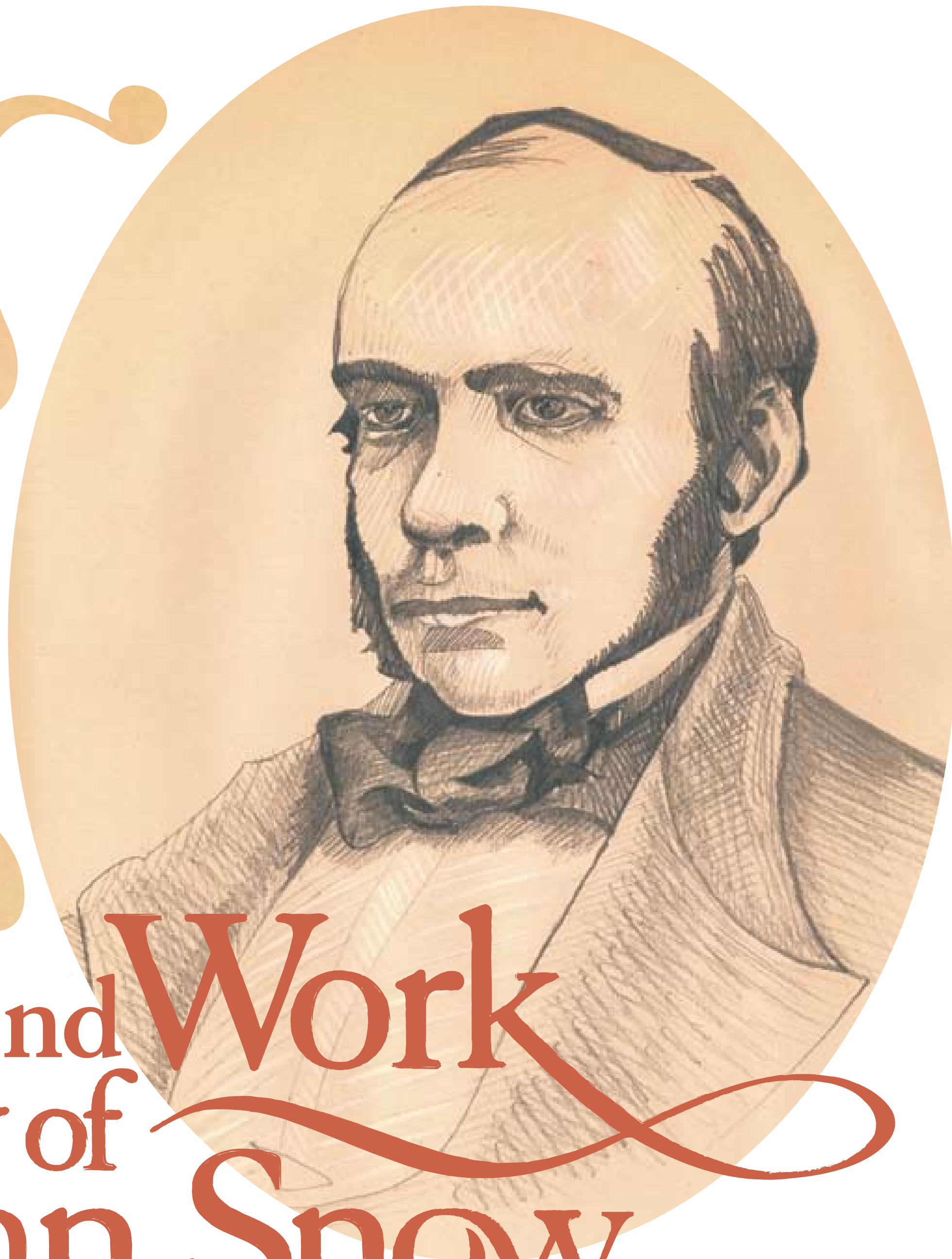
Investigating science as inquiry through Snow's work involving cholera



The Life and Work of John Snow

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Due to his work to determine how cholera was spread in the 18th century, John Snow (1813–1858) has been hailed as the father of modern epidemiology. In addition to his work in epidemiology, Snow was also a famous physician and a leading pioneer in the development of anesthesia. As testament to his stature, Snow was recently voted the greatest doctor of all time in a poll by England's *Hospital Doctor* newspaper (Grant 2003). That is high praise indeed, but how can and how should the life and work of an 18th-century English doctor influence biology teaching in 21st-century secondary schools?

This article presents an inquiry model, The Life and Work of John Snow, which teachers can use to develop a series of biology lessons involving the history and nature of science. The lessons presented use a combination of literature, history, critical thinking, and simulation to promote "the use of history in school science programs to clarify different aspects of scientific inquiry, the human aspects of science, and the role that science has played in the development of various cultures" as recommended by the National Science Education Standards (NRC 1996, p. 107). In this article, the model is presented in four parts: the effects and occurrence of cholera; the context (environment) in which Snow worked; Snow's character and work involving cholera; and a simulation representing the spread of disease. Depending on the amount of time available in your science program, and the depth to which you pursue some of the issues, two to three days would be an adequate amount of time to complete the lessons.

Part one: Cholera

We begin The Life and Work of John Snow by providing students with a brief background on cholera including the causes, effects, occurrence, and treatment of the disease. Depending on the age of your students, this information can be either presented by the teacher or a focus of student research. The Centers for Disease Control and Prevention (CDC) provides comprehensive information about cholera (see "On the web" at the end of this article), which we use in presenting the disease background. While the present-day risk of contracting cholera in North America has been greatly reduced, waterborne diseases such as cholera are still potential threats, as demonstrated by Hurricane Katrina in 2005. Outside of the United States, in Africa, Asia, and Latin America, cholera remains a serious health issue. Aside from the information acquired from the CDC website, media reports of disease outbreaks can be used to connect the science classroom with the broader world. Once students are familiar with current information about cholera, we visit the past and the social and scientific environment in which Snow worked.

Part two: London and miasma

The appalling social conditions in London in the mid–18th century were vividly described in the works of Charles Dickens and in the newspapers of the day. On September 24, 1849, for instance, a journalist reported on a visit to the London district of Bermondsey, "In No. 1 of this street the cholera first appeared 17 years ago, and spread up it with fearful virulence; but this year it appeared at the opposite end, and ran down it with like severity…" (Mayhew 1849). At that time, cholera was a major reason for the highest death rate in Britain's cities since the Black Death. More information on social conditions at the time can be found in the online article "London's 'great stink' and Victorian urban planning" (Daunton 2004). This material provides excellent background reading for students.

In the mid–18th century, cholera and other diseases were thought to be caused by miasma, a poisonous, airborne, foul-smelling vapor filled with particles of decomposing material. The miasmatic theory of disease was strongly supported by the doctors of the time, unsurprising given the correlation of cholera with the foul-smelling waters described by Mayhew (1849). The observation that cholera was associated with poor sanitation, and that improvements in sanitation and the consequent reduction in foul odors lowered the incidence of the disease, supported the theory. The theory was so strongly accepted that the 1854 discovery of the disease pathogen, *Cholera bacillus,* by Filippo Pacini, was completely dismissed.

Part three: Evidence, persistence, and character

After gaining an appreciation for the scientific and social environment of the mid–18th century, students learn about Snow's life and work, specifically. A plethora of information about Snow is found on the "John Snow" website (see "On the web") developed by the University of California, Los Angeles (UCLA) School of Public Health's Department of Epidemiology. To examine the scientific thought processes and personal qualities that Snow brought to his work, we introduce students to a copy of Snow's landmark work, *On the Mode of Communication of Cholera* (1855), which is also found on the website (see "On the web"). This 39-page pamphlet demonstrates the quality and incisiveness of Snow's application of scientific inquiry to cholera. The salient points in the pamphlet, which can be highlighted for students, are Snow's discussions around the communication and pathology of cholera, as well as the sections that focus on the connection between polluted water and cholera. In addition, the pamphlet's visual material—such as Snow's celebrated 1854 Broad Street map and the Broad Street pump—can be reproduced as PowerPoint presentations or overhead transparencies to engage student interest.

Also available on the UCLA website is the article "The father of modern epidemiology: Doctor John Snow blames water pollution for cholera epidemic" (Vachon 2005), which is of particular importance in providing the content for a classroom discussion (see "On the web"). Depending on time constraints, students can read the entire article, or parts one and two of this article may be presented by the teacher perhaps as an overhead/PowerPoint presentation or provided as a handout. However the material is relayed, certain points are critical for students to grasp in order to understand how Snow applied scientific inquiry. These critical points of the web article are outlined in the following section and each point is supported by specific information and direct quotes from the article. The critical points outlined not only demonstrate the nature of scientific inquiry, but support the reasons Snow is regarded as the father of modern epidemiology.

The father of modern epidemiology: Part one

The following notes could be used as the basis for either classroom discussion or written work. Through *questioning*, *observing*, *reasoning*, and *testing*, Snow arrived at a conclusion that disproved the prevailing explanation of the day.

Questioning: "He did a lot of thinking about the possible causes of contagious diseases, and he came to the unconventional conclusion that they might be caused by invisibly tiny parasites" (part one, paragraph 8). Science requires asking questions. What many students do not recognize is that science also requires creativity to develop both the questions and potential answers. While a possible answer may not be completely correct, students should be encouraged to be creative and prepared to make mistakes.

Observing: "Snow felt that the miasma theory could not explain the spread of certain diseases" (paragraph 10). Observations are the basis for the development of scientific ideas. Snow noticed "details that others often overlooked" (paragraph 2) and observed that miners suffered from cholera while working deep underground, even though water and sewers were not nearby (paragraph 10). In Snow's mind, this observation, and the later observation involving Blenkinsopp's death (paragraph 12), were pieces in a puzzle.

Reasoning: "All of them reported that their first symptoms had been digestive problems. Snow reasoned that this proved that the disease must be ingested with polluted food or water" (paragraph 13). Using Snow's observations that the first cholera symptoms appeared in the digestive tract, we ask students to write a hypothesis as to how the infection could spread and to justify their position from the observations made by Snow. We then ask students to consider what their hypotheses demonstrate regarding the miasmatic theory, and to be prepared to present both their hypotheses and reasoning to the class.

Testing: "If just a few drops of that fluid contaminated a public water supply…" (paragraph 14). Scientific knowledge is tentative. Snow sought out evidence by which he could evaluate his developing hypothesis. He spoke to colleagues and questioned water supply companies. In looking for evidence, Snow also demonstrated that science is a public activity that can be used to benefit society—as opposed to the negative connotations that are often attached to science, such as in debates over genetically modified foods.

Snow's pamphlet (1855) had little effect on the thinking of his colleagues. However, in publishing his results, Snow demonstrated the courage of his convictions and belief in the evidence he collected in the face of opposition. His work and research also provided an excellent example of the scientific peer-review process. Although his ideas and hypothesis were rejected, he continued to gather data from the cholera epidemic of 1848–1849. Given that he began working with cholera patients in 1831, Snow's resolve demonstrated the perseverance that science often demands.

The father of modern epidemiology: Part two

In the second part of the article on the UCLA website, more aspects of Snow's work provide material for classroom discussion on the use of scientific inquiry. Snow demonstrated that he was *creative*, *courageous*, *pursued anomalies*, and *collaborated* with colleagues to achieve a result.

Creative: "The following summer, cholera broke out in London in the district where Snow was working. He suspected that it was being spread by contaminated water piped in from the Thames River. He searched through municipal records and discovered that two private companies were supplying water to the district… Snow decided to compare the mortality rates of consumers of the two sources of water" (part two, paragraph 1). This quote highlights two important points. First, Snow's data collection was methodical, thorough, and guided by his hypothesis. A variety of data collection methods were used: document analysis, statistical analysis, surveys, interviews, mapping, and microscopy. This is a significant consideration, as many students limit themselves in terms of data collection and sources. Second, Snow was quick to seize opportunities for advancing his scientific knowledge. To make the most of every opportunity, scientists need to be organized and possess initiative, creativity, and commitment to their work.

Courageous: "His critics were not impressed by the results of the survey" (paragraph 6). Snow did not develop a perfect hypothesis, but of course one rarely does. What he did develop was a hypothesis that allowed him to collect evidence directed toward answering a particular question. The fact that he could not identify the "poison" specifically responsible (paragraph 8) does not detract from his hypothesis or quality of data. Science has many examples of similar advances made because individuals were prepared to propose and support with data novel ideas, which were verified by later scientific studies. For example, Mendel concluded that two "factors"' were passed from parent to offspring for each trait. Morgan's work on *Drosophila* in the early years of last century confirmed *genes* as Mendel's factors.

Pursued anomalies: "Snow was able to gather hard evidence about cases that, at first, did not appear to be connected to the epidemic… [He] was curious about places in the neighborhood where there was a low incidence of cholera" (paragraphs 27–28). The persistent rejection of his hypothesis did not deter Snow from continuing to collect data in creative ways, or from arguing the merits of his case. The tenacity of Snow in pursuing anomalies indicates the value of a robust hypothesis in guiding the work of a scientist. Snow showed persistence in pursuing his own investigation and following up several anomalies—a widow who died miles from the source of contaminated water, and a brewery and workhouse where death rates were much lower than expected (paragraphs 27–29). Snow's pursuit of anomalies demonstrates that not all scientific questions have one correct answer, and, apparent anomalies do not necessarily indicate that a hypothesis is wrong.

Collaboration: "Snow was asked by the Reverend Henry Whitehead to join a committee of the St. James Parish to investigate the causes of the outbreak. Whitehead disagreed with Snow's theory about the cause of the epidemic, but he liked Snow's honest and straightforward method of investigation" (paragraph 31). Science is a social activity in which the capacity to work together is often not sufficiently recognized by students. Whitehead brought an understanding of the local area and an analytical mind to the mystery of the disease outbreak. He may have disagreed with Snow, but remained open-minded enough to respect the value of Snow's data. Whitehead's recognition that a child's death was linked to the timing of the cholera outbreak was critical—Whitehead made the connection between a cesspool, the source of the contamination, and a well, which provided the final piece of evidence to support Snow's hypothesis (paragraphs 34–35).

The work of Snow may have been ignored by the Board of Health, but Snow demonstrated the value of asking questions and pursuing an answer with tenacity, creativity, and courage. Snow did not know the full answer to the questions he asked, but he was prepared to work in spite of the inherently incomplete available knowledge. In looking at Snow's achievement, our aim is for students to begin to develop an appreciation of the history and nature of science. The following simulation, we believe, helps to reinforce this appreciation.

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Part four: Theory and practice

An important part of Snow's work was to track the spread of cholera, in an effort to locate the source. In this final part of the inquiry model, students simulate the spread of waterborne diseases using commonly available materials:

- Polystyrene cups
- Household ammonia solution (to check the dilution, teachers should test the method before working with students)
- Water
- Gloves
- Wrap-around, splash-proof safety goggles
- Universal indicator (UI)

Before beginning the simulation, we warn students of the dangers of caustic solutions such as ammonia. Students must wear gloves and wrap-around splash-proof safety goggles, and be advised that the appropriate first-aid response if affected by ammonia is to flush that area with water. (**Safety note:** The safety concerns related to ammonia may be found at *www.flinnsci.com/Documents/MSDS/A/Ammonia.pdf*.) After reviewing the safety precautions, we complete the following steps:

1. First, we fill less than half a cup of water for every student in the class. Into one cup, instead of water, we pour less than half a cup of ammonia. Because ammonia is caustic, this step is best done by the instructor prior to the lesson. To demonstrate how the UI works, before handing out

cups, we show students the reaction between ammonia and the UI and between the UI and water (for comparison).

2. Next, we have each student collect a cup and instruct each student to find a partner. One student pours his or her solution into the partner's cup. That partner pours half of the combined solution back into the first student's cup.
3. Each student repeats this three times with different partners (allowing the spread of ammonia to various cups throughout the class).
4. We then go around the room and place one drop of UI in each student's cup. Purple indicates the presence of ammonia, which in this simulation represents infection. Students record the results (the number of "infected" cups).
5. For the final step, we properly dispose of the cups according to our local safety guidelines.

After the first exchange of water, two "people" (the original carrier and one other) will be "infected." After the second exchange, there will be four infections, after the third exchange, eight infections, and so on. The idea is to give students an understanding of how rapidly infections can move through a population. By using the first extension activity, in the following section, the rate of infection can be quantified.

Extensions

For advanced students, the simulation can be adapted to predict, explore, and graph exponential growth after each exchange of ammonia solution. One potential exercise is to have students predict the number of "infections" for a particular number of exchanges and then test their predictions. Another adaptation is to consider the ethics of testing each person. For example, students can be asked to discuss and explore the ethical implications of mandatory testing for various diseases and infections. Additionally, after The Life and Work of John Snow model is completed, students' knowledge about infection rates could be applied to: historical events other than cholera, such as the plague; current events, such as the rate of HIV/AIDS infections (Latta 1996); or persons such as Typhoid Mary, the first person in the United States identified as a healthy carrier of typhoid fever, who in the early 1900s infected several people while working as a cook (Ochs 2007). (**Editor's note:** For additional information on Typhoid Mary, visit PBS's NOVA programming website at *www.pbs.org/wgbh/nova/typhoid/mary.html*.)

We have used The Life and Work of John Snow in secondary science classes and in science teacher education programs. For teachers, the model's material enables exploration of the issues of disease and scientific inquiry at many levels. For students, science is humanized through the examination of Snow's life and use of scientific inquiry to tackle cholera. ■

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On the web

- CDC Infectious Disease Information (Cholera): *www.cdc.gov/ncidod/diseases/submenus/sub_cholera.html*
- On the Mode of Communication of Cholera: *www.ph.ucla.edu/epi/snow/snowbook.html*
- The father of modern epiclemiology: *www.ph.ucla.edu/epi/snow/fatherofepidemiology.html*
- UCLA John Snow website: *www.ph.ucla.edu/epi/snow.html*