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An Element of Controversy

The Life of Chlorine in Science, Medicine, Technology and War

Edited by Hasok Chang and Catherine Jackson

from research by undergraduate students at
University College London

British Society for the History of Science

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Front cover illustration: Blueprint for a chlorine chamber for the cure of respiratory diseases. Reproduced by permission of Edward G. Miner Library, Rocherster, New York.

Back cover illustration: Chlorine gas, courtesy of the Department of Chemistry, University College London. Photo by Gretchen Siglar.

Contents

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Chlorine Disinfection and Theories of Disease

Anna Lewcock, Fiona Scott-Kerr and Elinor Mathieson

1. Introduction

In the modern world, chlorine is widely used as a disinfectant. Its distinctive smell has become familiar from numerous household cleaning products and swimming pools, and it is even present in our drinking water. However, it was a long journey from the first fumigations carried out by Guyton de Morveau in 1773 to the familiar processes of disinfection used today. Despite the early promise shown by chlorine-based disinfectants, it took them many decades to be accepted as reliable and effective means of preventing the spread of disease. It was not until the beginning of the 20th century that chlorine was introduced as a disinfectant in water. Throughout the 19th century numerous individuals promoted chlorine disinfection, but these attempts were shrouded by controversy. There were a wide variety of obstacles. No one seemed to know how exactly the chemicals worked, until the germ theory of disease was established and the microscopic observation of bacteria became routine. It was very difficult to measure the effectiveness of disinfection, so there were continuing controversies about how well various disinfectants worked. At the same time, some harmful effects of the chemicals were also observed. Consequently, each time chlorine disinfection was introduced, disillusionment set in gradually after an initial burst of enthusiasm.

We will begin, in Section 2, by tracing the rise and fall of some of the most salient episodes in the use of chlorine disinfectants before the 20th century, made by Labarraque, Semmelweis, Nightingale, and many others. In Section 3 we will give a more systematic and in-depth analysis of the theoretical debates surrounding the mechanism of contagion and the action of chemical disinfectants. That discussion will show the

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enormous complexity of the debates, and indicate the impossibility of giving a completely general account. To illustrate what a truly full analysis might look like, we give a detailed analysis of one episode in Section 4, namely the use of chlorine in the attempt to battle the cholera epidemic of the early 1830s in Britain and the United States. Many more detailed analyses like that will be needed before we can reach a full understanding of the long and tortuous history of chlorine disinfection; however, our admittedly incomplete discussion can already highlight some factors that may well have general relevance.

2. A series of false dawns

A defining moment in the history of chemical disinfection came in the year 1773 when the cathedral at Dijon, in eastern France, was infected with "putrid exhalations" given out from the bodies that had been left in the vault. These exhalations, or smells, had become so powerful that the cathedral had been abandoned as unusable. Louis-Bernard Guyton de Morveau (1737–1816), a well-known local chemist, was called into deal with it.[1] He believed that the miasma being given off by the bodies could be neutralized with the vapor of hydrochloric acid (then known as muriatic acid, as explained in Chapter 1), made from salt and sulphuric acid. The success of this operation established Guyton and the Dijon Cathedral as a legendary reference point in the subsequent history of chemical disinfection. Similarly, in England James Carmichael Smyth (1741–1821), physician to George III, used nitrous acid[2] in 1780 in churches, prisons and hospitals to destroy contagion; he published this use of the disinfectant in 1795, and received an award of £5000 from the

[1] See Guyton (1801); for a brief English-language introduction, see Guyton (1809). See also Winslow (1943), pp. 239–242. Guyton, soon to be one of Lavoisier's most important colleagues, began his career as a prominent lawyer in Dijon. Later he was a leader of the Revolution, serving as the first president of the Committee of Public Safety, until removed as a moderate; afterwards he was a senior statesman of French science, twice director of the *Ecole Polytechnique* among other things. On Guyton's life and work, see W. A. Smeaton's entry on him in the *Dictionary of Scientific Biography*, vol. 5, pp. 600–604.

[2] Or nitric acid; the two terms were interchangeable at that time.

government for his contribution.[3] After Smyth's award John Johnstone claimed that his father James, a doctor in Kidderminster, had used acid fumigation as early as the 1750s. Johnstone said of the fumigations: "Before mineral acid vapours no antidote was known to be capable of destroying the malignant influence which in the form of gaol fever has often depopulated nations and poisoned the intercourse of society."[4] Guyton's colleague Antoine-François de Fourcroy in 1791–92 used chlorine gas (known as oxymuriatic acid then) for fumigations, and it was admitted by Guyton himself as a superior disinfectant to muriatic acid. The use of chlorine was introduced to England by William Cruickshank, who used it to purify water in 1800.[5] These initial successes, however, seem to have been short-lived.

Some experiments carried out over a century after Guyton's work shed further light on why his method was short-lived. In the estimation of Frederick Andrewes:

> Chlorine gas, at least in the presence of moisture, is a more powerful disinfecting agent than sulphurous acid. However, once a room has been 'chlorinated', the air should be almost irrespirable (if the room has been sealed properly), producing severe bronchial spasms, after twenty four hours. Any animal left in the room during the operation will die . . . . Finally, metal objects may be tarnished and vegetable dyes bleached.[6]

It is highly probable that those employing Guyton-style fumigations in the late eighteenth and early nineteenth centuries also encountered these problems, and this may be why the fumigations were mostly discontinued. But there were other methods of utilizing chlorine that were more effective.

A salient revival of chemical disinfection was made by Antoine-Germain Labarraque (1777–1850), French chemist and pharmacist, who started using chlorides of soda and lime as disinfecting agents in the early 1820s. He claimed that chlorides diluted with water had many uses — on skin ulcers, in the toilet, as injections, for washing cloth dressings, for washing hands, and for applying to the nose when dealing with the sick,

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[3] All of the secondary sources claim that Smyth received his award in 1796, yet Smyth's own writing seems to suggest he must have received it in 1801 or 1802.
[4] Johnstone (1803). Johnstone's brothers Edward and James Junior were also advocates of acid fumigation.
[5] Smith (1869), p. 15.
[6] Andrewes (1907), pp. 103–104.

to name but a few. He also recommended leaving plates of the solution in rooms and changing them daily, in order to destroy exhalations. "In the cases of asphyxia produced by the exhalations of vaults, sewers or any considerable masses of putrefying animal substances", Labarraque recommended that the patient should breathe concentrated chlorides. He also suggested that the chloride of soda diluted in water be used to stop the decomposition of dead bodies.[7] He published the results of his experiments in various scientific journals, and his practical recommendations gained broad official approval. Labarraque boasted:

> After three years of uninterrupted success among the sick . . . , and, especially, after a considerable number of experiments on animal matters in a state of putrefaction, the Royal Institute of France proclaimed, in their turn, the beneficial effects of the applications of the chloride of lime and soda by decreeing me a first prize, at their public sitting on 26 June 1825.[8]

It does not seem, however, that Labarraque had a theory of why chlorine had such healing powers. Like the 18th-century pioneers, it appears that Labarraque had discovered the notable effects of chlorine disinfectant but had no idea as to why it was able to prevent disease.

In December 1825, the Council of Health of the Lazaretto of Marseilles resolved that chlorides should be used for the fumigations in the lazarettos.[9] This was found to be far more successful than the Guyton fumigations; in May and August 1826, when the quarantine physician and health officers attended sea typhus patients, the use of chlorides prevented them from catching the disease from their patients. In contrast, in 1818 in the same place and under the same circumstances, "the typhus was communicated to the health officers and quarantine physician, notwithstanding the daily use of Guyton fumigations".[10] Intriguingly, Guyton's method seems to have been in use, at least in Marseilles, half a century after his initial trial, but it was not as successful as in the iconic case of the Dijon Cathedral. With Labarraque's new discoveries, chlorine disinfection once again became an object of attention; however, we have not seen any evidence that it became a very general practice.

[7] Labarraque (1830), p. 6.
[8] Labarraque (1829), p. 4.
[9] Lazarettos were hospitals for the diseased poor — in this case, more precisely, ships used for quarantine.
[10] Labarraque (1830), p. 6.

The next phase of chlorine disinfection came in as a measure of general hygiene, as instructed by the sanitary reforms recommended by Edwin Chadwick (1800–1890) in Britain, as well as others across Europe in the 1830s and 40s. In this instance disinfection in general became very muddled with other procedures, such as providing good ventilation. Indeed, in such a context, there was clearly no particular theory of disinfection and how it operated in preventing the spread of disease. In Austria, for those who were necessarily in contact with the sick (doctors or ministers for instance) there was an extensive list of instructions to safeguard against infection:

> Never visit on an empty stomach, but only after a stimulating drink (coffee, tea, wine or liqueur), and chew ginger, calamus, orange peel or peppermint cookies, or smoke tobacco while in the sickroom, taking care to spit out the accumulated saliva. Do not visit patients if you feel ill yourself, if you have been up all night, if you are drunk or overly warm or cold or if you have just experienced strong emotions. Wear an outer garment of waxed cloth, hold your breath while in the immediate proximity of the ill and avoid their exhalations. Salve the hands with rose pomade before actually touching them. Upon leaving a sickroom, wash hands and face in a chlorine solution and gargle with a mixture of vinegar or red wine and water, blow your nose, comb your hair, change your clothes and take at least one warm bath weekly.[11]

Apparently, the significance of chlorine as a disinfectant was not clearly differentiated from things like taking a bath. Nowadays these two practices are understood to be on completely different levels, for taking a bath will not kill microbes as disinfectant will. Indeed, disinfection became popular at this point in the nineteenth century as "an extra precaution". Chlorine was particularly popular in Russia, where its gas was used in fumigations, chloride of lime was rubbed over furniture and food, and also used to line breastplates, gloves, hats and coats; bottles of it were also held to the mouth, and those in contact with the sick were advised to wash their entire bodies with chloride of lime (or vinegar).[12]

By the time the Hungarian physician Ignaz Semmelweis (1818–1865) entered the scene in the late 1840s, any focus on chlorine disinfection as a medical practice seems to have been lost completely. Puerperal fever was rampant in the obstetrical wards in the Vienna

[11] Baldwin (1999), p. 50, from sources dated in the early 1830s.
[12] Ibid., pp. 50–51.

General Hospital, where Semmelweis worked. He became convinced that this was due to infection carried on the hands of doctors and medical students into the medical wards from the dissecting rooms.[13] In May 1847 Semmelweis introduced the practice of hand-washing in chlorinated lime[14] before examining patients, and the incidence of puerperal fever went down from 11.4% to 1.27%.[15] The results were published, and the practice was recommended in Vienna over the next three years. However, Semmelweis and his co-workers did not have an agreed-upon idea of exactly what it was that they were destroying with chlorinated lime.[16] Without the support of a theory, many doctors may have been wary of this practice. Indeed, Semmelweis was not successful in spreading the use of chlorine disinfection on a large scale. This may also be because he did not publish the presentation he gave on his doctrine at the Medical Society of Vienna in May 1850. Semmelweis did eventually publish a book but by this time people thought they would already be familiar with its content so did not read it. Semmelweis's work was thus misunderstood and misrepresented, and there were also priority disputes with people like James Young Simpson, who had published a paper on the analogy between surgical fever and puerperal fever.[17] In a minority of cases Semmelweis's work did have an impact, for in the 1850s Murphy of Dublin, Routh of London and Yilanus of Amsterdam were all supposed to have adopted chlorine disinfection because of Semmelweis.[18] However, on the whole Semmelweis became a bitter and neglected figure, his theory roundly rejected by the medical establishment. His appointment in Vienna was not renewed, and he died in an insane asylum

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[13] There is a large and growing literature on Semmelweis. Our account is taken from several sources, including Carter (1985), Carter and Carter (1994), and Hague (2002). Interestingly, the Semmelweis case has even drawn the attention of some philosophers of science, starting with its use in Carl Hempel's classic textbook (1996, chapter 2); for an up-to-date and historically informed account, see Gillies (2005).

[14] Chlorinated lime is generally referred to as "calx chlorata" in 19th-century pharmacopoeia. It was the name given to the dirty white powder obtained when slaked lime (calcium hydroxide) is exposed to the action of chlorine gas. It was known as a bleaching powder, and in aqueous solution ("liquor calcis chloratae") it was used in medicine as an astringent, antiseptic and disinfectant. We thank Anna Simmons for this information.

[15] Clegg and Clegg (1973), p. 173.

[16] Carter and Tate (1991), p. 252.

[17] Carter (1985), pp. 42–45.

[18] Hague (2002), p. 28.

after returning to his native Hungary. For Semmelweis's work to be accepted, the dominant concepts of disease had to be overthrown, as we will discuss further in Section 3.[19]

Chlorine disinfection was employed in the Crimean War (1853–56), but with frustratingly little effect. During the first winter it became evident that the British military had forgotten all lessons on hygiene standards that had been learnt at great cost of money and lives during the Napoleonic Wars earlier in the century. Following this, Florence Nightingale played a crucial role in introducing general hygiene standards to the barrack hospitals, reducing the hospital mortality rate from 40% to 2%. However, it is difficult to discern to what extent the improvements were due to chemical disinfection. Dr. Cruickshank, the senior medical officer in the barrack hospital, and Mr. Selkirk Stuart, the purveyor, indicated that chlorine-based solutions were used as disinfectant. Stuart's report on the hospital stated:

> I have placed a washing tub in each place [in the privies] with Sir William Burnett's solution of chloride of zinc: I found, however, that the patients were in the habit of emptying them and employing the tubs for washing their shirts, so I placed another tub there that the might use that. They now use both.[20]

It is possible that chlorine disinfectants were commonly known to people in official positions but not to the general public. Indeed, those reporting from the Crimean War Hospitals claimed that the orderlies were most unsatisfactory. Drawn from the ranks without any regard to their aptitude or inclination for the employment, they were mostly men whose weak constitution made them unfit for the hardships of a campaign, or convalescents who had not sufficiently recovered to return to service.[21]

During the 1860s, it seems that chlorine disinfection in fact became less popular. Robert Angus Smith commented in 1869 that disinfection was still "so little practised, and the theory so little developed, that we can scarcely fix upon any generally recognised modes of procedure", though he did note that chloride of lime was the best known substance.[22] The manufacturer and chemical theorist Henry Bollmann Condy (1826–

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[19] Carter and Carter (1994), cited by Hague (2002), p. 46. Gillies (2005, pp. 171–177) gives a detailed assessment of that point.
[20] Selkirk Stuart, cited by Coates (2000), pp. 111–112.
[21] Coates (2000), pp. 87–88.
[22] Smith (1869), p. 31.

1907) noted that the use of disinfection to prevent the spread of disease was not common practice in "modern investigation".[23] To evidence this, he highlighted the outbreak of malignant fever in the port of Liverpool in 1861, the spread of which could have been prevented. Condy identified various substances that were in use as disinfectants prior to his own work, including chlorine, hypochlorite of lime, and nitrous acid. Of those, Condy considered nitrous acid as the most effective and least harmful, whilst chlorine was the most objectionable; therefore he lamented the fact that Smyth's system of disinfection, using nitrous acid, was superseded with the almost exclusive use of chlorine. Condy thought that chlorine was not a very good "neutralizer" (see Section 3.2 for a further discussion of this idea). Condy also demonstrated how chlorine and the chlorous gases evolved from the hypochlorites, although undoubtedly effective, were open to serious objections on account of their irritating and corrosive action on animal and vegetable life. As an alternative to chlorine, he proposed using a solution of alkaline permanganates, and marketed it as "Condy's Patent Fluid or Natural Disinfectant".

Condy might have had an interest in denouncing chlorine, in order to promote his own product; however, there is much evidence to suggest that chlorine disinfectant was regarded as highly unsatisfactory by many others, too, in the 1850s and 1860s. The renowned chemist August W. Hofmann (1818–1892) stated: "the chlorine evolved is frequently found objectionable by, and injurious to patients".[24] Edward Nicholson was more emphatic about the dangers of chlorine and chlorides:

> Chlorine, otherwise a most effective deodorising agent, especially in the convenient shape of chloride of lime, has the disadvantage of a most villainous odour. Burnett's chloride of zinc, and the other metallic salts, require to be spread over a large surface to be of any benefit, and all are highly poisonous to man and beast. I have seen two fatal cases of accidental poisoning by Burnett's chloride of zinc [used in the Crimean War]. In the farm and in the kennel great care would be necessary to prevent accidents from bottles and saucers of this highly poisonous and corrosive fluid being left about.[25]

There were indeed incidents of poisoning by chloride of zinc, when people mistook the liquid preparation as fluid of magnesia or gin. The

[23] Condy (1862b), pp. 1–2.
[24] Quoted in ibid., p. 16.
[25] Quoted in ibid., pp. 25–26.

Family Herald reported in 1858: “a great number of accidents, even deaths, have occurred from the chloride disinfectors now in use”.[26] The *Social Science Review* considered that the decline in the popularity of chlorine disinfections was perfectly understandable:

> There are several objections to the employment of chlorine; it has to be evolved by the frequent repetition of a chemical process; it is difficult to determine the quantity diffused; if introduced in very large quantities it is irritating to the lungs; and altogether it is uncertain and not practical. For these reasons the employment of chlorine as a deodoriser and disinfectant, is by no means so common in these days as it were some ten or fifteen years ago.[27]

Chlorine disinfection evidently remained controversial, even almost a century after Guyton’s high-profile introduction of the practice. Although it seemed to have some effect in warding off disease, its exact effect was difficult to ascertain. And its misuse could cause ill-health and even death. To understand why it was so difficult to develop it into a more reliable and verifiable process, we must understand the state of theories about contagion and disinfection before the establishment of the germ theory.

3. Uncertainties in theories of contagion and disinfection

3.1. Theories of contagion

It is commonly said that before the modern germ theory of disease was established, there were two main theories of disease: the contagion theory, and the environmental theory (including the “miasma” theory).[28] This neat dichotomy, however, is quite artificial. In the late 18th century, there were thought to be two types of contagion: specific and general.[29] Specific contagion arose from some particular origin, and caused a particular type of disease. General contagion arose from the putrefaction or fermentation of plant or animal substances, including the effluvia of

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[26] Quoted in ibid., p. 28.
[27] *Social Science Review*, 28 June 1862; quoted in ibid., p. 27.
[28] For the distinction between environmental and contagionist theories, see La Berge (1992). On the blurriness of the boundary between the two theories, see Porter (1999), and Gillies (2005), p. 172.
[29] Smyth (1799) explains this distinction.

the lungs.[30] In effect, it is difficult to see any real difference between general contagion and miasma. Ordinary practitioners like James Johnstone often attributed disease to both contagionist and environmentalist causes; he thought that it was plausible for cold weather to cause a fever, or even kill patients. Vernon Farrar maintains that before the nineteenth century contagion was a "purely philosophical question."[31] There certainly were competing ideas as to what contagion actually was. For example, Latham Mitchell, a New York doctor, even thought that contagion was nitrous oxide; Humphry Davy and Thomas Beddoes refuted this claim by breathing the gas (which is, incidentally, how they first discovered the much-publicized effects of nitrous oxide).

The transmission of contagion was thought to happen in three ways: firstly by simple contact, secondly by communication into a wound, and thirdly via air passing into the lungs and then the blood. The latter mode of transmission could occur in two ways, either by inhaling effluvia directly from the sick, or by inhaling "fomes" or "fomites" (concentrated particles of disease, resulting from the repeated precipitation of contagion into the atmosphere). These fomites could be precipitated on to clothes and blankets, where they remained dangerous for a long time; this explained how infection was spread even when no one appeared to be ill. Fomites could be broken up by combustion and spread throughout the air, becoming more diluted and less potent. James Carmichael Smyth shared the belief that contagion was diluted in the open air, and that disease was passed on either from direct contact with a sick person or from contact with their clothes.[32]

The most feared diseases were malignant or putrid fevers, which included diseases like jail and hospital fever. The main symptom of these contagious fevers was that they caused the putrefaction of flesh. Johnstone believed that a mysterious agent of putrescence existed within bodies, which under certain circumstances would rot the flesh; in his view, "no one can doubt the existence of some degree of putrescence in

[30] See Alderson (1788).
[31] Farrar et al. [1976] (1997), p. 37.
[32] Smyth does not say how contagion is passed on by blankets etc.; that is, he does not mention fomites, but his ideas are generally in line with those of Alderson, so he might have had an idea very close to that.

living bodies".[33] Johnstone considered the action of putrescence to be the breaking down of the structures in the body, forming a melted mass of humours. Living bodies could be protected from putrefaction by two means: the motion of the blood in the veins and arteries, and the removal of acrid fluids from the body by perspiration. These beliefs about contagion implied that ventilation and fumigation were required to remove effluvia from the rooms of the sick. The concern expressed by Johnstone was typical of medics at the time:

> The necessity of changing the air in the sick room, by successive ventilation, arises from the constant destruction of a certain property in that fluid of breathing, which renders it afterwards useless; likewise from the atmosphere being filled with the excrementitious steams which fly off from the patient's body continually, and which putrefy in a stagnant un-renewable air, and render it truly poisonous, a pabulum morbid rather than of life.[34]

Generally, crowded and confined environments such as ships, prisons and the dwellings of the poor were identified as breeding grounds of contagious disease.[35]

Theories of disease became increasingly more important in the nineteenth century, when Europe was engulfed in various contagious diseases. The Industrial Revolution resulted in high population densities in towns and cities, causing a great increase in the number of the urban poor living in unsanitary conditions. Populations grew considerably, with that of Great Britain and Ireland growing from 10 million in 1750 to three times that number by 1850.[36] From the early eighteenth century, increased industrialization and the growth of giant ports and trading routes also meant that commercial contact with populations overseas increased dramatically. Diseases that had previously been confined to distant shores could now easily make their way across vast stretches of land and ocean thanks to the increasing use of new methods of transportation introduced by the Industrial Revolution.[37] In the early decades of the nineteenth century, Britain was repeatedly hit by waves of pestilence; influenza, smallpox, typhus, dysentery and cholera were

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[33] Johnstone (1758). This is not to say that Johnstone did not believe in contagion, only that putrefaction could happen on its own as well.
[34] Ibid.
[35] Bynum and Porter (1993), p. 321.
[36] Barton (2005).
[37] Kohn (2001), p. 38.

common killers.[38] Throughout Europe epidemics raged and mortality rates rose as the attempts to ward off sickness and disease simply appeared to fail.[39]

Under these conditions, the contagion theory actually began to lose ground. Products of environmental putrefaction, particularly animal matter, were thought to spread disease, in contradiction to earlier ideas of contagion. This gave rise to a movement dubbed anticontagionism, particularly strong in the 1820s and 1830s. Anticontagionists regarded popular belief in contagion as unscientific and primitive, and followers of *laissez-faire* economics saw measures such as quarantine as politically suspect, inefficient and obstructive to trade. English sanitarianism drew heavily on anticontagionism, adopting a less causal and more correlative mode of reasoning. English sanitarian theorists, led by Edwin Chadwick and Thomas Southwood Smith (1788–1861), avoided speculations on the causes of disease, in a manner influenced indirectly by the sceptical philosophy of David Hume. Chadwick, when writing his report on the sanitary condition of the labouring population of Great Britain, accepted the miasmic theory of disease, according to which disease was generated in the miasma given off by decaying organic matter.[40] But Chadwick's ideas were rejected, partly because his sanitary reform did not wipe out disease.

The theory of disease in the middle of the 19th century was dominated by chemically influenced ideas about the pathological process, referring ultimately to the activity and selective affinities of organic molecules. This idea was taken up by John Snow (1813–1858), who is normally regarded as a prototypical germ theorist. The repeated onslaughts of cholera between 1830 and the 1860s encouraged speculation about epidemic disease. By the 1860s the position on "filth" had become relatively refined. Epidemic disease was now thought to be due to changes in organic material that had once been part of the animal body. This view accommodated the theories of Snow and the like, which suggested the specific role of choleraic or typhoid discharges in the water supply. Snow is most famous for his conclusion that water from a particular public pump was the cause of a cholera epidemic in the Broad Street area of London during the 1840s. Snow rejected the miasmatic

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[38] Ibid., pp. 411ff.
[39] Conrad et al. (1995), p. 371.
[40] Pelling (2001), p. 25.

theory of disease, but Peter Vinten-Johanson et al. and Michael Worboys state that Snow's ideas on disease were far from constituting a germ theory. In fact, his water-carrier theory for the spread of cholera was based upon his personal experience and his reading of Newton. Snow was "intellectually predisposed by Newton's ideas to consider the intestines a primary site of infection and impure water a potential source of morbid poison".[41] That Snow's ideas have been interpreted differently by different historians illustrates the extent of overlap between competing theories of disease. Margaret Pelling argues that "even 'germ theorists' used the concepts of contagion, infection and miasma as if they were difficult to distinguish, overlapping or even interchangeable".[42]

In the second half of the 19th century, the theory of contagious diseases entered a phase that is more familiar to us today, due to developments most commonly attributed to the work of Louis Pasteur (1822–1895) and Robert Koch (1843–1910). This history is thoroughly covered in the standard literature in the history of medicine, so we will only highlight a few aspects of the story that are most relevant for our current purposes. Early in the nineteenth century John Grove postulated that the ova of parasites and the spores of fungi normally circulated in the blood.[43] Many investigators including William Farr and Justus von Liebig speculated that there was a living factor behind diseases, but this was a suspect idea since it seemed to be dredged up from the dim past, certainly linked with vitalism. Fermentation was often used as an analogy to explain the "multiplication" which seemed to characterize infectious diseases. Many scientists believed that fermentation and putrefaction were the result of some kind of spontaneous generation. By the 1840s enough was known about the properties of gases to rule them out as the direct agents of infectious disease, and many theorists were now in search of the *materis morbi* that generated contagion; it seemed likely that it would resemble highly organised particles of matter, like the pollen of flowers.[44]

Pasteur's great contribution was to pursue the analogy between fermentation and disease in a concrete and productive manner, while ruling out ideas of spontaneous generation. Just as fermentation was

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[41] Vinten-Johanson et al. (2003), p. 40; see also Worboys (2000), pp. 113–116.
[42] Pelling (1993), p. 310.
[43] Pelling (2001), p. 30.
[44] Ibid., p. 27.

caused by yeast and bacteria, so diseases could also be caused by microorganisms, and carried through the transfer of microorganisms. The British surgeon Joseph Lister (1827–1912) independently pursued similar ideas. Picking up the old familiar idea that bad air was responsible for contagion, Lister told his students at Glasgow University that "the something" carried in the air, the miasma, was probably not a gas or effluvium but more in the nature of a fine dust resembling pollen.[45] F. G. Jacob Henle (1809–1885) in Germany was another pioneer of the germ theory. He did not so much state that contagion consisted of living organisms, as describe how this might be recognized in an ideal world.[46] Notably Henle taught Koch, who later established the germ theory through the isolation and microscopic identification of some key disease-causing microorganisms, spearheading the "bacteriological revolution" of the 1870s and 1880s.[47] Koch began his pioneering bacteriological work with his study of anthrax. The techniques he employed were later used in his search for a bacteriological cause of tuberculosis. In 1884 Koch rediscovered, isolated and first cultured the cholera microbe.[48]

The practice of disinfection gained new impetus from bacteriology. Although German surgeons, following Koch, extolled the virtues of heat sterilization over chemical antiseptics,[49] Koch's discoveries also had the effect of reviving people's faith in chemical disinfection.[50] In the end, there was combined use of asepsis by heat, and disinfection by chemicals.[51] During the late 1880s and early 1890s, public health authorities targeted particular channels of transmission and the points of passage between bodies where bacteria were vulnerable to disinfectants. This is not to say that sanitary practices ceased or were downgraded; indeed, attempts to solve problems such as water purity, sewage treatment

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[45] Cartwright (1977), p. 20.
[46] Bynum and Porter (1993), p. 326.
[47] Bynum and Porter (1993), p. 329.
[48] Reiser (1978), pp. 84–85. Apparently, this had previously been done in 1854 by Filippo Pacini (1812–1883), an Italian physician and anatomist. With his microscope he observed unique bacilli in intestinal mucosa taken from the autopsy of a cholera victim. His findings were ignored.
[49] Worboys (2000), p. 187. Asepsis was a movement during the 1890s to make the whole surgical environment germ-free by means of heat rather than chemical antiseptics.
[50] Baldwin (1999), pp. 165–166.
[51] Worboys (2000), p. 187.

and food safety also gained new credibility from bacteriology.[52] By the closing decades of the nineteenth century, chemical disinfection had been widely accepted, and the explanations of its disinfecting properties that had been wildly postulated by advocates earlier in the century, were now presented as fact.

3.2. Theories of disinfection

Given the variety and intermingling of different theories of contagious diseases just outlined, it will come as no surprise that there were also various competing ideas about how disinfectants produced their putative effects. At one level, no *theory* of disinfection was needed, and a disinfectant was merely a substance that appeared to ward off disease. In Europe it was fairly common knowledge that measures of quarantine and disinfection reduced the risk of disease being spread.[53] Many of the successful disinfection measures were promulgated long before the association between microorganisms and disease.[54] People had simply observed that under certain circumstances the spread of disease was not so rapid. Therefore it is important to keep in mind that "disinfection" before the late 19th century did not mean the modern notion of killing disease-carrying microorganisms. Samuel Rideal,[55] writing in 1895, commented that before the germ theory of disease became generally accepted, the term "disinfection" was "used to include the destruction of infectious matter and the removal of any noxious odours to which such matter gives rise."[56]

Perhaps fumigation was the earliest widespread method of disinfection. The idea of fumigating buildings as protection against disease was first established during the plague in Europe. At this time the London College of Physicians recommended employing sulphur, arsenic, charcoal and nitre. These fumigations were not understood as means of destroying contagion, but as means of drowning out or keeping out the plague by using heat, smoke and powerful smell.[57] As a result, fumigations were not entirely unknown to people of the later half of the 18th century, and it is

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[52] Ibid., p. 235.
[53] Baldwin (1999), p. 49.
[54] Benarde (1970), p. 211.
[55] Rideal was a leading analytical and consulting chemist, and worked at University College London as an assistant lecturer from 1883 to 1889.
[56] Rideal (1895), p. 1.
[57] Johnstone (1803).

not difficult to see how the idea of using mineral acids or chlorine gas would have arisen. No clear distinction between them and other (rather ineffective) fumigants seems to have been made. Johnstone and his contemporaries used fumes from amber, lemon, camphire and sulphuric acid in the rooms of the sick. Smyth argued that all contagions were destroyed by extremes of hot and cold, and diluted in fresh air and water; however, where these physical means were unusable, he recommended chemical means such as fumigations by nitrous and muriatic acid for destroying the contagion.

Theories of disease based on the notion of putrefaction did not make a formal distinction between an antiseptic, which prevented the rotting of flesh, and a disinfectant, which stopped the spread of the disease. Putrid fevers were caused by putrid effluvia, which caused putrefaction of the flesh. In this area of medicine there was little difference between what caused an epidemic and what caused symptoms in individuals, and no real separation between public health and the health of the individual. As a result of this, there was a continuity of treatments, which assumed that whatever would prevent the flesh from putrescence should also prevent the spread of disease or the putrefaction of the air. This is one of the reasons that the introduction of disinfection by muriatic and nitrous acid was not met with greater excitement. Muriatic acid had been sold in the street of London as a quack remedy since the time of the plague.[58] In the late 18th century some regular doctors experimented with muriatic acid in the treatment of malignant and putrid disease, and as a means of inoculation.[59] The introduction of muriatic or nitrous acid as a disinfectant would have not seemed any more novel than its use as a regular remedy. James Johnstone recommended that patients take muriatic, vitriolic and nitrous acids as antiseptics to prevent their own bodies from putrefying, in addition to recommending fumigation with muriatic acid. It is feasible that other doctors in the mid-18th century would have used the same or similar medicines in this manner.

Also strange to the modern eye is the widespread belief that smell was indicative of contagion. Smell and contagion were rarely regarded as exactly the same thing, but it was believed that if you got rid of smell then you got rid of miasma or contagion. Smyth wrote that a powerful

[58] Fordyce (1790).
[59] Ibid. This article mentions his use of it and other practitioners since the 16th century.

smell and contagion were "from the same family" and arose from a common cause, and so if a treatment removed the smell in a building it will also have removed the contagion.[60] Labarraque advised the Paris Prefecture of Police in 1823 to use a solution of chloride of lime on corpses to be examined; "the fetid smell will cease". To "prevent the putrid odour from being reproduced", Labarraque urged that the cloth covering the corpse should be sprinkled with the liquid chloride of lime often.[61] When advising on the disinfection of vaults and vessels for urine and feces, the smell was again emphasized: "If the offensive smell is not quickly destroyed, repeat the operation at the end of eight or ten minutes. If the infection proceeds, in whole or in part, from urine or fecal matters spread on the ground, it will be proper to sprinkle this likewise with the same solution."[62]

In all these cases, the practitioners had little concrete idea as to how the disinfectants actually worked. It was merely that the desired effects were observed. This was probably also true of Semmelweis, and those issuing Burnett's solution and the like in hospital wards of the Crimean War. Some 19th-century theorists did attempt to construct theories of disinfection, but the results were mixed. One popular line of thought was that disinfectants in some way neutralized the substances responsible for contagion. This idea may be traced back to Guyton: he believed that the contagion being given off by the bodies were rich in ammonia gas, and that if he could neutralize the ammonia with an acid, then the church would be purified. Beddoes believed that venereal disease and putrid disorders could be healed by highly oxygenated substances. In his publications on venereal disease he included testimonies from medical colleagues who had been trying out oxygenated substances in the treatment of syphilis; these included John Johnstone and Edward Johnstone's finding that hyper-oxygenated[63] acids (muriatic, nitrous and sulphuric acid) destroyed putrid flesh in very small amounts, and that nitre would purify flesh.[64]

[60] Smyth (1799).
[61] Labarraque (1829), p. 5.
[62] Ibid., p. 6.
[63] This concepts reflected Antoine Lavoisier's oxygen theory of acids, according to which oxygen was the essence of acidity and higher oxygen content gave stronger acidity. See Chapter 2, Section 3, for a detailed discussion of Lavoisier's theory.
[64] Beddoes (1795).

Condy also described disinfection as a neutralizing process. He thought oxidization was a key to disinfection: "The researches of recent times on the composition and economy of the atmosphere, point clearly to oxygen, as the chief means by which natural disinfection is accomplished."[65] Citing George Wilson, Condy claimed that ozone (discovered by Schonbein in 1840) was "disinfectant par excellence", as it was understood to be a strongly oxidizing substance.[66] Condy noted that there were two classes of disinfectants: "deodorisers", and "true disinfectants". He explained the inadequacies of chlorine: "chlorine only unites with hydrogen[,] and in the absence of moisture, from which it can liberate oxygen, it is a feeble neutraliser of the other elements of organic substances, such as carbon, nitrogen, sulphur, phosphorous etc."[67]

Lister was probably the first person to develop modern-sounding notions of disinfection, coupled with the germ theory of disease. Lister learned about Pasteur's germ theory in 1865, and seized on it as a potential weapon to allow him to overcome his own problems: Lister worked in an overcrowded hospital, with bodies from the 1849 cholera epidemic buried four feet below his ward; nearby there was a burial pit for paupers, barely covered over. Having read that carbolic acid was being used to control the decomposition of sewage in Carlisle, he began to use a crude carbolic (German creosote) in wound dressings. Lister's method successfully prevented hospital sepsis and he then applied the antiseptic principle to the preparation of germ-free ligatures and surgical materials.[68] Though Lister himself did not use chlorine or chlorine compounds, the acceptance of his antiseptic system boosted the fortunes of chemical disinfection in general, and therefore aided in the acceptance of chlorine disinfection.[69] What Lister did was to give "antisepsis" a new theoretical connotation, and as the germ theory carried the day, the terms "antiseptic" and "disinfectant" became more or less synonymous once again by the end of the century.[70]

The increasing popularity of the germ theory saw changes in official practices as early as 1865, when the British government's General

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[65] Condy (1862b), p. 2.
[66] Condy (1862a), pp. 20–23.
[67] Condy (1862b), p. 5.
[68] Rains (1977), p. 36.
[69] Pelling (2001), p. 31.
[70] Bynum (1994), p. 135.

Memorandum, advising local authorities on how to prevent cholera, recommended "disinfection . . . with regard to infectious discharges from the body of the sick".[71] According to the Parliamentary Papers of 1867–68, disinfection was included in the measures taken to prevent the importation of disease and to limit its spread on arrival.[72] Still, many remained uncertain about various issues linked with the germ theory, not least about the benefits of disinfection. The international congress in Weimar in 1866 heard mixed results of disinfection. The different preventative measures that had been carried out throughout the century gave rise to many debates, in which political factors played an important role. Liberals opposed "exclusive" measures because they objected to the state interfering in personal affairs and introducing policies that damaged the economy. Popular opinion was also wary of medical power, which was understandable especially since the medical profession itself was so uncertain about the theory of disease. Sanitarians suspected that disinfection was being promoted by chemical manufacturers, simply to boost the demands for disinfectants.[73] In addition, there were difficulties in documenting whether disinfection had made any noticeable difference in the spread or virulence of epidemics. This was made clear at the 1874 Sanitary Conference, where the British stood almost alone in their defence of disinfection against attacks from the Austrian and German delegates.[74]

Even after the widespread acceptance of the germ theory of disease, how exactly chemical disinfection worked remained a contentious

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[71] Worboys (2000), p. 115.
[72] Baldwin (1999), pp. 153–154.
[73] Worboys (2000), pp. 129–130. It appears that the Sanitarians fears were not completely unfounded. In the late 1880s at least, manufacturers took advantage of the niche in the market for disinfectants, despite the practice having not been fully established scientifically. Commercially available disinfectants included: Sanitary Fluid, John H. Fuller of Reading; Calvert's Carbolic Acid and Preparations, Calvert & Co., Manchester; *Savonnerie Antiseptique*, E. Delamore, Paris, Rouen (*Methode du Docteur Lister*); Jeyes' Fluid, Jeyes' Sanitary Compounds Co. Ltd, 43 Cannon Street, London; Lysol Antiseptic and Disinfectant for Surgical and General Use; The Odamine Disinfectant, Fluid, Powder, Row and Taylor of Norwich, 1896; The Government Disinfectant, A Pink Carbolic Powder, The Government Sanitary Co., Established 1866. Evidence of these products can be found in Disinfectants Ephemera Box 1, The Wellcome Library for the History and Understanding of Medicine, London.
[74] Baldwin (1999), p. 166.

issue. Samuel Rideal, writing in 1895, stated that chlorine in particular had three possible modes of disinfecting action:

> (1) By replacing the hydrogen in organic substances, thus forming innocuous compounds and poisoning bacteria. Such action would be slow, and "would scarcely occur at all except in sunlight" but would be the only possible action on dry matter.[75]
>
> (2) Offensive gases caused by putrefaction would be decomposed by chlorine, as the sulphuretted hydrogen (hydrogen sulphide, H_2S), which was always thought to be present, would be decomposed into sulphur and hydrochloric acid. Phosphuretted hydrogen from animal matter would be also decomposed, as the ammonia (and its compounds) present would first form ammonium chloride and nitrogen, and the ammonium chloride would then be further decomposed by more chlorine (which would, however, also produce intensely acrid vapours which attacked the eyes).
>
> (3) The most important action of chlorine was thought to be in its role as an oxidation agent. Rideal explained: "In the presence of water, more especially in light, it [chlorine] combines with hydrogen to form hydrochloric acid, and liberates oxygen —
>
> $$H_2O + Cl_2 = 2HCl + O$$
>
> The oxygen so formed is far more active than atmospheric oxygen [O_2], and is in a condition to burn up the putrescent matters and kill the organisms which accompany the putrefaction."[76]

Some of these ideas (as well as others) were in fact circulating much earlier in the century. They were now recycled, not much changed but presented as more certain with the backdrop of a universally accepted underlying concept of disease.

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[75] Rideal (1895), p. 58
[76] Ibid.

4. Chlorine in the cholera epidemic of the early 1830s

Our discussion in the preceding sections has outlined the faltering steps of chlorine disinfection, and pointed to some of the factors which created obstacles for its acceptance. But our account so far is relatively superficial, since we have not yet made an in-depth study of any particular phase of that long history spanning more than a century. In this section we attempt a detailed study of one important episode, surrounding the cholera epidemic of 1831–32. This study will reveal crucial contextual factors that have some general relevance, and also illustrate the complexity of the web of factors that will need to be untangled in each situation if we are to reach a satisfactory understanding.

4.1. Cholera and chlorine

On Monday 6 February 1832, Londoners desperately observed a national day of fasting and penance in a final plea to be spared from the "fell destroyer of the human race" that was drawing ever nearer, the *cholera morbus*.[77] One week later London's first case of cholera was reported, and the disease began to cut an indiscriminate swathe across the capital. Cholera emerged from India, producing four devastating pandemics in the 19th century (1817–23, 1826–37, 1846–63 and 1865–75).[78] In June 1831 King William IV had announced the establishment of a central Board of Health, a body consisting of six doctors and five public servants, whose job was to keep cholera from Britain's shores. However, the Board itself only had advisory powers, and although it sponsored various experiments (including an investigation into the alleged disinfecting properties of chlorine) most of its members had absolutely no experience with the disease, and ultimately they could not prevent cholera from reaching the British Isles in October 1831.[79] The disease landed on England's northeast coast in the town of Sunderland and quickly spread throughout Britain. More than 21,500 people fell victim in England and Wales, and a further 9,500 in Scotland. By March 1832 Ireland was

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[77] "Cholera Morbus", in "Foreign Department — Analysis of Foreign Medical Journals", *The Lancet*, vol. 3, issue 66, 1 January 1825, p. 470.
[78] Kohn (2001), p. 38.
[79] Bynum (1994), p. 74.

struck, losing 25,000. London's fatalities numbered just under 7,000 in that first outbreak.[80]

Reports of cholera from around the world during the pandemic generated a great deal of anxiety, and articles in medical journals such as *The Lancet* provided updates on the progress of "that dreadful scourge of mankind", which did little to quell the unease:

> So rapidly destructive, indeed, has been its progress; so widely devastating its career, that it has literally passed on like a flood, sweeping all before it; depopulating cities and annihilating armies, and realising to us, in modern times, those horrible pestilences which prevailed in days of yore.[81]

Part of the alarm caused by cholera was that it simply did not seem to behave in the same way as other diseases that had ravaged the globe in the preceding centuries. Quarantinist strategies that had been of use in previous attacks of pestilential disease did not seem to work when it came to dealing with this new menace. Medical opinion remained essentially undecided as it became clear that cholera was not as strictly contagious as the plague, and its incidence "varied by class, season, region, neighbourhood and person",[82] spreading capriciously and refusing to follow regular patterns of human intercourse or consistently respond to climatic or similar factors.[83] A sense of desperation is apparent in medical correspondence of the time; for example, Dr. Henry Bronson of New York declared in 1832:

> If I am asked the essential, non-contagious cause of cholera, I answer frankly — *I do not know*. Every agent in nature, real or imaginary, has been accused. Electricity, magnetism, earth, air, water, sun, moon, planets, comets, have each been arraigned in vain. There is a mystery which hangs over the origin and spread of epidemics, which will probably never be removed. The philosophers of the present day are no wiser on this subject than those who lived three thousand years ago.[84]

Treatment of cholera in the years prior to its arrival on Britain's shores was confidently asserted to be achieved through doses of brandy,

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[80] Kohn (2001), pp. 12, 38; Pelling (1978), pp. 1–2.
[81] "Notes on the Epidemic Cholera, by R. H. Kennedy", in "Reviews of Books", *The Lancet*, vol. 10, issue 241, 12 April 1828, p. 55.
[82] Baldwin (1999), pp. 123–124.
[83] Pelling (1978), p. 2.
[84] Bronson (1832), p. 4.

opium and calomel,[85] and bleeding by leeches.[86] In the opinion of one Dr. Armstrong, “there is no cordial half so good in the apothecary’s shop as brandy”, and one may often save a patient from the collapse following an attack of cholera by administering a good dose of this cordial along with opium.[87] Understandably, once cholera arrived in Britain, faith in these remedies began to waver and more reliable alternatives were sought.

The sheer horror of cholera and the ineffectiveness of traditional remedies stimulated an investigation of potential preventatives and cures with renewed vigour. Around the early 1830s one notices an increased incidence of chlorine and its compounds in the medical literature, not only as a potential disinfectant, but also as a possible cure for disease. In the pages of the *Lancet* in the years around the great cholera pandemics, chlorine is suggested for use in treating a wide variety of complaints, including everything from scarlet fever, gonorrhoea and consumption, to hydrophobia, bad breath, and ptyalism (excess production of saliva). Chloride of lime appears to have been quite widely used as a disinfectant, and also mixed with water to form a lotion that could be applied to the skin.[88] Although it was recognized by at least some of the medical community that noxious smells were not always indicative of, or even necessarily associated with, disease or contagion, chloride of lime was also often used to eradicate odours emanating from putrefying vegetable or animal matter or the general smell of disease.

In early September 1831, *The Lancet* published recommendations from the Board of Health on “Preliminary Steps to be Taken on the First Appearance of Cholera”. It contained the instruction that once diseased persons have been removed and quarantined, rooms and houses should be “thoroughly exposed to a constant current of air, and recourse had to all well-known means of purifying houses, particularly the use of chloride of lime; and the bedding and clothing of the sick person after removal, should be soaked in a slight solution of the chloride in water, and well

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[85] Calomel is mercurous chloride — a purgative, cathartic, and liver stimulant, which can readily decompose into highly poisonous substances. See “Cholera Morbus” (note 77), p. 278.
[86] Armstrong (1825), p. 364.
[87] Ibid., p. 365.
[88] Laurence (1832), pp. 10–11.

washed."[89] This is evidence that the chlorides were indeed being used as disinfectants, though it is quite possible that their ability to destroy the putrid odours produced as a result of disease could have been the main incentive for their use. When cholera did arrive in Britain, chlorides were put into use as part of a profusion of techniques and methods employed in an attempt to ward off cholera.[90] Fumigations using chlorine gas were also employed in private houses to try and protect inhabitants against infection.[91] However, there was a considerable amount of controversy regarding the use of chlorine and chlorine compounds as disinfectants. The controversy at this time was not limited to Britain, but quite active in the United States as well.

We cannot give a complete account of this widespread controversy, but we can make a good start by examining two salient opponents of chlorine disinfection. One was Henry Bronson, a leading cholera expert in America and professor at the Yale University Medical School. His 1832 text is the most extensive treatise we have found on the employment of chlorine against cholera. He claimed, after an in-depth study of cholera and various supposed treatments and preventatives, that chlorine disinfection was categorically ineffective. He even declared that in more than one case an attack of cholera was "satisfactorily traced to the free respiration of chlorine." Bronson argued that the use of chlorine was not only dangerous in itself, but that by weakening the respiratory system it would make people more susceptible to disease.[92] In his tirade against chlorine disinfection, Bronson also attacked the supposed scientific explanation of chlorine's action, which was based on the idea that chlorine destroyed the harmful compounds by taking the hydrogen away from them. He challenged the idea that all disease-carrying compounds contained hydrogen. Even if they did, Bronson asserted, some of them might be based on substances that had a greater affinity for hydrogen than chlorine, and therefore there was no guarantee that chlorine disinfection

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[89] "Board of Health — Preliminary Steps to be Taken on the First Appearance of Cholera", *The Lancet*, vol. 16, issue 418, 3 September 1831, pp. 727–728.

[90] In monetary transactions coins were to be stirred in bowls of vinegar before and after exchange, letters and papers were to be fumigated, animals were to be killed, contact with other people was to be avoided as much as possible. See Baldwin (1999), pp. 49–51.

[91] Baldwin (1999), p. 50.

[92] Bronson (1832), p. 8.

would work.[93] He also reported a concern in the medical community that people were lulled into a false sense of security by the fact that chlorine masked the smell of "noxious effluvia" and other odours associated with sickness and disease. Bronson was keen to point out the naiveté of this belief, and noted that some of the most deadly diseases, such as smallpox, measles and jail fever, had no perceptible smell.[94] He also noted that with the advent of the so-called disinfectants, people's general level of cleanliness and hygiene was falling. He complained that "the old and vulgar means of purifying, such as washing, and scouring with soap and water, ventilation, sweeping, scraping and removing, &c. were frequently abandoned, not only as costly, but *as behind the improvements of the age*."[95] Instead of using common-sense methods of cleaning and removing filth and muck, people were just sprinkling chlorides around, placing their faith in this new, seemingly *scientific*, method of keeping clean.

The other striking opposition came from *The Lancet*. On January 21, 1832, a lengthy article on "Chlorine Gas" appeared in *The Lancet*, whose page headers announced "Proofs that Chlorine Gas Possesses No Anti-Pestilential Properties" against "Alleged Disinfecting Properties of Chlorine". This article was presumably approved, or possibly even written, by the editor of *The Lancet*, Thomas Wakley (1795–1862). *The Lancet* was founded in 1823, and was the premier journal–cum–medical newsletter in the English language.[96] Its founder and editor for forty years, Wakley was waging a war against any kind of quackery, chicanery, nepotism and charlatanism; he was "utterly fearless and determined, a man who could crush an enemy as he would a wasp".[97]

The article reported the opinions of leading physicians on the disinfecting powers of chlorine. Dr. Tweedie of the Fever Hospital and Dr. Roupell of the Seaman's Hospital in London were of the opinion that chlorine had no effect in preventing the spread of disease in their hospitals. The eminent Dr. Cowper of Glasgow was "decidedly of the opinion that the chlorides possess no power or efficacy whatever in destroying infection". Mr. Robertson of the convicts' hospital ship *Canada* reported favourably on the chloride of lime in preventing the

[93] Ibid., p. 5.
[94] Ibid., p. 10.
[95] Ibid., p. 9.
[96] Froggatt (2002), p. 667.
[97] Ibid., p. 669.

spread of infectious disease, but Drs. Latham, Bright and Elliotson of St. Bartholomew's, Guy's, and St. Thomas's Hospitals had no observations to offer on the disinfecting properties of chlorine.[98] After also consulting authorities with experience of the cholera in northern Europe, the *Lancet* endorsed the recent conclusions of the Board of Health:

> chlorine gas is utterly inefficient in preventing the spreading of contagious diseases in hospitals or other places, where there is a fresh supply of infection continually emanating from patients labouring under such diseases. . . . its employment . . . would be decidedly injurious, if interfering with that free and thorough ventilation, which is more essential than any other condition whatever, to the healthy state of these establishments.[99]

The *Lancet* bitterly dismissed the thought of wasting any more time on the fraudulent claims of chlorine disinfection:

> Taking all the preceding facts into our deliberate consideration, we cannot resist the conviction that this mischievous source of delusion is now fully and satisfactorily exposed; and we trust we shall hear no more of the *disinfecting* agency of chlorine, the chlorides, &c. Their agreeable powers as correctors of stenches we do not deny, but we entreat the community not to be misled by the vulgar and most erroneous notion, that offensive smells and infectious miasms [sic], are either identical in their nature, or usually associated in their existence.[100]

After this editorial outburst, it is no surprise that very few articles regarding chlorine or chlorides appeared in the *Lancet* for at least a year or so.

4.2. Physicians vs. chemists

How can we make better sense of the vitriolic reactions against chlorine disinfection just mentioned? At least part of the explanation can be found in an examination of the emerging medical–scientific community, with clashing ideas of territory and rights over certain areas of intellectual investigation and authority. The most major fault-line was that separating physicians and chemists. In the first quarter of the 19th century, the relationship between the medical and chemical communities appears to have been perfectly amicable. Indeed, in 1824 *The Lancet*

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[98] "Chlorine Gas", in "Discussion", *The Lancet*, vol. 17, issue 438, 21 January 1832, p. 597.
[99] Ibid.
[100] Ibid., p. 599; emphasis original.

extolled the virtues of chemistry and the importance of its findings to medical practice, declaring that "there is not a more important or valuable branch of Medical education than Chemistry." Not only that, but chemistry was "now justly regarded as the ground-work of all medical knowledge, and it is also indispensably a most important part of surgical education; for chemistry alone is the only key to physiological investigation."[101] In recognition of the importance of chemistry to medicine, the journal also initiated a weekly chemistry column to educate its readers on the basic principles of this new branch of scientific enquiry. However, by the 1830s this fraternal relationship appears to have started breaking down. The chemistry columns in *The Lancet* disappeared,[102] and a rift between the two disciplines emerged with the physicians seeming distinctly antagonistic towards chemists.

Chlorine disinfection seemed to be based on *chemical* rather then *medical* principles, which set it decisively on the chemists' side of the fence; but its goal was to have a positive impact on health and disease prevention, which was the domain of the medical community. By blurring these boundaries, chlorine effectively set in motion a border dispute that played a part in its downfall. When chemists amused themselves with investigations of heat or electricity, they were of little threat to medicine and its control over the loftier dominion of health maintenance and disease prevention. However, when chemistry appeared to be getting above its station and encroaching on the territory of those aristocrats of science, the physicians, it was not to be tolerated. Early symptoms of disquiet in the medical camp are discernible in a dispute over the prescribing powers of chemists in the early 1830s. Not only were a variety of "quack" remedies readily available in the 19th century, but chemists appear to have been freely prescribing genuine drugs and treatments to their customers. In the eyes of the physicians, who had undergone years of training to fully comprehend the functioning of the human body and its response to drugs and treatments, for an unqualified chemist to be able to prescribe medicines was simply unacceptable. The fact that presumably physicians would be cut out of the diagnosis and

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[101] "Chemistry", in "Discussion", *The Lancet*, vol. 1, issue 25, 21 March 1824, pp. 384–385.

[102] The "Chemistry" columns in their original form only appear to have lasted until December 1824. A series of "Lectures on Chemistry" by Professor Brande was published from October 1827, but this too seems to have disappeared by August 1828.

prescription loop, and lose out on any monetary recompense for their services, could also have provided cause for their outrage.

A letter to the editor of the *Lancet* by an "Old Authorised Prescriber" provides evidence of the antagonism brewing between physicians and chemists:

> In some of the late numbers of THE LANCET, I have observed several letters apparently written by persons belonging to that class of professional men, who have recently acquired the appellation of "*General Practitioners*," complaining in bitter terms, against the druggists for encroaching upon *their* province, by prescribing for the sick. Now, Mr. Editor, I should be glad to know by what authority, except that of local custom and sufferance, they themselves prescribe.[103]

This correspondent noted that it was merely social convention that gave physicians any authority over prescribing for the sick, suggesting that the indignation felt by the medical community was based purely on an ingrained doctrine of medical authority and rights over certain activities. In another letter to the *Lancet* in June 1831, a person identifying himself as "A Chemist and Druggist" begged recognition for those people other than physicians who "live by medicine, [and] who . . . ought not to be lost sight of", and requested that chemists be distinguished from "the mere retailer of drugs" by being awarded a certificate or diploma on producing an attestation signed by two doctors and paying a fee.[104] Beneath this letter was printed a comment from Wakley in his characteristically merciless style:

> In inserting the above letter, we shall offer no other remark than this:— Neither chemists, nor druggists, nor any other persons, should be allowed to dispense prescriptions without undergoing a strict examination to prove their competency. In a word, they should be licensed by some well-qualified authority. — ED. L.[105]

One can easily imagine which "well-qualified authority" the editor had in mind.

The concern for professional prerogatives felt by the physicians of the nineteenth century has been highlighted by some modern-day

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[103] "General Practitioners", in "Correspondence", *The Lancet*, vol. 13, issue 338, 20 February 1830, p. 711; emphases original.
[104] "London College of Medicine. Chemists and Druggists", in "Discussion", *The Lancet*, vol. 16, issue 410, 9 July 1831, p. 476.
[105] Ibid.

commentators. Margaret Pelling notes that “long reviews in the medical journals traced the progress of chemistry from its former alleged position of dependency on medicine, to its current claims to being a science in its own right; and discussed, usually with caution and sometimes with misgiving, its entry into areas of medicine other than the pharmaceutical.”[106] Pelling also notes unwillingness on the part of physicians to accept a relation between research and practice, so any suggestion that those whose primary interest was something other than medicine (chemistry or microscopy, for example) could contribute to solving medical problems was distinctly unwelcome.[107] This became difficult when it came to disinfection, as chemists felt they had something to contribute but were actively excluded and discriminated against by the medical community.

This is particularly evident in the vitriolic words of Dr. Bronson again, who seemed highly resentful of the “modern alchemists” as he repeatedly called them, and distinctly unwilling to accept them as scientific brethren. With respect to chlorine disinfection, Bronson drew a sharp distinction between physicians and chemists with one particularly disparaging comment: “Nine-tenths of the medical world still go on doubting, while chemists continue their scientific reveries, publishing to the world their closet speculations, and anon repeating the stale story about ‘the cathedral of Dijon’.”[108] Bronson’s assertion that a huge majority of the medical community doubted its worth was most likely poetic licence, but serves to vividly illustrate the perceived divide between the two groups. Bronson went on to further demonstrate the hostile feeling towards the chemists from the medical community in claiming:

> Those who have appeared as the advocates for chlorine, have been almost to a man *chemists*, who have had no *practical* knowledge of the subject which they have handled. Their *facts* have been gathered in the laboratory. Their conclusions have been the fruits of study. Their philosophy has been the result of speculation. How much, then, are their assertions and opinions worth?[109]

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[106] Pelling (1978), p. 132.
[107] Ibid., p. 156.
[108] Bronson (1832), p. 8. This refers to Guyton’s fumigation of the Dijon Cathedral in 1773, discussed in Section 2.
[109] Ibid., p. 10.

These comments categorically devalued any contribution made by chemists to the fight against cholera, or any other area of investigation where the medical community believed itself to have ultimate authority. In Bronson's view chemists were only speculating in the laboratory, ignorant of actual practice. Even Chester Averill of Schenectady, New York, a proponent of chlorine disinfection, seems to have felt the need to apologize for its connection with chemistry and defend it against any discredit by association:

> Chemists as well as others are liable sometimes to deduce too great inferences from particular facts; but there have been so many facts illustrating the action of chlorine upon contagious or infectious matter, as to lead them to conclude, that most if not all virus of vegetable or animal origin contains hydrogen which can be abstracted by the action of sufficient free chlorine, and thus the virus destroyed.[110]

4.3. Science: method and status

In the debates recounted above, various protagonists invoked the notion of "science" and the "scientific" method, in order to strengthen their own positions. This is worth examining in some detail. Since the 1830s was an important juncture in the professionalization and a self-conscious mobilization of the scientific community, especially in Britain, it will be interesting to place the chlorine debate into that broader context. As science was trying to become recognized as a profession, it was important to present and defend a coherent and standardized method of research. This resulted in an unwillingness to accept findings that were not the result of precise and meticulous adherence to the approved method. However, a closer look reveals that there was no clear consensus on what exactly the scientific method was. Therefore, the rhetorical use of the concept of science will also help us trace the tensions developing within this emerging scientific and medical community.

In the early 1800s, there were essentially three types of medical practitioners: physicians (learned and university-trained), surgeons, and apothecaries.[111] As John Harley Warner emphasizes, many of those who wished to reform medicine opposed the medical hierarchy of the day, which placed the physicians over all else. They accused institutional

[110] Averill (1832), p. 16.
[111] Haigh (1991), p. 189.

leaders of favouring social qualifications over the scientific, thus devaluing science as grounds for professional recognition and removing incentives for scientific enterprise.[112] By emphasizing science over social status, reformers hoped that those practitioners who lacked the advantage of high social standing or patronage could hope to elevate themselves by excelling in science.[113]

The debates on the reform of medicine in Britain often took place in the context of a widespread concern about the "decline of science" in English medicine. The worry was that English medical science was degenerating in comparison to the blossoming of science across the Channel.[114] In the wake of the French Revolution, the reorganization of medicine in France established Paris as a "centre unmatched in its medical vitality". Medical students from all over the world swarmed to the hospitals and dissecting rooms of France to study, reporting back on the superior techniques, methods and clinical ideas found there. Intense comparisons between French and English medicine led to the conclusion that England was decidedly behind France in "medical *science*".[115] In the United States there was similar concern with the backwardness of American medicine, and reformers looked to France and French science as offering a guide to professional and social uplift. In the United States, the most promising aspects of French science were seen in its epistemology, a denunciation of rationalism in favour of a commitment to sensual empiricism. By adopting the French epistemology that was responsible for the country's success in science, Americans hoped to attain comparable success in transforming medical practice.[116] It appears then, that "science" in early 19th-century medicine was partly what mid-status practitioners felt they could take from the French example to help them reform medical practice in the United States and England, in their attempt to encroach upon the territory of the more learned or gentlemanly physicians.[117]

The defensive reaction of the established physicians against the chemists peddling chlorine disinfection makes better sense in this context.

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[112] Warner (1991), p. 145.
[113] Ibid., p. 149.
[114] Ibid., p. 136.
[115] Ibid., pp. 137–139.
[116] Ibid., p. 153.
[117] Ibid., pp. 6–7.

Elizabeth Haigh observes that the gentlemanly physicians were already losing ground to the other classes of practitioners, as surgeons were allowed to treat patients with externally applied salves and lotions, and apothecaries were increasingly becoming medical advisers to the middle and even upper classes.[118] Warner notes that the "institutionally entrenched elite" tended to dismiss complaints about the decline of English science in medicine and criticized the reformers' "excessive zeal" for French science, focusing instead on the exceptional standard of English *practice* over what they considered scientific "speculation".[119] It was necessary for them to argue that an emphasis on medical *science* might not be entirely compatible with the aims and ideals of English medicine and the interests of the patients. One student, writing home from France, criticized the French system as seeming "to think that the perfection of medicine consists not so much in keeping patients alive as in foretelling with precision the appearances which will be found after death".[120] Despite the acknowledged progress made by science, the conservative medical profession greeted comparatively revolutionary ideas such as chlorine disinfection with reluctance and apprehension.[121] Such a simple answer to disease prevention as chlorine and chloride of lime seemed to suggest that disease and ill health could be easily reducible to only a few basic causes, which was more likely to be taken as quackery than a genuine theory of disease and infection. Physicians tended to cling to a multi-factorial view of health and disease, and continued to view epidemics as "spawned by the ineluctable cosmic forces which had always absolved the doctor of responsibility for the fate of his patients."[122]

At the same time, physicians could not afford to dissociate themselves from "science" completely, with its desirable connotations of objectivity, knowledge and control, on which they could base their claims of diagnostic expertise and therapeutic efficacy.[123] Increasingly, it had to be a scientific outlook that distinguished the physician from the quack and the amateur. As a result, each side employed the rhetorical strategy of

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[118] Haigh (1991), pp. 189–190.
[119] Warner (1991), pp. 140–141.
[120] Voyageur, "Parisian news", letter to the editor (1 May 1828), *London Medical Gazette*, vol. 2, quoted in Warner (1991), p. 147.
[121] Magner (1992), p. 266.
[122] Ibid.; see also Pelling (1993), p. 133.
[123] Bynum (1994), p. 93.

claiming a superior scientific method for itself, rather than taking an anti-science stance. There was a vague general consensus on the inductive method during this period, as expressed by the chemist William Henry, who was experimenting on disinfection by heat during the cholera epidemics. Henry observed that the business of science was to collect facts and investigate individual truths through observation and experiment, and then employ induction in order to arrive at general laws "more or less comprehensive in their extent, and serving, like the classes and orders of natural history, the purposes of an artificial arrangement."[124] However, there was still a great deal of latitude in the interpretation and employment of the inductive method in particular situations, and it is tricky to pin down precisely what was meant by an investigation or experiment being "scientific", or a theory being "proven by" or "founded in" science.

Some advocates of chlorine disinfection argued that its efficacy had been proven by science. For example, Chester Averill recounted an experiment carried out in which the shirts of six cholera victims were soaked in a chloride solution. The shirts were then left to dry and donned by six healthy men, who proceeded to exercise vigorously and work up a sweat, presumably to stimulate the infectious potential of any matter remaining on the shirts. None of these six men became ill, and this was taken as distinct evidence of chlorine's disinfecting powers.[125] Further proof was presented in the fact that employees at bleachworks or in chlorine or chloride manufacture often had "ruddy healthy faces"[126] and were less likely to fall victim to typhus and other diseases.[127] Averill argued that, after reading all the opinions and facts that he had presented, no man "free from prejudice and willing to give the matter more than a superficial examination . . . can doubt that chlorine possesses energetic disinfecting powers — that its use is not at present empyrical — *but is founded in science*, and *is the result of deduction from observation*."[128]

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[124] Farrar et al. [1976] (1997), p. 42.
[125] Averill (1832), p. 5; see also Laurence (1832), p. 25.
[126] Smith (1869), p. 47.
[127] Averill (1832), p. 8. See Chapter 9 for a similar observation in the early 20th century, which led to the idea of using chlorine for the prevention and treatment of influenza.
[128] Ibid., p. 13. Averill had provided a summary of the major findings on the efficacy of chlorine to the Hon. John I. Degraff, the mayor of Schenectady, who sought his advice on whether chlorine could be used to deal with the latest outbreak of cholera in the city.

Averill's assessment echoed that of Andrew Ure (1778–1857), English chemist and geologist, who claimed:

> The remarkable power of chlorine, and its official compounds, chloride of lime and soda, in decomposing and destroying the fetid effluvia of animal and vegetable bodies in a state of putrefaction, has been so long known, has been verified in so many instances, and is susceptible of such direct demonstration, as to be beyond the cavils of medical pyrrhonism [extreme scepticism] in its most wanton mood.[129]

Averill also opined in support of chlorine disinfection that "the mode of its operation has been explained by science. There has been less blind experiment with it, than with, perhaps, any other agent that has contributed to our health and comfort."[130]

However, some other advocates of chlorine disinfection admitted that scientific evidence to support its claims may have been lacking. For these figures, there was a dilemma — particularly with the constant pressure of cholera at their backs pushing them to find and use any possible treatment or preventative. Richard Laurence, writing in 1832, provides a particularly good example of this quandary. Acknowledging that precisely *how* the disinfecting action of chlorine works was not yet known, he nonetheless entreated all medical men to freely administer the chlorides in cases of cholera.[131] His plea to the medical community advocated bending the rules of science as he himself understood them:

> When we contemplate the mortality which has hitherto attended this disease, together with the rapidity of its progress, and the slowness of recovery in those whom it does not destroy, ought we not reasonably to conclude that no probable means should be left untried to counteract its virulency? Theory, I well know, ought to follow experiment, and not to precede it; but when the properties of a remedy, producing a peculiar effect, are ascertained in one case, can it be deemed unwise or unimportant to prove or disprove the theory grounded upon the result of that case by trying it in another?[132]

Arguments such as Laurence's would not have impressed the harshest critics, who denied in the first place that chlorine disinfection was effective. Those critics were keen to argue that the seeming efficacy of chlorine was shown to be spurious, if analyzed according to proper

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[129] Andrew Ure, quoted in Averill (1832), p. 4.
[130] Averill (1832), p. 16.
[131] Laurence (1832), p, 10.
[132] Ibid., p. 25.

scientific method. A striking instance of this type of criticism occurs in the 1832 *Lancet* article discussed above. *The Lancet* took pains to criticize the methodology employed in what was perhaps the most prestigious experiment in support of chlorine disinfection, carried out by no less than Michael Faraday.[133] Faraday had prepared two parcels containing smallpox matter, one immersed for three hours in a vessel containing one part chlorine gas and twenty-four parts atmospheric air, and the other immersed for the same time in one part chlorine gas and forty-nine parts atmospheric air. Three people were inoculated with the material from the first parcel, and none of them fell ill. Four others were inoculated with material from the second parcel, and they only experienced slight inflammation around the inoculation site. All seven people were then vaccinated and "had the disease in the most perfect and regular way, thus showing their susceptibility to have taken to small-pox, had not the virus[134] been deprived of its contagious quality by the influence of chlorine gas."

Faraday's experiment was categorically dismissed by the *Lancet*. First of all, the smallpox matter should have been divided into *three* parcels: "one exposed to atmospheric air alone for the same period that the second was acted on by dilute chlorine, and the third preserved in the usual way without any exposure." The suspicion here was that such an experiment with a proper control group would have revealed that the apparent action of chlorine was spurious, most likely attributable to the action of atmospheric air. The *Lancet* also opined that a larger number of cases should have been tested, though it did acknowledge that a large-scale trial with smallpox would be "objectionable in a legal and moral sense." The article stated that "on the whole, we feel perfectly satisfied that the experiments on small-pox matter . . . are perfectly useless with reference to the point at issue." Rather strangely, the article went on to describe approvingly a similar experiment by Bousquet in France on cow-pock, in which inoculation with diluted chloride of soda solution did not appear to halt the spread of infection.[135] This experiment was presented

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[133] "Chlorine Gas", in "Discussion", *The Lancet*, vol. 17, issue 438, 21 January 1832, pp. 598–599.
[134] According to the Oxford English Dictionary, the term "virus" at this time could be taken to mean "a morbid principle or poisonous substance produced in the body as the result of some disease", rather than the modern sense of the word.
[135] "Chlorine Gas", p. 599.

as direct evidence of the inefficacy of chlorine in destroying infectious matter, although it seems to have involved much less rigorous testing than Faraday's, and used cow-pock rather than a human disease.

5. Conclusion

The halting progress of chlorine disinfection was a many-splintered thing. There was not one simple cause-and-effect connection which prevented chorine disinfection from becoming a widespread practice, but a combination of factors all contributing to chlorine disinfection being overlooked or ignored. The arrival of cholera in Britain in 1831 acted as a stimulant to push research in the area of disease treatment and prevention, including the use of chlorine and chlorine compounds as disinfectants. However, despite numerous reports of successful trials, the practice never took root. Concern with a meticulous adherence to the scientific method, rather than madly trying anything that might work against the cholera, seems to have hindered the acceptance of chlorine disinfection. The friction between chemists and physicians provided a further obstacle. These factors, which were perhaps peculiar to that particular phase of history, worked in conjunction with others that were more general and enduring. Most prominent of the latter factors was the lack of a stable, reliable and well-articulated theory of disinfection, which also needed to be backed up by a credible theory of contagious diseases. Until the bacteriological discoveries of the 1880s and 1890s, attempts at disinfection were little more than "shooting in the dark", in the words of Peter Baldwin, as "no one had any idea of what they were seeking to destroy, nor therefore how to do so. It was consequently impossible to know except indirectly which disinfectant substances were most effective and whether, indeed, the entire enterprise made any difference."[136] The full potential of chlorine disinfection could only be recognized with the maturity of the germ theory of disease.

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[136] Baldwin (1999), p. 165.

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