other. However, all the districts are contiguous and show similar death rates for the previous 1848 epidemic (when both companies drew from similar sources), and the effect shown in Table 1.1 is so marked that it can hardly be due to some subtle difference between the districts served†.

Just as Snow was completing his case by case enquiries into the districts south of the Thames detailed in his tables, there was a dreadful outbreak of cholera north of the Thames in Soho. 'Within two hundred

†When a district by district breakdown of the number of houses supplied by each company later became available, Snow reanalysed his data but the pattern was unaltered. He calculates the relative mortality of consumers of the two water suppliers as being in a ratio of about 1 to 6.

Figure 1.2: Snow's table of cholera deaths for districts with mixed water supply, 1854.

Sub-Districts.	Population in 1851.	Deaths from Cholera in the seven weeks ending 20th August.	Water Supply.				
			Southwark & Vauxhall.	Lambeth.	Pump-wells.	River Thames and ditches.	Unascertained.
*St. Saviour, Southwark	19,709	125	115	—	—	10	—
*St. Olave, Southwark	8,015	53	43	—	—	5	—
*St. John, Horsleydown	11,360	51	48	—	—	3	—
*St. James, Bermondsey	18,899	123	102	—	—	21	—
*St. Mary Magdalen	13,934	87	83	—	—	4	—
*Leather Market	15,295	81	81	—	—	—	—
*Rotherhithe	17,805	103	68	—	—	35	—
*Battersea	10,560	54	42	—	4	8	—
Wandsworth	9,611	11	1	—	2	8	—
Putney	5,280	1	—	—	1	—	—
*Camberwell	17,742	96	96	—	—	—	—
*Peckham	19,444	59	59	—	—	—	—
Christchurch, Southwark.	16,022	25	11	13	—	—	1
Kent Road	18,126	57	52	5	—	—	—
Borough Road	15,862	71	61	7	—	—	3
London Road	17,836	29	21	8	—	—	—
Trinity, Newington	20,922	58	52	6	—	—	—
St. Peter, Walworth	29,861	90	84	4	—	—	2
St. Mary, Newington	14,033	21	19	1	1	—	—
Waterloo Road (1st)	14,088	10	9	1	—	—	—
Waterloo Road (2nd)	18,348	36	25	8	1	2	—
Lambeth Church (1st)	18,409	18	6	9	—	1	2
Lambeth Church (2nd)	26,748	53	34	13	1	—	5
Kennington (1st)	24,261	71	63	5	3	—	—
Kennington (2nd)	18,848	38	34	3	1	—	—
Brixton	14,610	9	5	2	—	—	2
*Clapham	16,290	24	19	—	5	—	—
St. George, Camberwell	15,849	42	30	9	2	—	1
Norwood	3,977	8	—	2	1	5	—
Streatham	9,023	6	—	1	5	—	—
Dulwich	1,632	—	—	—	—	—	—
Sydenham	4,501	4	—	1	2	—	1
	486,936	1514	1263	98	29	102	22

and fifty yards [roughly 250 metres] of the spot where Cambridge Street meets Broad Street there were upwards of five hundred fatal attacks of cholera in five days. The mortality in this limited area probably equal[led] any that was ever caused in this country even by the plague; and was much more sudden, as the greater number of cases terminated in a few hours.' Snow's biographer writes:

While then the vestrymen [parish authorities] were in solemn deliberation they were called to consider a new suggestion. A stranger had asked, in modest speech, for a brief hearing. Dr Snow, the stranger in question, was admitted and in few words explained his view . . . . He had fixed his attention on the Broad Street pump as the source and centre of the calamity. He advised the removal of the pump handle as the grand prescription. The vestry was incredulous but had the good sense to carry out the advice. The pump handle was removed and the [epidemic] was stayed.

In his account of the outbreak Snow presents his evidence for believing that the Broad Street pump was the cholera source in the form of a map (see Figures 1.3 and 1.4).

Although the Soho area had piped water, the supplying companies only turned on their mains for two hours a day and not at all on Sundays. Many of the inhabitants thus drew some or all of their supplies from one of the water pumps marked on Snow's map. The recorded deaths from cholera during the epidemic are represented by a black bar indicating the location of the house in which the fatal attack started.

I began this chapter by talking about abstraction. The twentieth century reader brought up in a culture of statistics, graphs and maps may not grasp the degree of abstraction represented by Snow's map. She should pause and try to imagine the agony and sorrow associated with each black bar and the fear and terror of a time when the dead 'were removed wholesale in dead-carts for want of sufficient hearses to convey them'. Snow's map is a representation from which all that is

Table 1.1. *Cholera deaths by water company, 1854.*

Company	Number of houses	Deaths from cholera	Deaths per 10 000 houses
Southwark and Vauxhall company	40 046	1 263	315
Lambeth Company	26 107	98	37
Rest of London	250 243	1 422	59

Figure 1.3: Snow's map of the Broad Street outbreak (much reduced in scale).

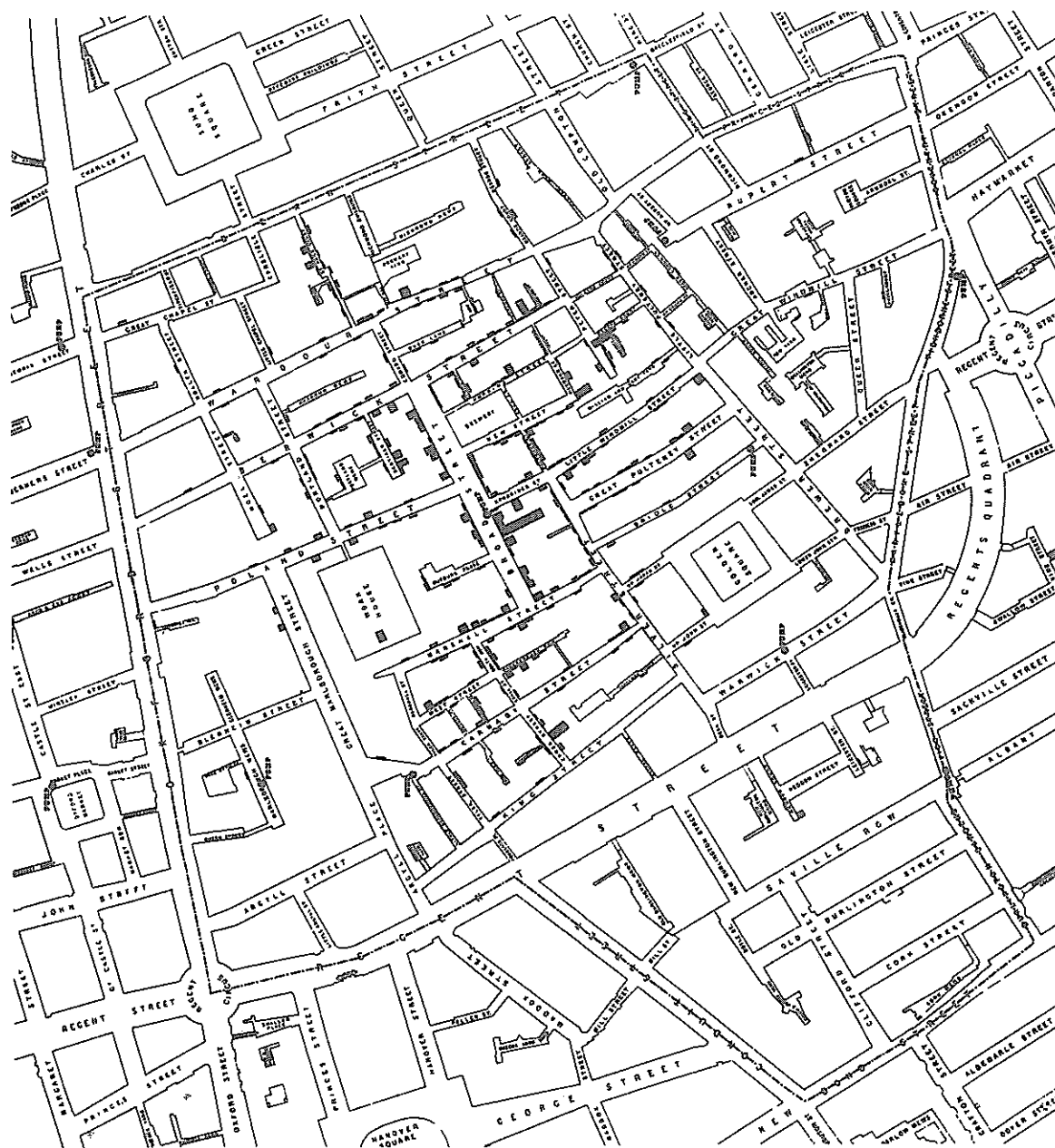
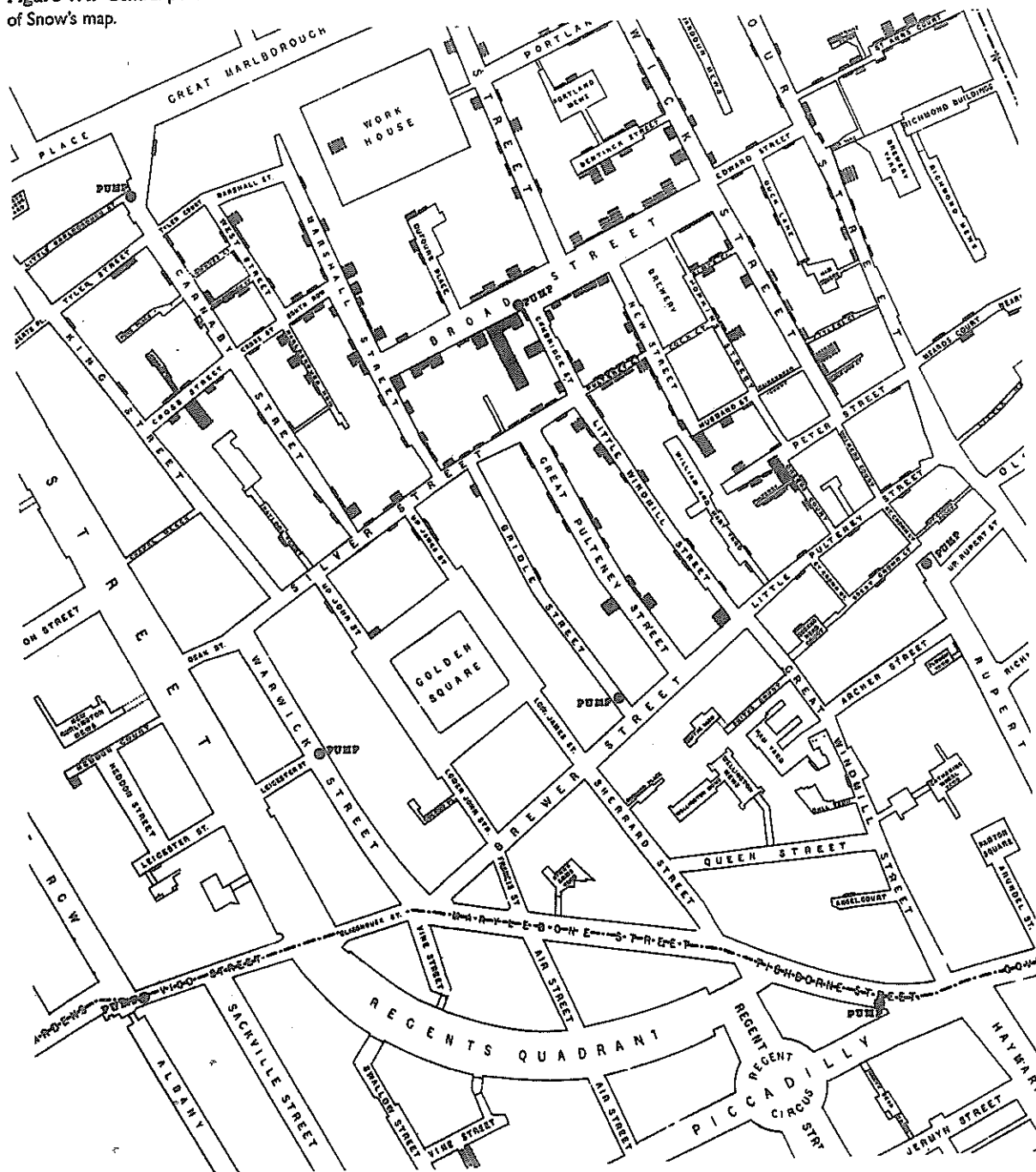




Figure 1.4: Central portion  
of Snow's map.



humanly important and all that is individual has been drained. It is, as it were, a shadow of a shadow and yet, by reducing all this human suffering to little black bars on a sheet of paper, Snow saved thousands upon thousands from similar deaths.

The remarkable thing about the Soho outbreak was its restricted geography. The map almost speaks for itself but Snow comments on it as follows:

It requires to be stated that the water of the pump in Marlborough Street, at the end of Carnaby Street, was so impure that many people avoided using it. And I found that the persons who died near this pump in the beginning of September, had water from the Broad Street pump. With regards to the pump in Rupert Street, it will be noticed that some streets which are near to it on the map, are in fact a good way removed, on account of the circuitous road to it. These circumstances being taken into account, it will be observed that the deaths either very much diminished, or ceased altogether, at every point where it becomes decidedly nearer to send to another pump than the one in Broad Street. It may also be noticed that the deaths are most numerous near to the pump where the water could be more readily obtained.

Snow gives other significant pieces of evidence. The Broad Street Brewery had its own well and allowed each workman a certain amount of malt liquor. None of its 70 or so employees fell seriously ill. A factory on the same street kept two tubs of water permanently filled from the Broad Street pump for its workpeople to drink from. Eighteen out of its 200 employees died of cholera. Snow also recounts the striking story of Mrs Eley, the widow of the founder of the factory, who had retired to Hampstead West End and

... had not been in the neighbourhood of Broad Street for many months. A cart went from Broad Street to West End every day, and it was the custom to take out a large bottle of the water from the pump at Broad Street, as she preferred it. The water was taken on Thursday, 31st August, and she drank of it in the evening, and also on Friday. She was seized with cholera on the evening of the latter day, and died on Saturday ... . A niece, who was on a visit to this lady, also drank of the water; she returned to her residence, in a high and healthy part of Islington, was attacked with cholera, and died also. There was no cholera at the time either at West End or in the neighbourhood where the niece died.

(However, a female servant who also drank the water did not contract the disease.)

Because we know that germs exist and cause disease we are happy to accept Snow's evidence at face value. Cholera can spread through

the water system and in the case of the Soho outbreak the source must have been the Broad Street pump. His contemporaries were less happy to accept a theory which postulated an invisible life form. A further problem with Snow's theory in so far as it concerned the Broad Street pump was that he was unable to explain how it became contaminated. The pump-well was opened and carefully inspected without revealing any 'hole or crevice by which impurity might enter' and chemical tests failed to reveal any particular contamination. It is thus not surprising that the government inspectors appointed to report on the outbreak entirely rejected Snow's theories.

The extraordinary eruption of cholera in the Soho district which was carefully examined ... does not appear to afford any exception to generalisations respecting local states of uncleanness, overcrowding, and imperfect ventilation. The suddenness of the outbreak, the immediate climax and short duration, all point to some atmospheric or other widely diffused agent still to be discovered, and forbid the assumption, in this instance, of any communication of the disease from person to person either by infection or contamination of water with the excretions of the sick.

Although the vestrymen joined the inspectors in rejecting Snow's condemnation of the pump, they seem to have felt that more investigation was called for and they set up their own committee of enquiry. In the face of governmental obstruction and local doubts (would not an enquiry damage slowly returning confidence and trade?), the committee pressed ahead with a door to door survey of the entire district. The curate of a local church, the Reverend Henry Whitehead, volunteered for the massive task of surveying Broad Street itself and managed to interview well over half its original inhabitants. (A good account of his work is given in [97].) Initially opposed to Snow's theories, he was forced to change his mind as the evidence accumulated and he found that of the 137 persons who drank water from the pump 80 developed cholera whereas of the 297 who did not drink the water only 20 did. Finally he discovered the key to the mystery. Just before the outbreak a baby girl had died of what could have been cholera in a house with a privy only a few feet away from the Broad Street pump. Digging revealed that crude and wrongly constructed drainage provided a nearly direct route for the contamination of the pump water. Moreover, the day that the pump handle was removed another occupant (the baby's father) contracted cholera and, in all probability, it had only been Snow's timely intervention which had prevented a second outbreak.

Snow died, hard at work on a book on anaesthesia, four years

later. His book on cholera which cost him £200 to prepare and publish sold only 56 copies but 'Dr Snow's Theory of Cholera' gradually won acceptance among many of those concerned with the disease. Among those convinced by Snow was William Farr. When an explosive epidemic of cholera hit East London in 1866 he was 'thus prepared ... to scrutinise the water supply' and, despite denials by water company officials, traced the source of the epidemic to open ponds, tainted by sewage from a nearby river, which were being used as emergency reserves. This practice was stopped and the epidemic ceased.

The New York epidemic in the same year was also handled according to Snow's ideas. It was not necessary to accept, or even to understand, the theoretical underpinnings of Snow's views to follow his practical recommendations. 'Boiling drinking water or disinfecting clothing and bedding were measures that any alert physician or board of health could carry out. At least there was no harm in trying.' Although the city had greatly increased in size and had certainly not become any healthier in general, the number of deaths was one tenth that in the previous epidemic of 1849.

The movement for clean water and proper sewerage, which was fuelled by many other sources, reached a successful conclusion in Europe before the end of the century. In 1883 Koch isolated the bacillus for cholera, providing the causative agent which Snow had been unable to give.

The last major European outbreak of cholera occurred in Hamburg in 1892. The merchant oligarchy which ruled the city had repeatedly postponed expensive changes in its water supply system and the inhabitants drank untreated water from the Elbe. The neighbouring town of Altona had a water filtration plant. A street divided the two cities. On one side the cholera raged unchecked; the other side was spared almost completely. John Snow had won his argument.

## 1.2 An altar of pedantry

The *Wall Street Journal* is a newspaper which prides itself on its hard-headedness†. On 2 June 1987 it ran an article entitled 'Human Sacrifice'.

Last Friday an advisory panel of the Food and Drug Administration decided to sacrifice thousands of American lives on an altar of pedantry.

Under the klieg lights of a packed hearing room at the FDA, an advisory panel picked by the Agency's Center for Drugs and Biologics declined to recommend approval of tPA, a drug that dissolves blood clots after heart attacks. In a 1985 multicenter study conducted by the US National Heart Lung and Blood Institute, tPA was so conclusively effective at this that the trial was stopped. This decision to withhold it

†In my experience people who claim to be hard-headed tell us more about their hearts than their heads.