

REVIEWS AND COMMENTARY

A New Perspective on John Snow's Communicable Disease Theory

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When John Snow undertook the studies of the cholera epidemic of 1854 in London, he was testing his theory of communicable disease, which had been enunciated in an oration delivered at the 80th anniversary of the Medical Society of London. Snow had been elected orator of the year for 1853 and, according to his biographer, had spent the better part of a year in preparation. The oration was titled, "On Continuous Molecular Changes, More Particularly in Their Relation to Epidemic Diseases." Although the text of this oration is readily available in the 1936 Commonwealth Fund facsimile reprint of Snow's more famous cholera studies, few modern epidemiologists are familiar with the work. In it, Snow lays out a theory which includes recognition that for each communicable disease there is a distinct and specific cause, that the causal agent is a living organism which is stable over many generations of propagation, that infection is necessary for communication to occur, and that the quantity of infectious material transmitted is increased by multiplication after infection to produce disease manifestations. Although Snow's theory is similar to Jacob Henle's formulations of a decade earlier, it is more precise, more comprehensive, and more explicit. On the basis of this work alone, Snow deserves broader recognition than he has received. *Am J Epidemiol* 1995;142:S3-S9.

cholera; communicable diseases; epidemiology; history of medicine, 19th cent.; Snow, John

The contagious nature of some epidemic diseases was recognized in Roman times and quite clearly described by Fracastorius in the late Renaissance (1). Nevertheless, concepts such as "spontaneous generation" and the "miasmatic" theory of epidemic disease production dominated until relatively recent times. As late as the 1850s, cholera outbreaks were attributed to "miasmas," "cholera atmospheres," and "elevation above the Thames." For example, in an 1849 report by the Sanitary Committee of the New York City Board of Health, it was reported, ". . . that the long continuance of the cholera atmosphere has created predispositions to disease which cannot of course, be at once eradicated" (2). Nevertheless, comprehensive and valid theories of infection were put forward in both Germany and England in the 1840s and 1850s. In particular, John Snow in 1853 articulated a comprehensive theory for the causes of communicable dis-

eases in an oration entitled, "On Continuous Molecular Changes, More Particular in Their Relation to Epidemic Diseases" (3), which for the sake of conciseness we will refer to as "On Continuous Molecular Changes." Within a year, Snow was able to test this theory in a series of epidemiologic studies of the London cholera epidemic of 1854. In this paper, Snow's work and that of his predecessor, Jacob Henle, whose causal concepts were later elaborated and rephrased as postulates by his pupil Robert Koch (4), will be discussed.

In 1852, the Medical Society of London elected Dr. Snow Orator for the ensuing year. Snow was 39 years old at the time and was destined to live only six more years. He had already achieved great success as an anesthetist, had carried out an extensive series of investigations of anesthetic gases, and had published important papers relevant to these activities (5). According to his biographer, Sir Benjamin Ward Richardson, a friend and contemporary, Snow spent the best part of a year in the preparation of his address (6, p. xxxvii).

The first five pages of "On Continuous Molecular Changes" consist of a rambling discussion of nineteenth century physics and chemistry, the latter emphasizing combustion processes, most likely reflecting Snow's interests in the medicinal uses of gases. It may

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be hypothesized that these obtuse pages have put off modern readers, most epidemiologists being unfamiliar with "On Continuous Molecular Changes." However, beginning at the end of the fifth page and continuing for several pages Snow turned to issues such as fermentation, procreation, and the maintenance of species. In the Preface to his oration, Snow had defined "molecular" as ". . . the attraction which exists amongst the particles of matter at insensible distances" (3, p. 145). It seems apparent that Snow's concept of "continuous molecular changes" referred broadly to those biologic processes, mentioned above, which have for their result the preservation of the individual and the species. Then on the ninth and following pages of the address, Snow turned his attention to the implications of his concept of continuous molecular changes to communicable diseases.

He began by pointing out that in addition to the positive effects of continuous molecular changes they also explained the mechanisms by which communicable diseases are propagated and maintained. He talked about:

. . . the multiplication and increase in the materies morbi of communicable diseases—an extensive group of maladies, each case of which is caused by some material that, as a general rule, has been produced in the system of another individual. The origin of these diseases, for aught we can tell, may be as remote as that of the beings they infest and exist on. (3, p. 155)

As already suggested, the concept of a "contagium vivum," i.e., a living agent as a cause of disease, had been advanced in ancient times and during the Renaissance. However, at least in the English language, the concept had never been developed to the extent that Snow was to develop it in "On Continuous Molecular Changes."

After listing the principle diseases of humans that he considered communicable, viz., "syphilis, small-pox, measles, scarlet-fever, typhus, typhoid and relapsing fevers, erysipelas, yellow-fever, plague, cholera, dysentery, influenza, hooping-cough, mumps, scabies, and the entozoa" (3, p. 156), Snow returned to a consideration of the nature of the causal agents. He said,

The material cause of every communicable disease resembles a species of living being in. . . that this organized matter possesses one great characteristic of plants and animals—that of increasing and multiplying its own kind. (3, p. 156)

He then extended the concept of continuous propagation as follows:

The molecular changes taking place in the materies morbi of some diseases resemble the changes in many living beings in another respect also: they permit of

being suspended, under certain circumstances, and recommence at the point at which they ceased. Thus the matter of variola and of vaccinia can be carried, in the dry state, to distant parts of the world without injury, like the seeds of a plant. (3, p. 157)

Snow then turned his attention to the effects produced by the materies morbi and in particular described, in quite modern terms, the concept of the incubation period:

No evident effects are produced at first by the reception of the material cause of any of these diseases. There is always a definite period, of longer or shorter duration, before the illness commences, which is called the period of incubation. As regards the materies morbi itself, this is a period of something more than incubation; it is a period of reproduction. (3, p. 157)

In these four brief quotations, it seems that Snow had captured the essence of most of the characteristics of the microbiologic agents of communicable disease. He recognized that for each communicable disease there is a distinct and specific cause, that the causal agent is stable over many generations of propagation, that infection is necessary for communication to occur, and that the quantity of infectious material transmitted is increased by multiplication after infection in order to produce disease manifestations. However, these ideas were not totally new when articulated by Snow in 1853. They had been largely formulated by Jacob Henle in the first chapter of his book, *Pathologische Untersuchungen*, published in 1840. This chapter, entitled "Von den Miasmata und Kontagion" ("Concerning Miasmata and Contagion") has long been recognized as a medical classic (7).

Henle did not base his conclusions on observations of his own nor did he, as will be shown with respect to Snow, continue to test his theories by observations in the field. He based his theories entirely on deductions from the observations of others. He began his chapter by classifying contagious diseases into two groups, epidemic and endemic. He identified epidemic diseases as those diseases that, in his words as translated by the late public health historian George Rosen, "a large number of individuals in a greater or smaller region suddenly fall ill at the same time and in the same manner" (7, p. 5). He identified endemic diseases as those which,

. . . in certain districts the individuals living there fall ill, one after another, in the same way; people, previously healthy, are attacked by the native disease when they go into such districts. (7, p. 5)

These definitions are consistent with those used by modern epidemiologists to describe these terms. Henle then went on to classify the epidemic and endemic

diseases into three subgroups, diseases caused by miasmas, miasmatic-contagious diseases, and pure contagions. In the miasmatic disease group, he placed only one condition, ague, a term which probably described a broad group of diseases characterized by recurrent chills and fever. In the miasmatic-contagious group, he allowed for the initiation of epidemics and endemics by "miasmatic influences" but argued that their propagation resulted from the transmission of a "contagium animatum." In the third group, diseases transmitted only by means of a "contagium animatum," Henle placed only syphilis, scabies, and several unnamed chronic skin diseases (7, pp. 7-9).

Henle's conclusions regarding the characteristics of the "contagium animatum" responsible, in a causal sense, for the occurrence and transmission of epidemic and endemic diseases may be summarized, in his translated words, as follows:

- The contagious agent is a substance which in the course of a disease is excreted by the sick organism. . . and which communicated to healthy individuals, produces the same disease in them. (7, p. 10)
- It is easy to prove that contagions. . . actually multiply within the diseased organisms. An atom of pox poison can produce a rash over the entire body. (7, p. 14)
- The symptoms of the disease do not appear directly after the entry of the contagious agent but rather after a certain period, which varies in the different contagions. (7, p. 14)

The question now arises as to whether Snow's conclusions regarding the causes of communicable diseases, as expressed in "On Continuous Molecular Changes," were original or derived from Henle's publication of 13 years earlier. Snow referred to other authors frequently in his essay and there seems to be no reason why he would not have referenced Henle if he knew of his work. Nevertheless, he might have known of it because, according to Rosen, an English summary had been published in 1840 in the *British and Foreign Medical Review* (8). Regardless of the originality of the work, we will complete our review of "On Continuous Molecular Changes."

The oration was divided into four parts, two of which have already been discussed, viz., Snow's general views on continuous molecular changes and his views on the nature and actions of the "materies morbi," i.e., the living causal agent of communicable diseases. In the third part of the oration, Snow discussed the weaknesses of the miasmatic theory of disease and in the fourth part he applied his communicable disease theory to the problem of waterborne diseases.

There is no need to dwell long on Snow's discussion of miasmatic causes of disease. Unlike Henle, Snow dismissed the concept summarily. However, one quotation from this part of the oration is particularly poignant for Californians:

We constantly. . . hear climates called healthy or unhealthy. . . California, for instance, was proverbial for the healthiness of those who resided there, and this healthiness was attributed to its climate. No sooner, however, was the discovery of gold made, than the cholera was conveyed across the mountains, by crowds of people, who left the route strewn with the dead bodies of those who died on the journey. (3, p. 162)

Finally, Snow turned his attention to the implications of his theory of the causation of communicable diseases to the spread of these diseases through the widespread distribution of drinking water. He said,

There is evidence tending to show that typhoid fever, . . . as well as cholera, are communicated by accidentally swallowing the morbid excretions of the patients, and that these latter may sometimes be conveyed to a distance with the drinking water. . . without losing their specific properties. . . It has been often argued that sudden outbreaks of cholera are incompatible with its propagation from person to person, but we know of no circumstances to restrict the number of persons who may receive the disease from one or two patients, under favourable circumstances for the distribution of the morbid matter. (3, pp. 168-70)

If Snow did not derive his theory of the causes and transmission of communicable diseases from Jacob Henle, where did he get it? The answer may lie in the 39-page pamphlet authored by John Snow entitled, "On the Mode of Communication of Cholera" published in 1849 (9). This document has been largely overlooked because its contents are included in the greatly expanded second edition published in 1855 and reprinted in a facsimile edition by the Commonwealth Fund in 1936 (10). It is also worth noting that in 1849 William Budd also came to conclusions closely similar to Snow's views regarding the cause and transmission of cholera (11). It is not known whether Snow and Budd were aware, at the time, of the convergence of their views on the cause and transmission of cholera.

Although the 1849 Snow pamphlet is rare, there is a copy in the National Library of Medicine in Bethesda. Its contents are revealing. Apparently the London cholera epidemic of 1848 diverted Snow's attention from his researches on anesthetic gases. Similar to Henle's approach 10 years earlier, he reviewed what was then known about the clinical and epidemiologic characteristics of cholera in order to formulate a theory of causation and transmission of this disease. Citing other authors and drawing on his own knowledge of

particular events related to the then current epidemic, he presented the following arguments:

- As the alimentary canal is affected earliest, it is likely that the causal agent enters through this route.
- As the most prominent symptom of cholera is diarrhea, it is likely that the causal agent leaves the body by this route.
- As the cholera excretions are colorless, they may contaminate bedding, clothing, and food without being noticed. If the cholera excretions contaminate rivers or streams from which water is taken for drinking or cooking, the *materies morbi* may be widely disseminated.
- Epidemics of cholera follow major routes of commerce. The disease always appears first at seaports when extending to islands or continents. It never attacks the crews of ships leaving a port where cholera is not present.

The 1849 pamphlet contains Snow's first original investigation of the relation of drinking water supplies to the occurrence of cholera in London. Using data obtained from William Farr in the Registrar General's office, he constructed a table showing that death rates from cholera varied greatly between different districts of London (9, p. 24). This table is reproduced in figure 1. Although Snow did not have exact information regarding the sources of water for the various districts, he had enough information to be able to argue that the districts with the highest rates (East and South) were served by water companies that obtained their supplies from known polluted parts of the Thames and that the districts with the low rates (West, North, and Central) obtained their water from relatively uncontaminated sources.

Snow included a public health prescription in the 1849 pamphlet. Based on the observations detailed in the pamphlet, he wrote:

... cholera might be checked. . . by simple measures which would not interfere with social or commercial intercourse. . . . It would only be necessary for all persons attending or waiting on the patient to wash their hands carefully and frequently, never omitting to

do so before touching food, and for everybody to avoid drinking, or using for culinary purposes, water into which drains and sewers empty themselves; or, if that cannot be accomplished, to have the water filtered and boiled before it is used. (9, p. 35)

The 1849 pamphlet ends with an explanation and apology which strongly implies that a sequel is intended:

It would have been more satisfactory to the author to have given the subject a much more extensive examination, and only to have published his opinions in case he could bring forward such a mass of evidence in their support as would have commanded ready and almost universal assent; but being preoccupied with another subject, he could only leave the inquiry, to bring it forward in its present state, and has considered it to be his duty to adopt the latter course and allow his professional brethren to decide whether there may be value to his opinions. . . . (9, p. 39)

Six years passed before the second edition of "On the Mode of Communication of Cholera" was published. However, it is clear that Snow's ideas about the nature and transmission of cholera were well developed in 1849 and formed the basis for his more comprehensive theory articulated in the oration.

Between 1849 and 1855, Snow published "On Continuous Molecular Changes," in which he generalized his observations and conclusion regarding cholera to a large number of specified contagious diseases. He also published a number of papers and letters on issues related to his investigations of anesthetic gases and reiterated his ideas and recommendations regarding cholera. The fact that Snow continued to publish papers addressing cholera issues between the appearance of the 1849 pamphlet and the delivery of the oration on continuous molecular changes indicates his continued interest in the subject. Although the papers on cholera published between 1849 and 1853 give no evidence of the development of the elaborate communicable disease theory enunciated in "On Continuous Molecular Changes," it seems likely that he was developing those ideas during that period. Thus, when elected Orator of the year by the Medical Society of London, it would not be surprising that he would take that opportunity to put forward his controversial ideas on communicable diseases in general in such a prominent forum.

The culmination of Snow's views on the waterborne transmission of cholera are contained in the greatly expanded second edition of "On the Mode of Communication of Cholera," published in 1855 (10). This volume contains all of the anecdotal material as well as the conclusions presented in the 1849 edition. It does not contain, in explicit form, Snow's views on the nature or characteristics of the "*materies morbi*" of cholera as expressed in "On Continuous Molecular

Deaths from Cholera in London; Registered from September 23rd 1848, to August 25th 1849

Districts of London	Population in 1841	Deaths from Cholera	Deaths to each 1,000 Inhabitants
West	300,711	533	1.77
North	375,971	415	1.10
Central	373,605	920	2.48
East	392,444	1,597	4.06
South	502,548	4,001	7.95
Total	1,948,369	7,466	3.83

FIGURE 1. Snow's first tabulation of cholera deaths in relation to geographic areas of London served by different water companies (9, p. 24).

Changes." However, the second edition does contain a description of Snow's studies of the cholera epidemic of 1854 in which he tested the hypotheses that the causal agent was a parasitic microorganism and was transmitted through the public water supply. In his introduction to the 1936 facsimile republication of this volume, Wade Hampton Frost, the first US professor of epidemiology, described Snow's studies as a "nearly perfect model" of an epidemiologic study (10, p. ix).

Snow used three approaches to test his theories. First, he conducted an ecologic analysis of the geographic distribution of cholera cases in London in relation to particular water supplies. Second, he conducted a retrospective cohort study of cholera incidence among users of various water supplies. And, third, he conducted a case-control investigation of the intense cholera outbreak in the Golden Square neighborhood of Soho where the infamous Broad Street pump was located.

Using the same technique employed in the 1849 pamphlet, but with considerably more precision, Snow organized 1853 cholera mortality data obtained from the Registrar-General for the districts south of the Thames according to the water company supplying each district. As shown in his table VI, reproduced here in figure 2, districts supplied by the Southwark and Vauxhall Water Company had generally higher cholera mortality rates than districts supplied by both the Southwark and Vauxhall and Lambeth Water Companies. In the three districts supplied exclusively by the Lambeth Water Company, no cholera deaths were recorded during the study period (10, p. 73).

Snow pointed out that the Southwark and Vauxhall Water Company obtained its supplies from the Thames at Battersea Fields, a portion of the river receiving large amounts of sewage as a result of the rapidly increasing use of water closets to replace the previously dominant privies and cesspools, which were more likely to retain contaminated excreta. The Lambeth Water Company obtained its supplies from the river at Thames Ditton, well above any of London's sewage outfalls.

Although these ecologic observations provided strong support for the conclusion that contaminated water was responsible for the transmission of cholera in the 1854 epidemic, Snow did not rest his case on these observations. He took advantage of the mixing of the water supplies suggested in his table VI to devise an ingenious experiment. He describes it as follows:

... the intermixing of the water supply... admitted of the subject being sifted in such a way as to yield the most incontrovertible proof on one side or the other.

TABLE VI.

Sub-Districts.	Population in 1851.	Deaths from Cholera in 1853.	Deaths by Cholera in each 100,000 living.	Water Supply.
St. Saviour, Southwark	19,709	45	227	Southwark and Vauxhall Water Company only.
St. Olave	8,015	19	237	
St. John, Horsleydown	11,360	7	61	
St. James, Bermondsey	18,899	21	111	
St. Mary Magdalen	13,934	27	193	
Leather Market	15,295	23	153	
Rotherhithe*	17,805	20	112	
Wandsworth	9,611	3	31	
Battersea	10,560	11	104	
Putney	5,290	—	—	
Camberwell	17,742	9	50	
Peckham	19,444	7	36	
Christchurch, Southwark	16,022	7	43	
Kent Road	18,126	37	204	
Borough Road	15,862	26	163	
London Road	17,836	9	50	
Trinity, Newington	20,922	11	52	
St. Peter, Walworth	29,861	23	77	
St. Mary, Newington	14,033	5	35	
Waterloo (1st part)	14,088	1	7	
Waterloo (2nd part)	18,348	7	38	
Lambeth Church (1st part)	18,409	9	48	
Lambeth Church (2nd part)	26,784	11	41	
Kennington (1st part)	24,261	12	49	
Kennington (2nd part)	18,848	6	31	
Brixton	14,610	2	13	
Clapham	16,290	10	61	
St. George, Camberwell	15,849	6	37	
Norwood	8,977	—	—	Lambeth Water Company only.
Streatham	9,023	—	—	
Dulwich	1,632	—	—	
First 12 sub-districts	167,654	192	114	Southwark & Vaux.
Next 16 sub-districts	301,149	182	60	Both Companies.
Last 3 sub-districts	14,632	—	—	Lambeth Comp.

* A part of Rotherhithe was supplied by the Kent Water Company; but there was no cholera in this part.

FIGURE 2. Snow's ecologic analysis of cholera deaths in 1853 according to water districts supplied by the Southwark and Vauxhall Water Company, the Lambeth Water Company, and both companies (10, p. 73).

In the sub-districts... 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... Each Company supplies both rich and poor...; there is no difference either in the condition or occupation of the persons receiving the water of the different Companies. Now it must be evident that, if the diminution of cholera, in the districts partly supplied with the improved water, depended on this supply, the houses receiving it would be... enjoying the whole benefit of the diminution of the malady, whilst the houses supplied with the water from Battersea Fields would suffer the same mortality as they would if the improved supply did not exist at all...

The experiment. . . was on the grandest scale. No fewer than three hundred thousand people. . . 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 the cholera patients, the other group having water quite free from such impurity. (10, pp. 74-5)

All that was necessary to realize the experiment was to determine the water supply for each house in which a cholera death had occurred, obtain a count of the total number of houses supplied by each company in the "mixed" districts, obtain the number of houses in the "rest of London," and the number of cholera deaths in that area. All of these data could be obtained, although determining the source of water for each cholera-affected household in the "mixed" districts was a daunting task. The findings were presented in table IX (10, p. 86), reproduced here in figure 3. According to Snow, these results were immediately transmitted to William Farr, the Registrar General, who subsequently initiated a confirmatory investigation. However, it was many years before Farr adopted Snow's theory of water transmission. In the interim, he believed that contaminated water was merely a "pre-disposing" factor.

During the course of the investigation of the water companies just described, Snow investigated a localized outbreak of cholera in the Golden Square neighborhood of Soho, near his own residence. He described the situation in the following words:

The most terrible outbreak of cholera which ever occurred in this kingdom, is probably that which took place in Broad Street, Golden Square, and the adjoining streets, a few weeks ago. Within two hundred and fifty yards of the spot where Cambridge Street joins Broad Street, there were upwards of five hundred fatal attacks of cholera in ten days. (10, p. 38)

Apparently Snow began his investigation of this outbreak on September 3, 1854 with an examination of the water from the Broad Street pump, which was located at the very center of the outbreak. He reported that, ". . . I found so little impurity in it of an organic

nature, that I hesitated to come to a conclusion" (10, p. 39). However, over the next several days, he ascertained that 61 cases had used water from the pump-well constantly or occasionally, six cases were reported to not have drunk water from the pump, and for another six cases, he could obtain no information regarding use of the pump water. As a result of his inquiry, on September 7, he advised the Board of Guardians of St. James parish to remove the handle of the pump, which was accomplished the next day (6, p. xxxvi). Snow also reported that among 535 inmates of a workhouse located within the outbreak area and having its own well, only five deaths from cholera were recorded. Similarly, among 70 workmen employed in a local brewery, no cholera deaths were recorded. These men were issued daily rations of malt liquor and were assumed to limit their fluid intake to these rations. The brewery also had its own well. The inmates of the workhouse and the workers in the brewery were the analogues of noncases in a modern case-control study.

Although Snow could find no direct evidence of sewage contamination of the Broad Street pump-well, he noted its proximity, within several yards, of a major sewer. He also noted the fact that the well penetrated a gravel stratum into which several nearby cesspools drained (10, pp. 52-3).

Snow's investigations of the London cholera epidemic of 1854 provide definitive evidence of the waterborne transmission of cholera and strong inferential evidence that the disease was caused by a subvisual animate parasite. However, the evidence that he presented in the second edition of "On the Mode of Communication of Cholera" was not immediately accepted in England and largely overlooked in Europe and America until the publication of the facsimile edition in 1936 (12). As already indicated, William Farr, probably the most important 19th century epidemiologist-statistician, did not accept Snow's theory for many years. Similarly, John Simon, the most prominent English public health advocate of the mid-to late 19th century, did not accept Snow's theories until the late 1860s.

The medical world has come to acknowledge the importance of John Snow's contributions to anesthesiology and the study of infectious agents and the diseases they produce. Last year, a transcription of Snow's manuscript Case Books containing details of his clinical anesthetic practice and his work as a family doctor was published by the Wellcome Institute for the History of Medicine (13). On July 21, 1987, the Association of Anaesthetists of Great Britain and Ireland, with Her Royal Highness, Princess Alexandra, in attendance, placed a plaque commemorating Snow as a

TABLE IX.

	Number of houses.	Deaths from Cholera.	Deaths in each 10,000 houses.
Southwark and Vauxhall Company	40,046	1,263	315
Lambeth Company	26,107	98	37
Rest of London	256,423	1,422	59

FIGURE 3. Snow's analysis of deaths and death rates from cholera in 1854 in households supplied by the Southwark and Vauxhall Water Company and by the Lambeth Water Company (10, p. 86).

"Pioneer Anaesthetist and Epidemiologist" on the site of his former residence in Frith Street, Soho (14). In Beckwith Street (formerly Broad Street), Soho, on the second floor of the John Snow Ale House, will be found many relevant memorabilia. Another plaque dedicated to Snow is located outside of the pub. Nearby, a replica of the infamous pump has been erected.

However, John Snow's place in the broader history of science has not yet been recognized (15). During his life, the true value of his work was but little appreciated. Richard H. Ellis, who edited the Case Books (13), has written,

The note of Snow's death, in *The Lancet*—then the most influential and percipient of all British medical periodicals—is a dispiriting testament to this. It merely said 'This well-known physician died at noon on the 16th. instant, at his home in Sackville Street, from an attack of apoplexy. His researches on chloroform and other anaesthetics were appreciated by the profession'. (5, p. xxii)

Both Henle and Snow based their theories on deductive reasoning. Henle relied exclusively on observations of others, while Snow included his own observations of the epidemiology of cholera in constructing his general theory of communicable diseases. Neither Henle nor Snow utilized the emerging technology of microscopy, which had already revealed the existence of microorganisms in association with disease to test their theories. For Henle, this is somewhat surprising as his major research on epithelial tissues necessitated the extensive use of microscopy. For Snow, one can speculate that, except for his untimely and premature death, he might have subsequently turned to this technology.

John Snow's theory of communicable diseases put forth in his oration "On Continuous Molecular Changes" deserves greater recognition than it has received. Although Jacob Henle's earlier theory lacks the clarity and precision of Snow's formulation, it has long been recognized as a medical classic. Furthermore, Snow tested and supported his theory with field observations while Henle returned to his pioneering pathologic and anatomical studies. It is hoped that future students of epidemiology will include "On Con-

tinuous Molecular Changes" in their consideration of John Snow's role in the development of their field and in the broader arena of health-related sciences.

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REFERENCES

1. Fracastorius H. Opera omnia, chapter I: What is contagion? In: Major RH, ed. Classic descriptions of disease, 3rd ed. Springfield, IL: Charles C Thomas, 1945:78.
2. Report of the proceedings of the Sanitary Committee of the Board of Health in relation to the cholera as it prevailed in New York in 1849. New York: McSpedon & Baker, 1849:42.
3. Snow J. On continuous molecular changes, more particularly in their relation to epidemic diseases. In: Snow on cholera. (Reprint). New York: The Commonwealth Fund, 1936: 147-75.
4. Evans AS. Causation and disease: the Henle-Koch postulates revisited. *Yale J Biol Med* 1976;49:175-95.
5. Ellis RH. Introduction. In: Snow J. On narcotism by the inhalation of vapours. (Facsimile ed). London: Royal Society of Medicine Ltd, 1991:xi-xxvi.
6. Richardson BW. John Snow, MD, a representative of medical science and art of the Victorian era. In: Snow on cholera. (Reprint). New York: The Commonwealth Fund, 1936:xxxvii.
7. Rosen G, trans. Jacob Henle: On miasmata and contagia. Baltimore: The Johns Hopkins Press, 1938.
8. Rosen G. Jacob Henle and William Farr. *Bull Hist Med* 1941;9:588.
9. Snow J. On the mode of communication of cholera. London: John Churchill, 1849.
10. Snow J. On the mode of communication of cholera. Second edition, much enlarged. In: Snow on cholera. (Reprint). New York: The Commonwealth Fund, 1936:11-39.
11. Budd W. Malignant cholera: its cause, mode of propagation, and prevention. London: John Churchill, 1849.
12. Vandenbroucke JP, Eelkman Rooda HM, Beukers H. Who made John Snow a hero? *Am J Epidemiol* 1991;133:967-73.
13. Ellis RH. The Case Books of Dr. John Snow. *Med Hist Suppl* 14. London: Wellcome Institute for the History of Medicine, 1994.
14. Ellis RH. Dr John Snow. His London residences and the site for a commemorative plaque in London. In: Atkinson RS, Boulton TB, eds. The history of anaesthesia. Royal Society of Medicine International Congress and Symposium Series no. 134, 1989, chapter 1:1-7.
15. Cameron D, Jones IG. John Snow, the Broad Street pump and modern epidemiology. *Int J Epidemiol* 1983;12:393-6.