John Snow revisited: Getting a handle on the Broad Street pump

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On September 7, 1854, a special committee of the parish of St. James, Westminster, London, met to deal with a sudden and violent outbreak of cholera in the neighborhood near Golden Square. After being relatively spared by earlier cholera epidemics in 1831 and 1848-49, St. James’s had suffered seventy-eight deaths the previous week, and totals for the current week were already mounting above 200. As the committee deliberated, a local physician, Dr. John Snow, asked permission to address them. Snow described his investigation of the cholera deaths in the area, revealing a marked clustering of fatalities around a single pump in Broad Street—a result that Snow later interpreted with a spot map. His interviews with survivors showed that the overwhelming proportion of the victims had drunk water from the pump. The committee ordered the handle of the pump removed on the following day.1

Commentators have embellished the Broad Street pump episode ever since Snow’s death in 1858. Snow’s self-taught biographer was the first to assert that the removal of the pump handle caused the cessation of the cholera outbreak;2,3 even though Snow’s own figures showed that the deaths in the locality had already begun to wane by September 7. A more dramatic variant has Snow personally removing the handle after stubborn officials refused to heed his data.4 On visits to London, we have witnessed walking-group guides describing how Snow waved the handle at his detractors. Even a display case in the Wellcome Institute Galleries of the Science Museum attests the end of the St. James outbreak with the removal of the pump handle. More recently, a popular comic strip transposed the incident to “the days of King Arthur,” and depicted the physician vigilantly removing the pump handle in the dead of night.5

When we study the Broad Street pump episode in detail, and place Snow’s work in the context of the medical and social beliefs of his time, a picture of a bold and original theorist and investigator emerges. No exaggeration or misrepresentation turns out to be necessary to explain why Snow has come to be seen as a hero by many modern epidemiologists.

Snow’s views on cholera

John Snow (1813-1858) grew up in York, the son of a laborer, and learned surgery by apprenticeship. He moved to London to upgrade his qualifications, write a formal study, eventually earning the M.D. degree from the University of London. He first became well known as a pioneer anesthetist, and in 1853 administered chloroform to Queen Victoria at the birth of Prince Leopold. His skill and industry is suggested by some dates relating to his early work with anesthetics—he first saw ether administered as an anesthetic in London in December 1846; by the end of January 1847, he had designed a new apparatus for administering ether in controlled concentrations; and in September 1847 he published a monograph describing his research into the actions of ether and discovering nearly eighty surgical cases in which he had administered it. He proceeded to do extensive research on anesthetics, write, for instance, the relationship between anesthetic properties and solubility in the blood. Snow’s insistence upon carefully controlling the dose of anesthetic administered, and on continuously monitoring the patient’s clinical response, were extremely influential in the development of anesthesia as a medical specialty in England.6

The income from his anesthesiology practice permitted Snow to reduce his general practice commitments so that he could pursue an obsession: to find an explanation for the communication of cholera from person to person. As an apprentice in the
north of England, Snow had noted for coal miners afflicted with cholera in the
epidemic of 1853-54. By the time another epi-
demic of cholera struck England in
1865-69, or perhaps much earlier, Snow
was skeptical about the prevailing View
that cholera was caused by impure air.

Conventional thinkers pointed to nat-
ural causes such as unfavorable atmos-
pheric and climatic conditions over
swampy areas, which could transform
decaying organic matter into poisonous
cums, or miasmas. When diffused into
the air and inhaled, the poison was
thought to enter potential victims’
blood and result in varying degrees of
inflammation, depending on individual
humoral dispositions. Most victims de-
developed diarrhea and recovered; but as
particularly susceptible individuals, the
diarrhea progressed to cholera.78-80

Some etiologists argued that whereas
vapors from decaying matter
whether produced by nature or hu-
mankind could cause cholera in suscepti-
ble individuals, the disease could also be
spread by personal contact (contagi-
ion), particularly by inhaling the
noxious breath of cholera victims.81-83

New medical knowledge based on
pathologic anatomy, clinical statistics,
and an emerging cellular theory of dis-
ease had yet to affect actual medical
practice. Typical medical practitioners
and most laypersons in the 1860s and
1870s, continued to view disease in hu-
moral terms as generalized disruptions
of the body’s natural balance, humoral-
ized framed most diseases as stages of
general inflammation. It was widely ac-
cepted, for instance, that both diarrhea
and typhus could rapidly progress to
cholera if either patient or healer mis-
managed the initial humoral imbal-
ance.84 But cholera was appearing in
this two-illnilential world View. By the
mid-nineteenth century, most physicians ac-
cepted both inoculation and vaccina-

tion as preventive against smallpox —
specific therapeutics against a specific
disease. There was also growing skepti-
cism in some quarters about the efficacy
of traditional therapeutic procedures such
as mercury and bleeding.9-11 But noti-
faction in the casebooks Snow kept sug-

gest that, as a general practitioner, he
was a conventional humoralist when it
came to diagnosing and prescribing.12

It is clear that by 1848 Snow had con-
cluded that narrowly miasmatic explo-

dations of cholera were unsatisfactory
because they could not account for the
disease’s documented association with
human transportation and travel routes.
That is, cholera must be contagious.
Moreover, a general blood poisoning
(resulting from inhaled miasmas or ef-
fluvia) could not explain why cholera
appeared to be a local affection of the
intestinal canal. Reasoning from anal-
ogy to diseases caused by intestinal
worms, Snow developed a hypothesis of
the pathophysiology of cholera as a
disease specific to the gastrointestinal
tract, caused by “some material which,
being accidentally swallowed,”92-12 multiplies in the intestines and then is
excreted in its victims’ watery stools.12-13

This idea led to the further hypothesis
that a healthy person could contract
cholera after contact with clothing,
food, or water contaminated by cholera
evacuations — water being of special
interest because it could best explain
transmission over larger distances and
outside the immediate household.
Snow deduced that the causative mat-

John Snow (right) and his map of cholera cases in Golden Square, London, 1854.
for was both particulate and colloidal of multiplying within the gut. In 1845, he stated that he did not think that the partic-
ules were "veritable animals, or even animalcules," and suspected a chemical process akin to fermentation or putrefac-
tion.11, 12 By 1855, he was referring to the particle as "most likely flat at a cell."13 It would, however, probably be overreading the evidence to view Snow as a true germ theorist ahead of his time.12, 26-27

Since Snow was admittedly unable to provide concrete evidence of the exist-
ence of a causative agent, he needed empirical verification for his hypoth-

esis of how cholera was transmitted. In mid-August 1849, Snow studied two
local choleran outbreaks within greater London (Surrey Court, Horsleydown, and Albion Terrace, Wandsworth Road), which strongly suggested me-
nerborne transmission. Each outbreak oc-
curred after one person in a row of
houses had become sick with diarrhea or cholera, after which the sewage from that house entered the water supply re-
ed upon by the other houses. Neatly
streets, which would presumably have
been exposed to the same general at-
mospheric conditions, were relatively
free of cholera. The few evidence from these living experiences, while admi-
gradually fragmentary, nevertheless en-
hanced Snow to publish a short monograph on the rhode of transmis-
ion of cholera within days of comple-
ing his investigations.14

Suggestive parallels exist between Snow's overall approach and the scien-
tific method suggested by John F.W. Herschel (1829-1971), an influential at-
ronomer. Herschel is generally cred-
ited with laying the conceptual hypothenusio-deductive method of ex-
perimental science. According to this method, investigators might reason ab-
strctly about how known facts should behave in new circumstances. For in-
stance, having in mind certain facts about the waterborne transmission of cholera, and then speculating about the circulation of a block of dwellings such as Surrey Court or Albion Terrace, Snow predicted that he would find, first, an isolated case of cholera, then, a means by which fecal contamination
could enter the local water supply, and
last, the occurrence of numerous other
cases among those using that water. Herschel also supported reasoning from analurgy, as Snow did in compar-
ing the choleran disease "poison" to the
known properties of intestinal para-

ta. Herschel emphasized how important it is for the investigator to seek out data that appear at first to disprove the hypothesis, as well as data that appear to confirm the hypothesis.11 Hertzel also spoke approvingly of the application of laws of probability to scien-
tific investigation.15 He argued, he said, that a person has fired a pistol 100 times at a water fountain to wall some yards away.

Again, suppose, the water to have been taken away, and we

were called upon, in the mere evi-
dence of the marks on the wall, to say where it had been placed; it is

clear that no reasoning would en-

able any one to say with certainty;

yet there is assuredly one place

which we may fix on with greater

probability of being right than any

other.11, 15-18

This example anticipates Snow's use of the snowball technique in his 1854 epio-
demiological investigation.

Snow's Golden Square Investigation

At the time of the outbreak in Golden Square, Snow was engaged in a major

survey of the relationship between cholera mortality and water supply in South-

London. Two water companies, the Lambeth Company and the Southwark and
Vauxhall Company, supplied most of that region during 1848-49, both

to their water from the Thames near the

outflow of major sewers. By 1854, how-


the Southwark 2nd Vauxhall Company had

used the same source as below. The two

companies had laid their mains along

many of the same streets, with adjacent

houses sometimes drawing their supply from

different companies. Snow stated:

No fewer than three hundred

thousand people of both sexes, of
every age and occupation, and of
every rank and station, from got-

little kids 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, what-
ever might have come from the

cholera patients, the other group

having some quite free from such

impurity.15

While still occupied with this South

London study, Snow learned of the out-

break near Golden Square, less than

a ten-minute walk from his residence. He

suspected that a local water source was

the cause because the outbreak was sud-

den, violent, and concentrated. But a

personal inspection of five local pumps on September 3 revealed no obvious

signs of organic impurity. Realizing that this water might have dissi-
nipated since the start of the out-

break, however, Snow determined to

apply the snowball technique to recon-

struct what had happened. He took a

list of all cholera deaths registered in

that district during the week ending

September 2 and made house-to-house

inquiries regarding all deaths occurring

between August 31 and September 2.

He found that seventy-three of the

eighty-three deaths attributed to

cholera were clustered near the Broad

Street pump; and there was evidence in
eight of the remaining ten cases that the
victim had drunk water from the
pump.13

True to Herschel’s method, Snow in-
quired specifically into a number of
cases that initially cast doubt upon
the pump theory. For instance, a work-
house and a brewery located very close
to the pump suffered little from cholera.
Snow learned that both had deep wells
on their premises and so did not use
any pump water. By contrast, an an-
numilation factory that filled its water
tubs with pump water had a high rate
of cholera among its workers, even
though many of them lived some dis-
tance from Broad Street. Snow also
learned of the case of the “Hampstead
widow,” who had previously lived in
Broad Street and had such a high opin-
ion of the pump’s water that she had
some of it sent daily to her in Hamp-
stead by cart. She and a visiting niece
who also drank some of the water both
died of cholera; Hampstead was other-
wise free of the disease.

Plan of relationship between cesspool at Number 40, Broad Street, and the pump.

The parish response
Snow was not the only one who ini-
tially had difficulty in associating im-
purity with the water of the Broad
Street pump. The water companies of-
ten supplied running water for only a
few hours a day, forcing users to collect
the water in barrels and cisterns. Espe-
cially in poor and crowded neighbor-
hoods, these vessels were poorly
maintained and often filthy. By con-
trast, the water from some street wells
seemed far cleaner.

Henry Whitehead (1825-1896), a clergy-
man appointed along with Snow to a
special cholera inquiry committee con-
vened by the police to investigate the in-
wanted outbreak, was initially skeptical of
Snow’s hypothesis. He knew of several
residents of Broad Street who seemed to
have recovered from cholera-induced
collapse by drinking freely of the pump
water, and imagined that a careful in-
quiry by a person who was more inti-
mately acquainted with neighborhood
would demolish Snow’s theory.13

Whitehead was able to conduct a com-
prehensive house-by-house survey of
Broad Street, whereas Snow, in his
three-day investigation covering a
much larger area, had relied mostly on
published data, had looked only at fatal
cholera cases, and had not reviewed
systematically people who had not
been attacked. Whitehead’s findings,
however, soon caused him to change
his views — among 101 residents of
Broad Street who had had an attack of
cholera, 80 drank the pump water and
20 did not; while among 136 residents
free of cholera, 57 had drunk the pump
water while 279 had not.13

The parish inquiry committee also
asked Snow to write up his results in
November 1854. Snow contributed a
characteristically thorough report, in-
cluding data unavailable to him in Sep-
tember and adding a table to show
cholera fatalities by day of the outbreak.
“It will be observed,” wrote Snow,
that the daily number of
fatal attacks was already
much diminished by
September 8th. For the
day when the handle of
the pump in Broad Street
was removed, and it is
not improbable that the
water had, from some
cause or other, ceased to
contain the cholera poi-
son.13

Nonetheless, it was Whitehead,
not Snow, who explained
how the Broad Street pump
came to be contaminated in the
first place. An infant at 40
Broad Street had developed
severe diarrhoea on August 28
and died on September 2.
The mother had soaked the in-
fant’s diapers in pails that she
emptied into a cesspool out-
side the front of her house —
three feet away from the
Broad Street pump. (Snow
did not investigate this case be-
cause it was listed in the Reg-
ister as “diarrhoea, not
cholera.” Whitehead’s discov-
ery led the inquiry committee
to order an excavation of the pump and cesspool area, even though the pump and well had previously been examined by the paving board of the parish and declared to be without defect. The new excavation revealed that the well and the cesspool both had decayed brick linings that readily allowed seepage from the house drains and cesspool into the well.21, 22

The official public health response

Both the parish committee report that endorsed Snow’s hypothesis, as well as the expanded edition of Snow’s cholera monograph that described his South London and Golden Square investigations, received favorable review in The Lancet.23 But Snow’s ideas fared less well, initially, with national public health authorities. Here we summarize briefly the reactions that we have described in more detail elsewhere.3

At first glance, Snow’s arguments might seem well adapted to impress public health officials. He utilized statistical arguments of the sort favored by Benthamic health reformers such as Edwin Chadwick (1800-1890) and William Farr (1807-1883) in the previous decades.24 His denunciation of polluted water as the culprit was in keeping with the Victorian sanitary revolution and feijt for cleanliness. But Snow’s explanation depended upon specific causation and localized response in the alimentary tract, whereas the sanitary reform movement of the day was mistrustful with respect to disease causation, and humoralist with regard to host responses. Filth was equated with surface appearances that offended the senses, not with microscopic particles inadvertently ingested by particular victims. And filth and bad smells were thought to cause the entire gamut of disease, depending upon the constitutional predisposition of each individual; most sanitary reformers thought it premature to identify any particular sort of filth as causing one specific disease, while holding other sanitary conditions blameless. This dominant view was expressed in an editorial in The Times of London on October 19, 1854:

Arthur Hill Hassall’s drawing of “vibritones” in the rice-water stools of cholera victims. [From, Bernardino M. Jaffé & Filippe Philby, A summed on sera of cholera (here, 1852-1853).]

Let us give the smallest amount of attention to those gentlemen who would drive on any [single form of sanitary] improvements exclusively as a specific against Cholera...With figures you may literally prove anything.

...Common sense and the univer-
sal experience of mankind inform us that a constant and fresh supply of pure water is one of the most important specifics in the pharmacopoeia of the ALLMIGHTY against all disease...[T]he preference be given to those [water companies] who supply the fluid in its purest state, with much reference to the particularities of cholera.25

Further, the medical literature of the day contained many reports of cholera outbreaks that seemed to exclude a waterborne explanation. Snow himself even acknowledged a case report of a hapless hospital worker who had mistakenly drunk from a vessel containing the “rice-water” stools of a cholera patient but never contracted the disease.26 Snow was misinterpreted as attributing “every case of Cholera to the use of polluted water.”27 28 and caricatured as someone who tolerated general filth so long as the water supply was clean.

Thus, the findings of the Committee for Scientific Inquiry of the General Board of Health endorsed an expansionist approach to sanitary reform. Although the report mentioned Dr. Snow’s “belief,” the committee added five reasons to adopt it—despite the fact that they represented the updated spatial map of cholera cases in the Golden Square area contained in the report of the parish committee.29 Instead, the General Board of Health concluded that stagnant water in the air, rather than impurities in the water, was the principal source of the 1854 epidemic throughout England, whereas a certain local state of uncleanliness with pathologi-

A striking example of the power of framing scientific paradigms is evident in the cholera inquiry led by medical scientist Arthur Hill Hassall (1851-1894) to the Committee on Scientific Inquiries. He observed an epidemic of cholera in London and realized that it marked the first time that he called “vibritones” in the rice-water stools of cholera victims. Others found a few of these particles in the air of a cholera ward in a hospital and in some impure water samples. Hassall noted their absence in normal stool. Writing at the end of his life, with the benefit of hindsight, Hassall concluded that he must have been looking at rice water, almost thirty years before that bacterium was first recognized.30 In 1854, however, Hassall had to fit his empirical observations into a humoral world view, and so concluded that the vibritones were symptoms of the body’s response to cholera, not the cause. Imag-

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Later reactions to Snow's theory

Snow died in 1858 at forty-five; he suffered a fatal stroke virtually the day he completed the manuscript of his landmark monograph on chloroform and other anaesthetics. He had, however, lived long enough to see a slight shift toward his theories on cholera transmission among some sanitary reformers. William Fair, compiler of abstracts in the Registrar General's office and pioneer in the epidemiologic use of vital statistics, became enthusiastic about Snow's South London statistics early on and even helped Snow to obtain more data. In 1856, a second Board of Health report on the role of impure water in the 1854 epidemic, written by John Simon (1804–1900), medical officer of health of the City of London and a committed sanitary reformer on a misanthropic, attributed differences in cholera susceptibility in South London to the different sources used by the two water companies. But Simons never credited Snow's prior analysis, implying instead that the General Board of Health had independently compiled statistics that made a convincing case against impure water. Even writing forty years later, Simon maintained that Snow's investigation had merely "suggested," through Dr. Farr as intermediary, the lines for the General Board of Health study.

In the quarter century after Snow's death, some sanitary reformers did find Snow's statistics in the South London study convincing, but many of them selectively to business or micromanage world view. Dirty water, after all, was just a subcategory of filth, and everyone knew that filth causes disease. In 1883, Koch identified the cholera bacterium and demonstrated its presence in impure water at the site of an epidemic in India. But even Koch failed to cite Snow's research, despite the fact that Koch could have used Snow's earlier work to bolster his own case against sanitary reformers.

For English and Continental physiologists, the next apparent star on the cholera stage was Max von Pettenkofer of Munich (1818–1901). He held that an epidemic required three factors: a specific infectious particle; moist, porous soil containing decayed organic matter; and a toxic substance produced by the combined effects of the particle and the soil. Von Pettenkofer's theory was very popular in some areas, perhaps because it cohered partly with the emerging bacteriological perspective, perhaps because a multivalent explanation seemed more acceptable to materialists. Von Pettenkofer was no certain that Koch's bacillus, by itself, could not produce epidemics. This crippling tale brought von Pettenkofer additional converts, and for a time eclipsed the story of the Broad Street pump. In epidemiologic folklore, apparently less well publicized at the time, was the case of Rudolph Emmerich, a servant of von Pettenkofer's, who devised his principle a year experiment and developed a severe case of cholera for his pains.

The 1902 edition of Chol's textbook of medical states that cholera is propagated by contaminated water, omitting mention of von Pettenkofer, but again fails to mention Snow.

Some credit Snow's resurrection and current fame to the influence of the first professor of epidemiology at Johns Hopkins, Wade Hampton Frost, who edited a 1950 reprint of Snow's cholera monograph. The actual story is rather more complex; Snow was mentioned favorably in several nineteenth and early twentieth-century accounts. Frost may, however, have helped to shine the spotlight solely on Snow and thus eclipse the contributions of Whitehead and the parish committee. Snow's contributions, in retrospect, were substantial. He was able to reason from specific facts about the natural history and pathology of cholera, rather than from the dominant theories of the day. He then deduced from his pathology a physiological insights a hypothesis that could be tested by population-based, statistical methods, and constructed a theory that lent itself to experimental falsification, in contrast with miasmatic explanations that were so general as to appear to be "confirmed" by virtually any data.

Epilogue

Those wishing to do homage to John Snow and the parish board are warned not to look for the corner of Broad and Cambridge Streets in Snow's cholera monograph. Broad Street was extended, and renamed Broadwick Street in 1936, and Cambridge has become Lexington. In 1936, the corner pub — the "Newcastle-on-Tyne" in the days of the epidemic — was renamed "The John Snow" (a diabolic honor, since Snow was for a good part of his life a teetotaler), and a granite curbstone place at the sight of the long since demolished pump. In 1902, a more fitting tribute was erected, in the form of a reproduction of the pump itself — appropriately without a handle.

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