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John Snow, the Broad Street Pump and Modern Epidemiology

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John Snow was a genius in epidemiology. His achievement was to evolve an elegant, internally and externally consistent theory which concerned the mechanisms and processes involved in every aspect of the subject he had chosen to study. In order to do this he did not restrict himself to any method. He used all skills available to himself and his colleagues. He published his theory, and practical suggestions for the prevention of cholera arising out of it, both internally in medical meetings and to the medical press, and to the public in the form of pamphlets and in reports addressed to the appropriate authority. This surely should be the objective of all epidemiological work.

In a recent paper in this journal on the Broad Street Pump Dr Smith makes a construction based on a theory which has nothing to do with the behaviour of the cholera vibrio or with the people involved.[1] It consists of assumptions about the number of persons at risk and about a constant infectivity of the water supply, and it assumes that water was the only medium for the transmission of the disease. These assumptions are purely speculative and are at variance with contemporary evidence.

Henry Whitehead, a friend and collaborator of John Snow, showed that infection from the Broad Street pump after 2 September 1854 was most unlikely.[2] He himself drank from it at 11 pm on 3 September with no ill effects. Vehicles other than water were probably responsible for those infected after 2 September. In the same paper Whitehead shows that, although the removal of the pump handle did not abbreviate the epidemic, it prevented a recurrence. The father of the child whose excreta infected the Broad Street well from 30 August to 2 September, took ill on 8 September, the day the handle was removed. He was ill and died in the same room as his daughter, and since his domestic cesspit leaked into the well it was presumably reinfected.

Whitehead's epidemiology made important contributions to the understanding of cholera and to the ultimate acceptance of Snow's theory.[3,4] Since Smith's paper seems in accord with modern epidemiology teaching and in disagreement with the work of Snow which is often claimed as an early example of that teaching, a reappraisal of Snow and of his relation to current work is long overdue.

John Snow, as nearly everyone agrees nowadays, was a genius in epidemiology. But not all are agreed wherein his genius lies. Opinion was different in his own day. The most powerful medical authorities were convinced that he was mistaken or that his reports wrongly interpreted the facts that his researches uncovered.

We wish to make a statement about Snow's achievement and show how modern epidemiologists have misunderstood his work and misrepresented it as an early example of their own empiricist epidemiology.

Snow claimed no 'method' of epidemiology. Careful reading shows the way he worked and discloses the rich variety of skill and knowledge he introduced to his researches. He is clear that the way of life of the community, its economic system, its educational system, its culture, impresses itself on each of its members. He summarizes some of the ideas he developed thus: '... I enumerated various circumstances connected with the pathology of Cholera, and with its progress as an epidemic, which led me to the conclusion that it is propagated by the morbid poison which produces it being accidentally swallowed; that this morbid poison becomes multiplied and increased in quantity on the interior surface of the alimentary canal, and that it passes off in the ejections and dejections, to produce fresh cases of the disease in those who happen to take the morbid matter into the stomach. I explained what great facilities there are for the Cholera evacuations being accidentally swallowed in the crowded habitations of the poor, where the inmates cook, eat, live, and sleep in the same apartment, and pay little regard to washing the hands, since these evacuations are almost devoid of colour and odour, and are usually passed involuntarily in the latter stages of the disease. It is in the families of the poor that cholera is often observed to pass from one individual to another, while in cleanly dwellings, where the hand-basin and towel are in constant use, and where the rooms for cooking, eating and sleeping are distinct

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from each other, the communication of cholera from person to person is rarely observed. In the houses of the poor, also, the disease is hardly ever contracted by medical, clerical, and other visiters, who do not eat or drink in the sick-room, while it often fares differently with the social visitor, who comes either to see the patient or attend his funeral.

'The cholera has visited the mining districts of this country with unusual severity, in each of the epidemics we have had. The following is the explanation of this circumstance:— The pits are without any privies, and the excrement of the workmen lies about almost everywhere, so that the hands are liable to be soiled with it. The pitmen remain under ground eight or nine hours at a time, and invariably take food down with them into the pits, which they eat with unwashed hands, and without knife and fork; therefore, as soon as a case of cholera occurs among any of the pitman, the disease has unusual facilities of spreading in the way I have pointed out.

'In my former paper I also showed that the cholera evacuations have the property of communicating the disease after being mixed with the drinking-water of the people, and I related a number of instances in which sudden and severe outbreaks of the malady occurred in the epidemics of 1832 and 1849 among persons using the water of ditches and pump-wells contaminated with excrementitious matters. It is particularly to be remarked that, in those instances, there were one or two cases of cholera in the community whose evacuations polluted the water, just before the great outbreak. I also related a number of facts to show that cholera was communicated through the water supply to many districts of London, and to several other towns where the water was obtained from a river receiving the sewage of the town. This division of my views on cholera which refers to its communication through the medium of drinking water, has apparently obtained a greater amount of attention from the Profession, than my views respecting its more immediate communication by the cholera poison being swallowed without the water. While I speak on this division of the subject, however, I must beg the Society to bear in mind also the other part of my views, first alluded to, for I am well aware that the part which relates to polluted water will not of itself explain the whole progress of the disease as an epidemic.'[5]

Snow rejected the theory, prevalent in his time, that the infective material is a chemical substance which is not necessarily derived from another patient. He believed that it is a living cell: 'For the morbid matter of cholera having the property of reproducing its own kind, must necessarily have some sort of structure, most likely that of a cell. It is no objection to this view that the structure of the cholera poison cannot be recognized by the microscope, for the matter of smallpox and chancre can only be recognized by their effects, and not by their physical properties.'[6]

The same biological arguments explain the incubation period: 'The period which intervenes between the time when a morbid poison enters the system, and the commencement of the illness which follows, is called the period of incubation. It is, in reality, a period of reproduction, as regards the morbid matter; and the disease is due to the crop or progeny resulting from the small quantity of poison first introduced.'[7]

It seems, to us, that Snow here carried the germ theory of disease as far as anyone did before the advent of the science of bacteriology, at least as far as Henle and with more supporting evidence. The agent only remained to be visualized by Pacini in 1865 and cultivated on a plate by Koch in 1883.

Snow used statistics to help to confirm a theory he had already established, by providing supporting evidence he could not conveniently demonstrate in any other way. He did not use the statistics to provide the theory, as Farr had done in his demonstration of an association between the incidence of cholera and height above the level of the Thames. Snow was not seeking associations but connecting causal chains. Humean notions of cause so beloved by modern epidemiologists never enter his thinking.

Snow brought all his biological, medical and social knowledge into his enquiries and within medicine he deployed clinical, pathological, microscopical and chemical skills and knowledge and of course he expressed these skills logically and where appropriate with arithmetical analysis. He formed a theory about the communication of infectious diseases in general and cholera in particular and confirmed it by all means available to him including statistical analyses. His epidemiology was by no means one sided. He, a consistent materialist, made a concrete analysis of every situation and because of this formulated answers to the problem of the prevention of cholera and other gastro-intestinal disease in his own day which would solve the very difficult problem of food poisoning in ours.

In Snow's day, of the important sanitarians, only Budd accepted his theory. However, the message which many people associated with him, that water was somehow involved, was so telling that it was acted on both by local and central authorities.

Simon and Farr prepared material for a report which Simon made to the General Board of Health in 1856 on the 1848–49 and the 1853–54 cholera outbreaks, which clearly implicated polluted water as supplied by the water companies in London. It does not mention Snow.

Frazer comments: 'This statistical investigation, one of the most important of all the epidemiological investigations undertaken in this country, in conjunction with Snow's observations, conclusively proved that

materies morbi containing the cholera infection could be carried in water.'[8]

But Frazer is going too far. Simon and Farr merely showed an association with water. They were not concerned with *materies morbi* or with a cholera infection. These gentlemen believed that the culprit was an effluvium produced by rotting animal and vegetable matter, not necessarily specific to cholera but predisposing to it. As Snow has pointed out, you may blame water even if you think only an effluvium responsible, or if you think the effluvium is not specific but merely predisposes towards the disease. But he warns against ideas of predisposition: 'I do not deny that the period of life, being ill or well nourished, and other evident conditions of the patient, influence his liability to certain epidemic diseases. The predisposition objected to above is that which is assumed, without any symptoms of its existence, merely from the fact of the patient taking the disease.'[9] Here again we have Snow the materialist warning against a purely speculative notion.

The report then, did not prove the presence of *materies morbi*. Simon did not believe in them. He did not consider the material he was dealing with specific to any disease. Snow's statistics did not prove their presence. Nor could they. It was the whole concatenation of his evidence, including the statistics that proved the presence of the *materies morbi* and went a long way towards showing their nature as living, reproducing, cellular micro-organisms. The proof arose out of the public health practices which eliminated cholera from Britain in the next few decades.

In our day when the knowledge that much disease is caused by micro-organisms, is more than 100 years old and we have had time to reflect on it, John Snow's work is still misunderstood. For long he was forgotten. His Dictionary of National Biography entry by D'Arcy Power misrepresents his achievement and is inaccurate. Snow is mentioned in modern writing but this frequently misses the point that he was a rounded epidemiologist, unlike Farr who brought nothing to bear on the subject but statistics.

Modern awareness of Snow's work begins with the publication by the Commonwealth fund of 'Snow on Cholera' in 1936. Its editor, Wade Hampton Frost, in a brief introduction sets out Snow's achievement admirably.[10] In 1955 in celebration of the centenary of Snow's main work on cholera in papers read to the Royal Society of Medicine, Mackintosh presents a view that suggests that statistical work on cholera was all that Snow ever did.[11] Hill gives a more comprehensive picture but exaggerates the importance of Snow's statistics.[12]

This is the beginning of a modern return to the attitude among the profession which Snow complained of finding in his contemporaries. Modern epidemiologists concentrate on the water transmission of cholera because that involves the use of statistics in a way they understand, reducing all determination to chance, and denying necessity.

Among Snow's views on cholera, the first 'division' as he calls it, depends on evidence which involves examining the physical, chemical, biological, sociological and political processes. All these present as underlying trends, outstanding single cases and other tendencies which in their totality point clearly to a theory of cause and mechanism of infection. Although this sort of evidence is not entirely ignored in modern textbooks, it is neglected and wherever possible presented as chance occurrence to be subjected to the appropriate statistical procedure in the future. These forms of reasoning however, and this necessity, do enter into the experience of the majority of practising epidemiologists in their day-to-day duties, tracing the causes of outbreaks of communicable disease, or of industrial injury or poisoning. In these circumstances epidemiologists make a judgement on all the evidence, whatever its nature. This may include statistical material and an assessment of probabilities but it is never entirely that, or even mainly that. In this respect epidemiology textbooks dealing with infectious diseases stand apart, for they present this subject extensively.

Macmahon and Pugh mention Snow no less than nine times[13] but they do not even attempt to discuss those non-arithmetical parts of his epidemiology which long predated his statistical studies. In their general treatment of epidemiology they allot only a few paragraphs to this important subject and their discussion is entirely inadequate. On Snow's work, they concentrate on his observation that water is the chief method of spread of cholera and present that as if it were his main theory. They present even this in a way that does not distinguish Snow's theory from those of his chief antagonists. At the beginning of their book Macmahon and Pugh admit adherence to a Humean philosophy of cause. This does not absolve them from indicating that there are other modes of thinking in epidemiology and that they are represented in Snow's work.

Barker and Rose mention Snow twice. There is no mention of his theory. On the first occasion there is a gross inaccuracy: 'Undeterred he removed the handle of the Broad Street pump, and the number of new cases in the neighbourhood dropped impressively.'[14] On the second they say, 'Dr John Snow showed that the outbreak of cholera around Broad Street in London resulted from the contamination of drinking water with excrement from cholera sufferers.'[15] The pump handle was removed by, or on behalf of the local vestrymen, certainly not by John Snow, and both Snow and his contemporaries clearly state that the outbreak was declining anyway. As to the contamination of the well, Snow

says: 'Whether the impurities of the water were derived from the sewers, the drains, or the cesspools, of which latter there are a number in the neighbourhood, I cannot tell.'[16] In fact it was Whitehead who discovered the source of the contamination. Snow deduced it from his theory. Again their general epidemiological discussion omits a proper treatment of the construction of theories of causation. All determination is reduced to chance.

Morris mentions Snow three times.[17] He too concerns himself solely with Snow's statistics on water supplies. Although his book does not, like the others, set itself out to be a systematic text on epidemiology it does aim at community medicine and at 'students and practitioners of clinical and laboratory medicine.' It too should, therefore, at least consider the rest of Snow on cholera and the more general epidemiological principles that that raises, and not confine itself as it does to a narrow empiricism.

The Lilienfelds have written a more comprehensive text.[18] They discuss Snow, but only his remarks on water supplies. Like the others, they do not discuss his earlier, non-statistical work. There is a systematic neglect of the evidence upon which Snow built his theory. Without that evidence and that theory it is very doubtful that he would ever have embarked upon his statistical studies. As we indicated at the beginning, Snow was aware of this neglect.

The Lilienfelds have this to say: 'John Snow's achievement was based on his logical organization of observations, his recognition of a natural experiment, and his quantitative approach in analyzing the occurrence of a disease in a human population.'[19] This effectively summarizes the opinions of most modern epidemiologists. They are so convinced that there is an epidemiological method and that it is essentially arithmetical, probabilistic and empiricist that they miss the point of John Snow's contribution to science. In doing so they trivialize it as they trivalize epidemiology.

John Snow's contribution was to evolve an elegant, internally and externally consistent theory which concerned the mechanisms and processes involved in every aspect of the subject he had chosen to study. In order to do this he did not restrict himself to any method. He used all skills available to himself and his colleagues. He published his theory, and practical suggestions for the prevention of cholera arising out of it, both internally in medical meetings and to the medical press, and to the public in the form of pamphlets and in reports addressed to the appropriate authority. This surely should be the objective of all epidemiological work.

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