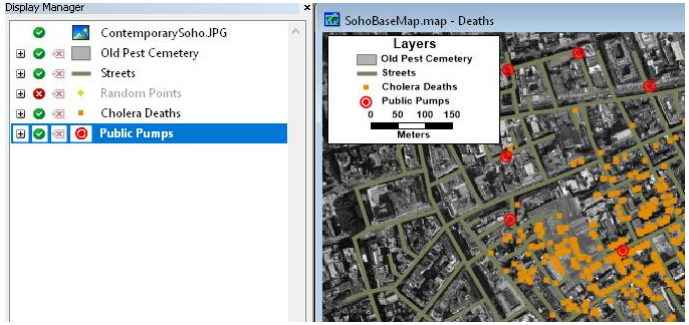
Soho Cholera Spatial Analysis

The objective of this tutorial is to identify with competing but related spatial analysis methods where most to the cholera deaths were concentrate and which pump was the closest to the cholera death.

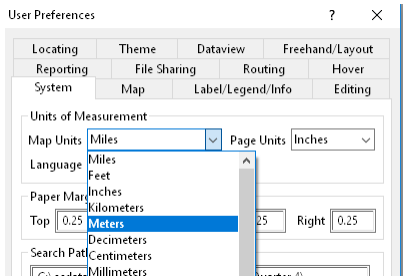
The data are based on John Snow's and the General Board of Health's investigation of the cholera epidemic in the summer of 1854 in Soho, London. More information on this study can be found in the appendix to this tutorial.

Setup Data

- Download **SohoCholera.zip** and unpack it into a tutorial directory of your choice.
- Open the map file **SohoCholeraBaseMap.map** with **File ▶ Open…** . Hint: A map file points to several layers and their visual attributes on the drive and package them together into map.
- Turn off the image layer **ContemporarySoho.JPG** . This image was obtained with Maptitude's **Tools ▶ Raster ▶ Google Earth Toolbar …** and is geo-referenced into the long/lat coordinates.

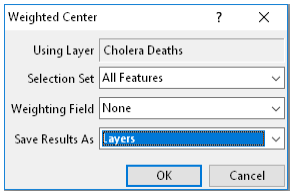


- Set the map units to meters with **Edit ▶ Preferences…**



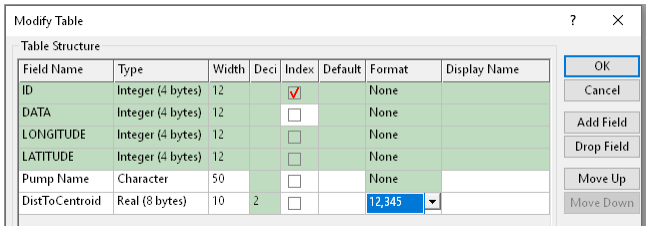
Task 1: Calculate the Center of Deaths and Distance to the Pumps

- Make the layer **Cholera Death** the working layer.
- Calculate the center of cholera death. Save the layer of the centroid and service area into a layer. Be careful use your tutorial directory as destination of these layers. Interpret the output.

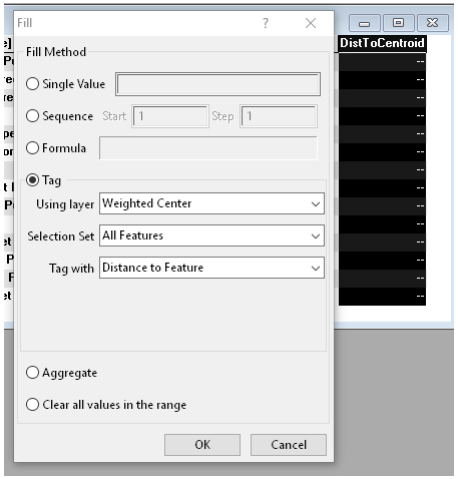


Note: the option **Weighting Field ▶ None** leads to the central point of the service area circle. In contrast, **Weighting Field ▶ Coordinates** calculates the geometric centroid (means of the death's longitude and latitude).

- In order to calculate the distance of the pumps to the newly generated centroid make public pumps the working layer.
- Open the pump's layer dataview and select the modify table options (you can also use **Dataview ▶ Table ▶ Modify…**)
- Add the field **DistToCentroid** to the dataview. Make sure it is of type **Real** .



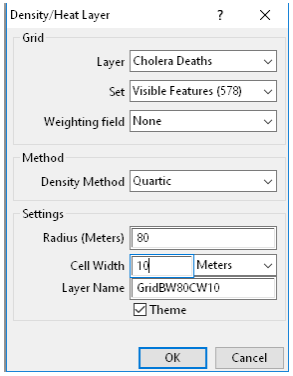
- Right-click on the header of the field **DistToCentroid** and select the **Fill…** options. Choose the **Tag** option, the **Weighted Center** layer and **Distance to Feature**.



- Sort the dataview by the distance to the central point. Which pump is the closest to the center of death?

Task 2: Density of Cholera Cases

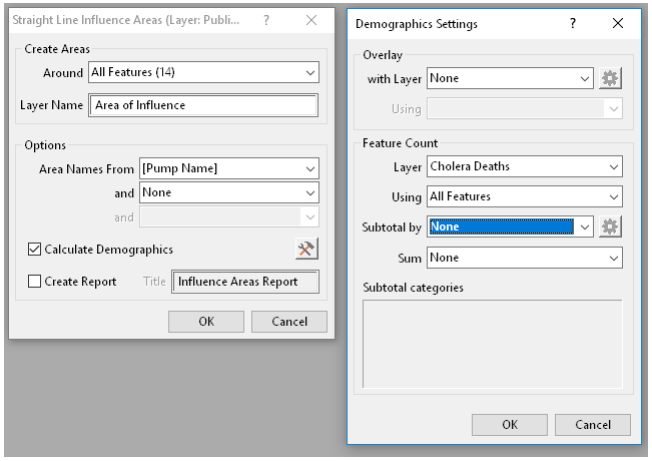
- Select **Tools ▶ Analysis ▶ Density/Heat Layer** with the parameters **Radius=80** and **Cell Width=10**:



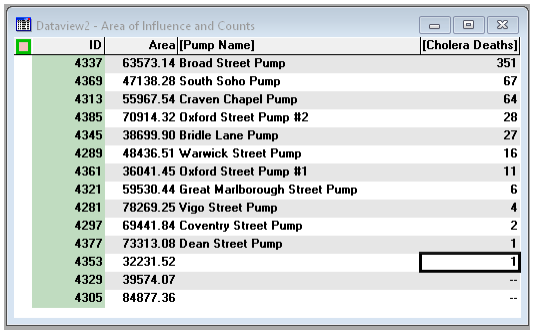
Interpret the patterns. What does the cell width do?

Task 3: Area of Influence

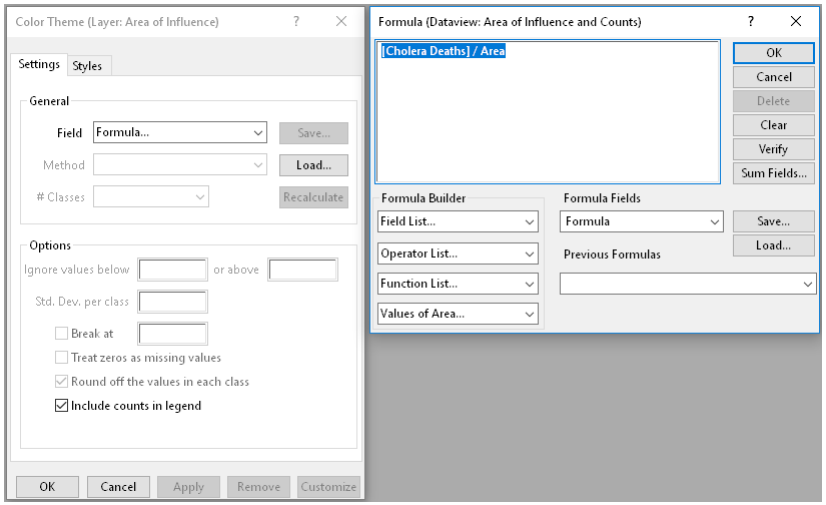
- Declare the pumps as working layer.
- Select **Tools ▶ Analysis ▶ Straight Line Influence Area…** . Continue to select **Calculate Demographic** to count the number of cholera death in each area of influence



- Make Area of Influence the working layer. Its associated dataview is:



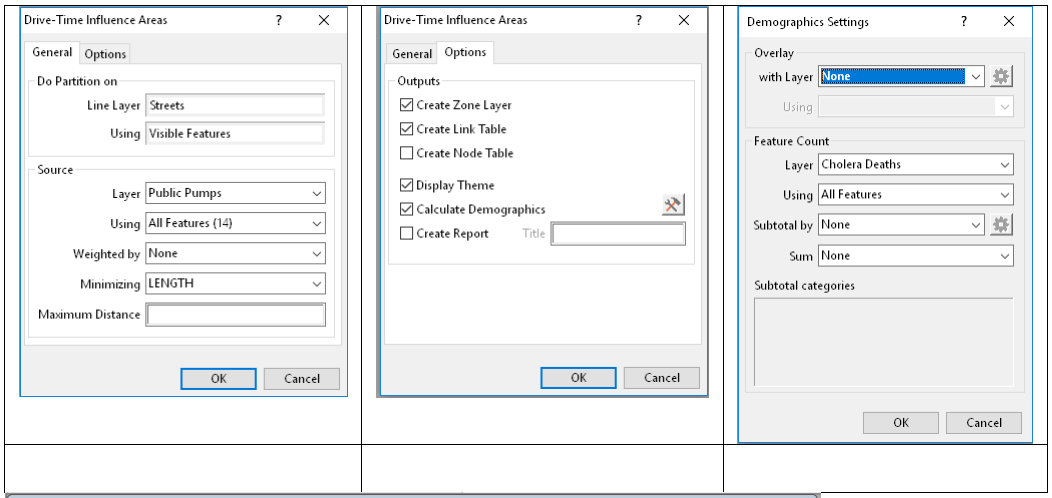
Map the density of death for the areas of influence with **Map ▶ Thematic Mapping ▶ Color…** . Define the formula **[Cholera Deaths] / Area** and choose just 5 classes.

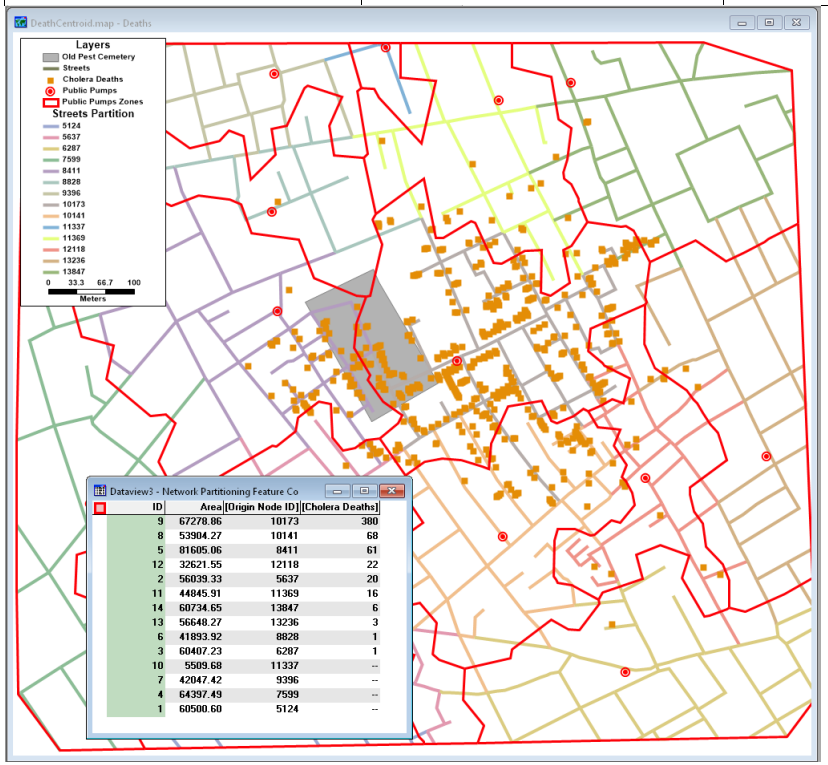


You may need to change the drawing order of the layers.

Task 4: Network Partitioning

- Hide the area of influence layer and make the **Streets** the working layer.
- Select **Tools ▶ Routing & Directions ▶ Drive-Time Influence Area…**.





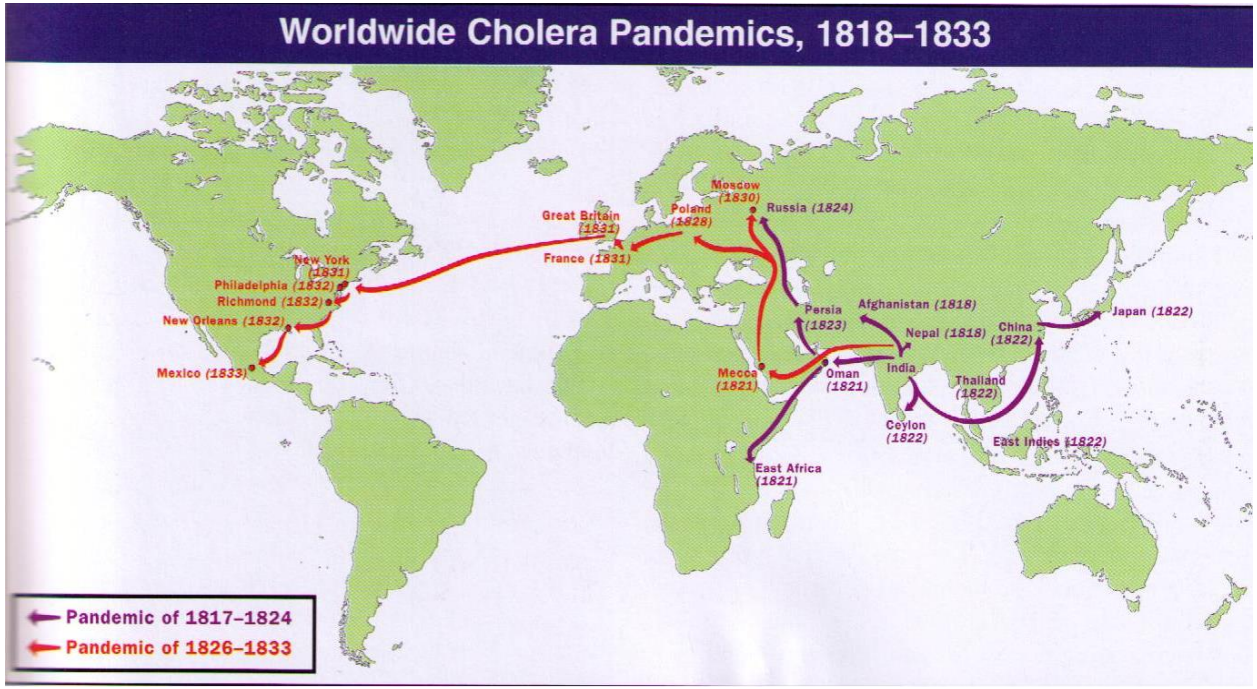
Tiefelsdorf, Spring 2018

Appendix: The 1854 Cholera Epidemic in London

General Information on Cholera

Global Distribution:

- World-wide known since the nineteenth century.
- Always locally endemic in India's Ganges River delta.
- Several pandemics in the early nineteenth century



- Mainly spread due to increased global mobility in the era of colonization and over-crown with bad sanitization in urban areas during the industrial revolution.

- Recent flair-ups in India, other parts of Asia, Africa, South and Central America (last major outbreak after hurricane Mitch, 1998)

Causative Agent:

- Bacterium *Vibrio Cholerae*
- Rapidly reproduces in human gastrointestinal tract. Impairs the capacity to absorb fluids.
- Can exist and reproduce for prolonged periods of time outside the human host in fresh and salt water
- Can live in a parasitic relationship with plankton Copepods
- Is dormant but still infectious in colder water, but flourishes in warmer water.
- The aftermath of natural disasters, causing infrastructure break-downs and dense encampments of survivors, are ideal breading grounds for cholera.

Symptoms:

- Incubation period 24 to 48 hours
- Mild to severe
- Severe symptoms: profuse diarrhea, vomiting, leg cramps
- Diarrhea leads to rapid loss of body fluids and essential minerals from the gastrointestinal tract. This causes dehydration, shock and subsequent death
- Without proper medical care case fatality is around 50 %

Treatment:

- Replacement of minerals and fluids lost through diarrhea.

- Critical cases require intravenous replacement
- Antibiotics can reduce duration and symptoms by attacking the bacterium.

Prevention and Control

- Use of clean water and cautious food preparation practices
- Travelers to areas with prevalent cholera should follow the motto: “Boil it, cook it, peel it or forget it”

Historical Impact:

- Social riots in major industrial agglomeration because cholera affect mostly the poor working class due to their cramped living conditions.
- Lead to specification of building codes focusing on sanitization
- Establishment of first Health Offices (General Board of Health under Edwin Chadwick, 1834)
- Establishment of first statistical bureaus capturing the general demographic patterns, birth, death and marriages (General Register Office und William Farr, Britain, 1836)
- Farr’s conviction: Statistics could uncover patters governing people’s lives, and that once these were discovered; society could develop tools to influence them.

The Cholera Epidemic in London 1854

- Discussion based on
  - Paneth N., et al., 1998. A Rivalry of Foulness: Official and Unofficial Investigations of the London Cholera Epidemic of 1854. *American Journal of Public Health*, **88**:1545-1553 http://www.ph.ucla.edu/epi/snow.html
  - Tom, Koch, 2005. *Cartographies of Disease. Maps, Mapping and Medicine*. ESRI Press

- Rothman K, and S.Greenland. *Modern Epidemiology. Chapter 2: Causation and Causal Inference.* Philadelphia: Lippincott Willians & Wilkins

- Scientific background:
  - The causal agent for cholera was not yet known in 1854. Robert Koch discovered it in 1884 while working in Bombay; Filippo Pacini isolated the bacterium earlier in 1854, but his finding and its significance did not become generally known.
  - The establish academic opinion followed Hippocratic tradition whose general perspective of good and bad airs and environments carried weight of a millennium of medical writing, thinking, and research. This lead to the diffuse *miasma* explanation.
  - In contrast, Snow's explanation was radical different but could not yet been proven until Koch's identification of *Vibrio Cholerae*. Snow suspected that Cholera was a contagious and water-borne disease.

The grand experiment

- A ubiquitous Cholera epidemic was ragging through London from mid-July to the end of September 1854
- The fatality was different in different areas of London
- Higher lying areas have had lower fatality than the lower lying areas around the Thames where also the population density was also much higher.

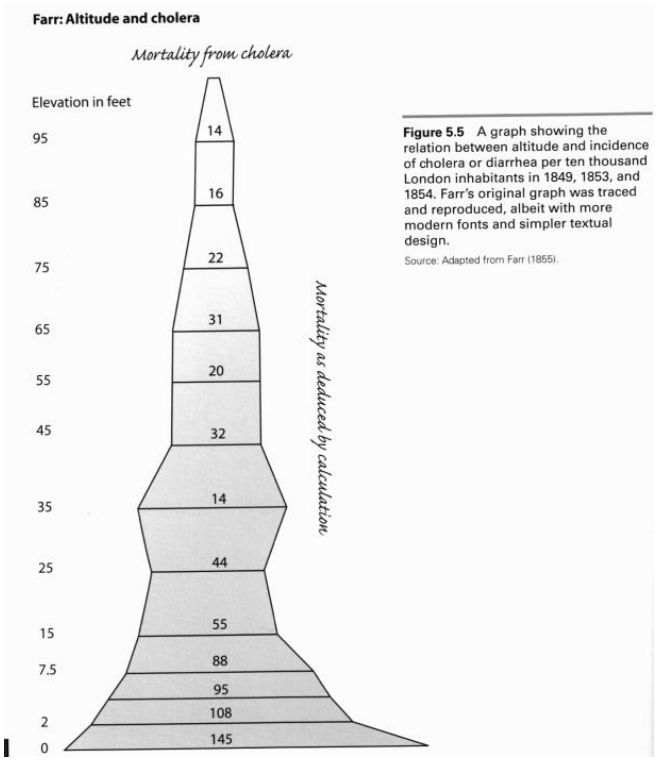


Figure 5.5 A graph showing the relation between altitude and incidence of cholera or diarrhea per ten thousand London inhabitants in 1849, 1853, and 1854. Farr's original graph was traced and reproduced, albeit with more modern fonts and simpler textual design.

Source: Adapted from Farr (1855).

- In addition, there was a difference in the fatalities in dependences on the different water service companies

Table 1.1.1 *Population, deaths from cholera and rate per 10,000 population in the areas served by the metropolitan water companies in the epidemic of 1849*

Water Company	Population	Deaths	Deaths/10,000 population
Southwark & Vauxhall	338,820	4,668	138
Lambeth	118,691	1,479	125
Kent	136,857	990	72
East London	443,915	2,312	52
Chelsea	192,236	876	46
New River	652,865	2,432	37
Hampstead	59,160	123	21
West Middlesex	249,950	473	19
Grand Junction	129,506	177	14

- The Southwark and Vauxhall Company took the water directly from the sewer-contaminated downstream Thames and served the low-lying neighborhoods of London
- In contrast, the Lambeth Company received its water from the cleaner upstream Thames and served predominately the higher lying areas of London.

- One area with 300,000 inhabitants was jointly served by both companies. A dual system of pipes was installed and the household could choose whether they buy 'fresh' water from either company

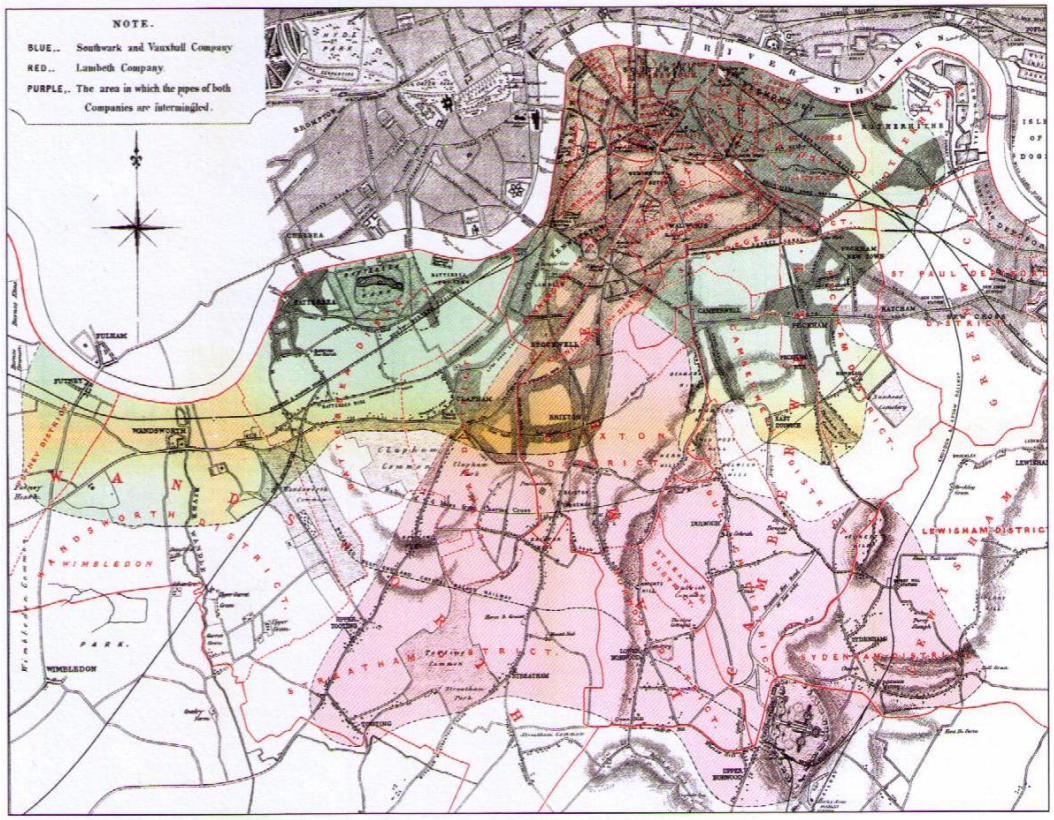


Figure 4.10 Snow's map of the relation between public water supply and cholera in London. Color variations distinguish between Southwark-Vauxhall, Lambeth, and conjoined water jurisdictions.

Source: Reproduced courtesy of College of Physicians of Philadelphia.

- To prove Snow's hypothesis that Cholera was water born and contagious Farr wrote: "To measure the effects of good and bad water supply, it is prerequisite to find two classes of inhabitants living at the same level {elevation}, moving in equal space, enjoying an equal share of means of subsistence, engaged in the

same pursuits, but differing in this respect, that one drinks water from Battersea {water supply}, and the other from Kew…"

- Snow found such an area that was jointly served. This area can be conceived of as a large *randomized trial*. People with identical characteristics are ***pseudo randomly*** assigned to either company. Potential other effects such as age were randomly distributed among both subpopulations. This allows to control for these characteristics and to identify the impact of the different risk factors. Snow demonstrated that those customers served by Southwark and Vauxhall Company, taking water downstream, experienced a higher death rates.

The Golden Square hot spot

- Against the background of the general cholera epidemic in London during the late summer of 1854 a hot spot of cases peak in Soho's Golden Square, August 31 to September 2.
- This hot spot drew attention by three groups of researchers with varying resources
    - John Snow. Individual physician residing in the Golden Square
    - The *Cholera Inquiry Committee* of the Parish of St. James, Westminster with a group of non-medical investigators.
      This committee was able to identify the index case (first cholera victim) and the structural failure of the Broad Street pump's foundation and an adjacent cesspool.
    - The Board of Health's *Committee for Scientific Inquiries* (CSI). A multidisciplinary research group, including medical, meteorological, and statistical/demographic experts, with sufficient field researchers. The field researchers were able to track diseased people, who were infected in the Golden Square but passed away elsewhere and they were able to collect mortality data for a longer time span.

- There were interactions among these groups and they shared their information.
- All committees generated spot maps of the cases and added information deem valuable:
    - Snow identify cases adjacent to the pump by its area of influence (shortest walking distance along the street network to the Broad Street pump)

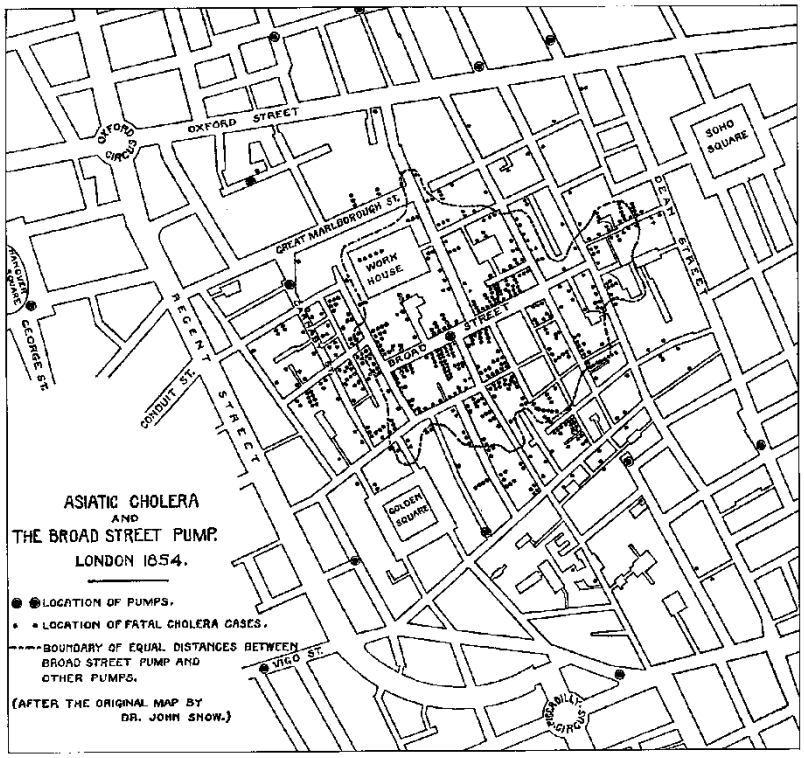


Figure 6.3 Sedgwick's 1911 adaptation of Snow's 1855 map of the Broad Street epidemic for Sedgwick's textbook on public health and sanitary science.

Source: Reproduction courtesy of University of Toronto Library.

    - The Cholera Inquiry Committee added existing sewer lines

  - The CSI added a medieval “Plague Pit” (1665), those grounds were supposed to be disturbed by sewer line construction. Foul odors were supposed to be emitted from the burial ground.
- Microscope just became an important tool in biological research and the CSI investigated stool samples and ambient air and water samples. They found animalcules matter in these samples, which however was deemed epiphenomenal (present everywhere).
- What would have happened if these would have had samples from a pre-cholera period to compare with?

Competing Hypothesis:

- **Snow** believed that agent of cholera was ***specific*** and ***contagious***: water contaminated by fecal matter leads to gastrointestinal manifestation.
  He had a clear causal mechanism in mind, where the ***cause*** precedes the ***effect***.
- Snow hypothesis was narrow and provided ample opportunity to refute it. It was able to deductively predict cases.
- Snow followed up on observations that initially refuted his hypothesis that the Broad Street pump is the source of hot spot:
  - Hampstead widow, who lived far from the pump. Her servant got water from the pump on her request.
  - Brewery workers in the Golden Square, who and their families received free beer. The brewery has had its own water well.
  - Relatives, who used inherited bed clothing of cholera victims.
  - Children, who passed by the pump on their way to school.
- The CSI adopted the prevailing anti-contagionist perspective which attributed cholera and many other diseases to the influence of decaying organic matter and its vaporous emanations or “miasma”.

Their approach was based on plain covariation, which allowed for spurious correlation and simple coincidental associations.

- This hypothesis was inductively derived by observations. It ignored cases that did not support the hypothesis.
- These emanations were nonspecific in that the causal pathway was general and happened under the "right" circumstances.
- This broad hypothesis is difficult to disprove because virtually all observations were coherent with it.
- The climate charts seem to support their hypothesis. But this is based on *spurious correlation*.
- The CSI dismissed Snow's hypothesis and found it irrelevant, because it had "no practical implications".
- The CSI hypothesis was environmental, one couldn't do much about it. Snow's hypothesis also was environment but would have permitted to interrupt the cycle of transmission.
- John Simon, a member of the CSI, later plagiarized Snow's report.
- An anecdote states that John Snow removed the handle from the Broad Street pump and therefore interrupting further introduction of the bacterium into the population.