

**Team ID:** BMES204

**School Name:** Barranca Mesa Elementary School

**Area of Science:** Epidemiology

**Project Title:** Code versus Cholera

**Problem Definition:**

John Snow believed that cholera was spread by drinking dirty water. He believed that the source of the cholera outbreak of 1854 was a public water pump on Broad street. He convinced the local council to remove the pump handle and the outbreak stopped. My research problem is to use Voronoi graphs to identify the infected water pump that caused the 1854 cholera outbreak in London.

**Background Information:**

John Snow (figure 1) created a map of the infected region in London. The map is shown in figure 2. He shows the locations of the water pumps and the number of people who died from cholera. In his map, the length of the bars next to the road represents the number of people who died of cholera. John Snow walked to find the closest water pump to each house (figure 3), and he showed that most sick people lived near the Broad street pump. He created a Voronoi graph. A Voronoi graph is a map with multiple points that shows areas that are closest to each point, such as a water pump.



Fig 1: A picture of John Snow

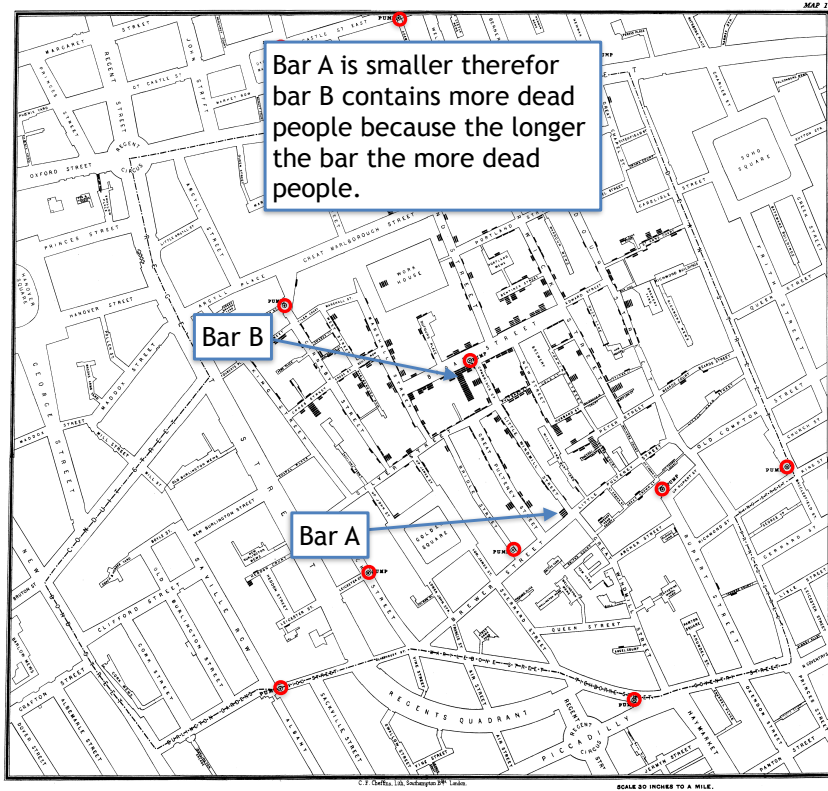


Fig 2: John Snow's map. The red dots are pumps.

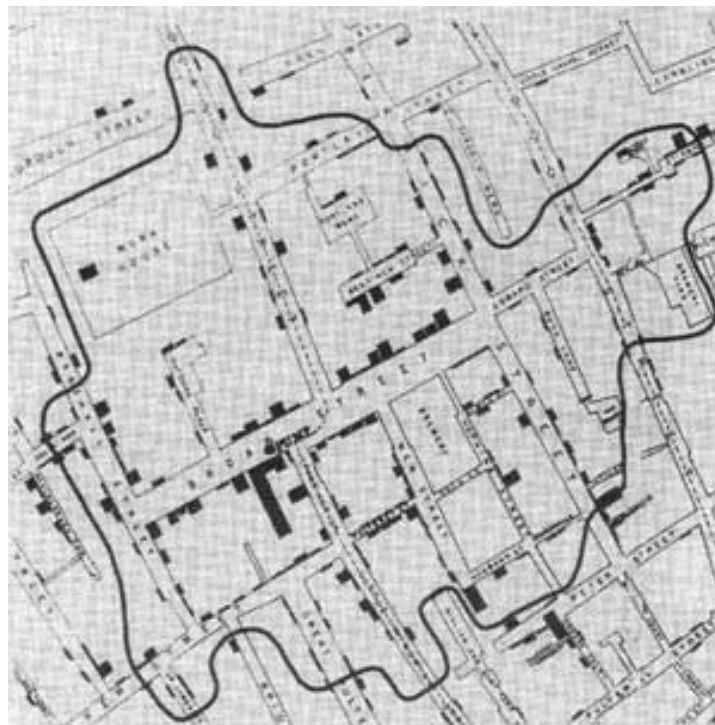


Fig 3: John Snow's original map showing the region of houses that are closest to the water pump on Broad street.

### Problem Solution:

I will use a Voronoi graph around the water pumps and then compare the area in which people are sick to the output of each segment of the graph. Then the area that matches up is the area with the infected pump.

The procedure that I will follow is as follows.

1. Download python 3 and scipy
2. Get the code for making a Voronoi graph.
3. Print the map of the area in which the outbreak was occurring that also has the pumps shown on it.
4. Label the pumps with a bright colored pen.
5. Find the coordinates of the pumps relative to the bottom corner of the map.
6. Put the coordinates into the Voronoi graph coding.
7. Run the code to make the Voronoi graph.
8. Then match the area in which people are infected to each of the areas around a pump. The area around a pump that matches the area of the infected people is the infected pump.

### Results:

I followed the procedure above and produced a Voronoi graph (figure 4).

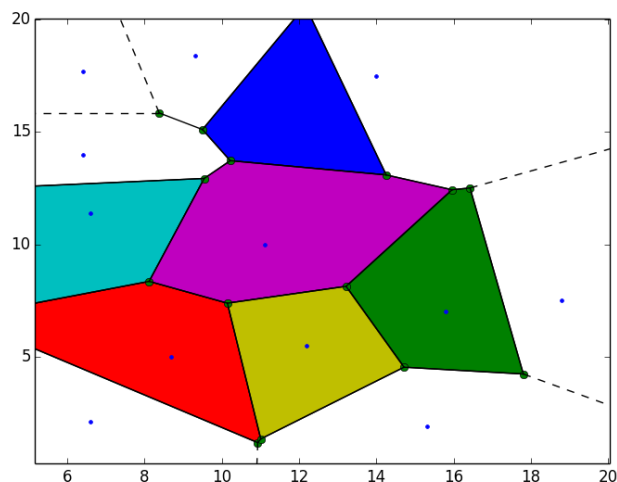


Fig 4: The final Voronoi graph from my computer code. The blue dots are the water pumps. The purple area is the area in which most of the ill people lived.

I placed this Voronoi plot over the map by John Snow and it is shown in figure 5.

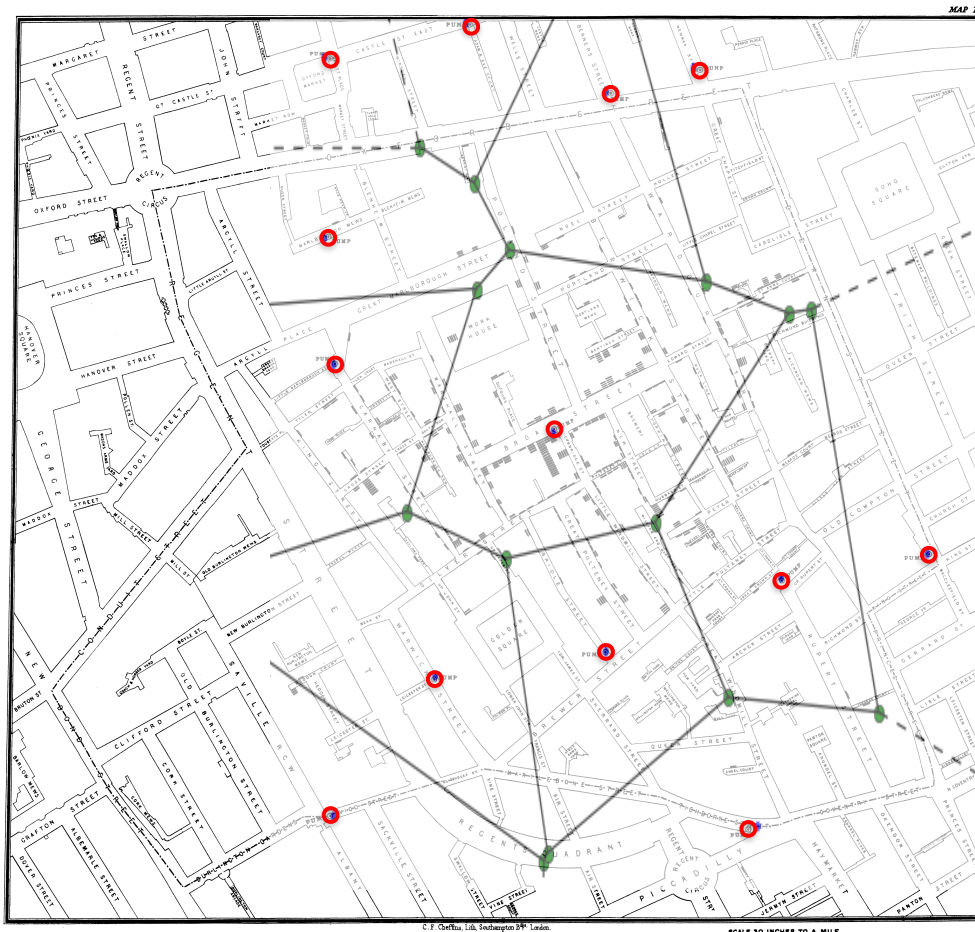


Fig 5: This is my Voronoi graph overlaying a map of 1854 London around broad street made by John Snow.

The black lines are the borders around an area in which people would go to a pump to get water. The blue dots are water pumps in figure 4. Figure 5 has red rings around the blue dots that are the water pumps. The number of ill people are shown with black bars next to the road where they live (figure 5). A longer black bar means more ill people died than a short bar. The section that is purple in figure 4 is the area that contains most of the ill people so it has the contaminated pump and is the Broad Street pump. The infected area is nearly the same size as the Voronoi region and it shows the people that would likely get water from the pump on Broad Street.

**References:**

1. [https://en.wikipedia.org/wiki/Voronoi\\_diagram](https://en.wikipedia.org/wiki/Voronoi_diagram)
2. <http://mathworld.wolfram.com/VoronoiDiagram.html>
3. <https://www.python.org/about/>
4. [https://en.wikipedia.org/wiki/John\\_Snow](https://en.wikipedia.org/wiki/John_Snow)
5. K. Tuhill, "John Snow and the Broad Street Pump on the trail of an epidemic", Cricket 31(3), pp. 23-31, Nov. 2003. <http://www.ph.ucla.edu/epi/snow/snowcricketarticle.html>
6. <https://www.cdc.gov/cholera/general/index.html>
7. <http://www.who.int/mediacentre/factsheets/fs107/en/>

**Team Members:** Andrew Morgan

**Sponsoring Teacher(s):** None

**Project Mentor(s):** Nathaniel Morgan

### Computer Code:

```
import numpy as np
import matplotlib.pyplot as plt
from scipy.spatial import Voronoi, voronoi_plot_2d

# make up data points
points = np.random.rand(13,2)

points = np.array([ [6.6, 2.1],
                    [15.3, 1.9],
                    [8.7, 5.0],
                    [12.2, 5.5],
                    [15.8, 7.0],
                    [18.8, 7.5],
                    [11.1, 10.0],
                    [6.6, 11.4],
                    [6.4, 14.0],
                    [12.2, 17.0],
                    [6.4, 17.7],
                    [9.3, 18.4],
                    [14.0, 17.5] ])

# compute Voronoi tessellation
vor = Voronoi(points)

# plot
voronoi_plot_2d(vor)

# colorize
for region in vor.regions:
    if not -1 in region:
        polygon = [vor.vertices[i] for i in region]
        plt.fill(*zip(*polygon))

plt.show()
```