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1 Fumigation, Disinfection, and Quarantine

In the course of the thirty years of sulphuric utopias examined in this book, fumigation was reinvented as a practice of disinfection aimed at transforming the routines of quarantine. Starting with the end of the eighteenth century, practices of eliminating bad odors (often by means of smoke) converged with the newly emerging paradigm of germ-free environments so as to create a new barrier to the transmission of diseases across the seas. A tradition of miasmatic and humoral theory, in which sulphur had acquired its own distinctive character, was thus met up with the newly established scientific approach to infection and its isolated agents. This was in turn grafted onto a system of disease prevention, which had been long challenged for its disruptive, costly, and untrustworthy design. Histories of fumigation, disinfection, disinfestation, and quarantine, we argue here, converged at the end of the nineteenth century in the unique configuration of sulphuric utopias. This chapter provides an account of the double history of fumigation as a therapeutic and hygienic technology, the political development of quarantine in the course of the nineteenth century, and a brief overview of disinfection practices and machines preceeding the invention of the Clayton machine.

Therapeutic Fumigation

There is little evidence to support that, with the exception of gynecological ailments, fumigation had been a method systematically employed for therapeutic purposes in Europe before the arrival of syphilis and the application of mercurial vapors for its cure. Mercury and sulphur had long been considered to be the foundational principles of all metals, a theory first evident in Islamic interpretations of the Aristotelian corpus and then adopted by Albertus Magnus in his *De mineralibus*.[1] By the early sixteenth century, however, in a "restatement of humoral theory," Paracelsus set his *tria prima*—mercury, sulphur and salt—as the three principles constituting the human body.[2] Mercury (or quicksilver) was seen as "the principle of activity or liquidity," sulphur as "the principle of heat or organization," and salt as "the principle of mass or solidity."[3] In this fundamentally alchemical perspective, each of the three principia was associated with a type of disease: mercury with putrefactive diseases like syphilis; sulphur with what we would today call metabolic disorders; and salt with disorders like arthritis, which were believed at the time to result from an imbalance of solids and liquids in the human body. Based on the homeopathic principle "*les semblables sont gueris par leur semblables*," Paracelsian medicine proposed a uniquely chemical cure for disorders and illnesses.[4] In this context, mercury's use as a cure of syphilis witnessed exponential growth, especially in the form of ointments, which antagonized guaiacum as the main therapeutic medium. At the same time, however, mercury also began to be employed as a fumigant for the cure of syphilis.[5] It was not until 1776 and the invention of a fumigation apparatus by Pierre Lalouette that the therapy of syphilis through mercuric vapors reached a technological threshold. Aimed at obviating problems and dangers presented by the practice of mercuric ointments, the internal consumption of mercuric products, and by pan-based fumigation, Lalouette's method was aimed at alleviating the symptoms of the "venereal virus" in the human body.[6] His machine was meant to mark a radical shift from the fumigator propagated by so-called Charbonniere, a "quack" who operated in Paris's Bicêtre and Invalides hospitals by covering the patient's head and inducing him or her to inhale the fumes of what Lalouette reported to be a cinnabar-based substance: "The sulphur combined with mercury, did indeed in burning, set a portion of the mercury at liberty, but the quantity that passed into thro' the mouth and nose, was by no means capable of destroying the virus."[7]

By contrast, Lalouette presented his fumigator as the result of combining scientific experimentation on the production of fumigating powders, diligent preparation of the patient, and the construction of the optimal fumigating apparatus (figure 1.1). The result was the following:

> It is an oblong square box, in which the patient is shut up: he sits on an open seat, and his seat is so contrived as to be capable of being raised or lowered as the height of the patient may require. At the bottom of the box, there is a square hole for the admission of the furnace. On a level with the bottom, at one of the sides of the box, there is an opening with a sliding door, through which the powder is to thrown onto the fire. At the top of the box there is another opening which shuts likewise with a sliding door—this is for the passage of the patient's head and neck. That the vapour may be more completely retained within the box, it is right to push the sliding door close to the patients neck, and to put a napkin slightly round it.[8]

Lalouette's fumigation machine was pathbreaking in that it was the first to employ experimental methods, engineering, and design in the production and operation of an apparatus aimed at using fumes or vapors for curing a human ailment. Importantly, like other technoscientific apparatuses at the time, such as the camera obscura, it included human subjects inside the interior of an apparatus, necessitating the assumption of bodily arrangements that may be considered to be part of a broader disciplinary form of biopower emerging in France at the time.[9]

The machine's blueprint and principles were to have a lasting impact in the development of fumigation technologies, especially ones utilizing

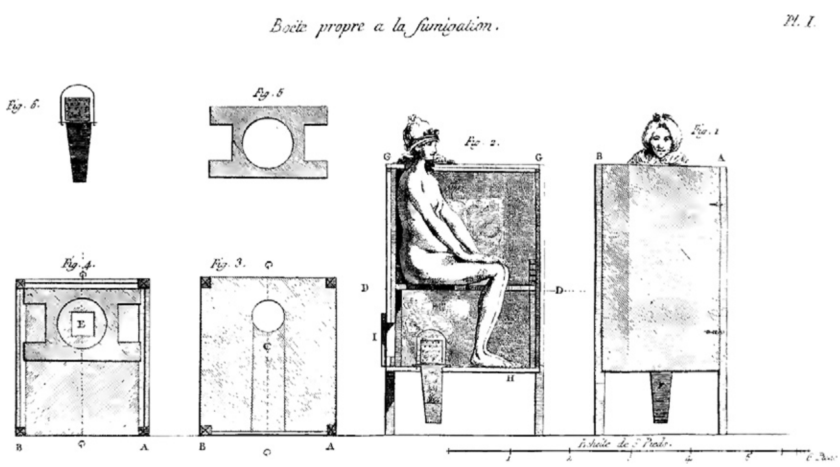

Figure 1.1
Illustration of Lalouette's fumigation machine.
Source: Pierre Lalouette, *Nouvelle méthode de traiter les maladies vénériennes, par la fumigation: avec les procès-verbaux des Guérisons opérées par ce moyen* (Paris: Merigot, 1776). archive.org / Francis A. Countway Library of Medicine.

sulphur. Writing in 1822, some of France's leading medical authorities claimed that, "the application of sulphurous fumigation in the cure of diseases has within a few years excited much attention in Europe."[10] At the center of this medical breakthrough was the invention of an apparatus that allowed sulphur to "be applied to the surface of the body, without the hazard of injuring any of the internal organs."[11] The invention was the work of Dr. J. C. Galès, whose attention was directed to the cure of scabies (*la gale*) while working at the Hôpital Saint-Louis in Paris, an institution exclusively concerned with what at the time were seen as "cutaneous diseases." Already associated by Giacinto Cestoni and Giovanni Cosimo Bonomo with *acarus scabei* in 1685, the disease was laboriously studied by Galès in 1812.[12] The French doctor conducted extensive experiments that showed the disease's causative agent to be the larvae of the *acarus* rather than a "poison" or "virus," while also demonstrating scabies' susceptibility to sulphur. The particular chemical already formed part of therapeutic methods employed against the disease, it being a central ingredient of ointments applied to the human skin before it was exposed to high temperatures.[13] This was a process that, needing repetition over many days, was said to be both very painful and to entail a sulphur-specific side effect: "the skin becomes so saturated with the sulphur, that this foul odor continues to be exhaled for weeks."[14]

Encouraged by the observed impact of sulphur on the acaria larvae, Galès first proceeded with applying sulphuric fumes to patients through the so-called *bassinoire* method:

> The patient was placed naked in bed, every part, excepting the head, being carefully enclosed in the bed clothes, and a pan with burning charcoal, upon which some flowers of sulphur had been thrown, was then introduced into the bed, and the fumes thus brought in contact with the whole surface of the body. By five or six applications conducted in this way, several patients were cured.[15]

Though effective, this process nonetheless risked burning the linen. It also caused serious cough to the patient as a result of the released fumes. "To obviate the inconveniences of the *bassinoire*," Galès proceeded to construct his "fumigatory box" (*boîte fumigatoire*), an apparatus consisting of a furnace and a "box" that was constructed so as not to allow fumes to escape its compartment during operation.[16] The base of the box was formed by two iron plates separated by a few inches. It was on the lower of the two that sulphur was introduced through an opening and was thus carried in an already ignited state inside a small vessel. Inside the main box, and with all openings closed, the fumes of the burning sulphur were carried into the main compartment, where the patient was seated through the iron plates' numerous holes. As can be seen in the diagram provided in Galès's memoirs on his invention, the patient's head was left outside the apparatus, covered with a leather hood, as his or her body was being fumigated (figure 1.2).

Galès explained that he "sought to combine the rules of physics with those of chemistry. By my method, the sulphur is volatilized by heat and thus enters the box at the same time at the caloric; the sulphuric fume covers the entire body uniformly, the face alone being sheltered."[17] As noted by Emerson, in his discussion of Galès's apparatus for *The Philadelphia Journal of the Medical and Physical Sciences*, the vapor entering the box was not

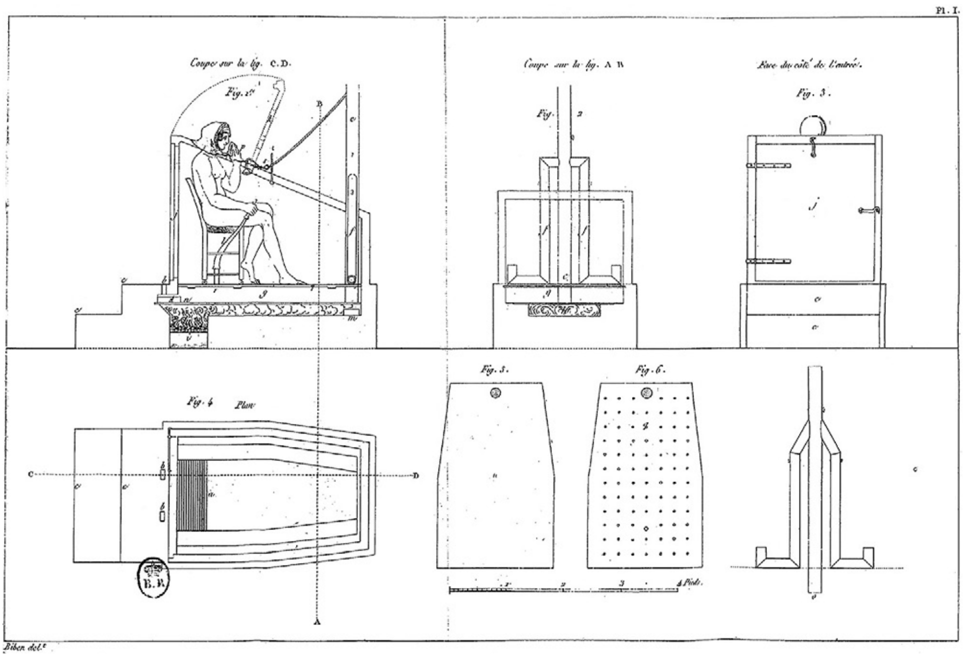

Figure 1.2
Illustration of Galès's fumigatory box.
Source: J. C. Galès, *Mémoires et rapports sur les fumigations sulfureuses appliquées au traitement des affections cutanées et de plusieurs autres maladies* (Paris: L'Impremerie Royale, 1816). gallica.bnf.fr / Bibliothèque nationale de France.

simply sulphur: "During the combustion which ensues, the atmospheric air, which cannot be entirely excluded, supplies a sufficient quantity of oxygen for the formation of sulphurous acid gas"; this was believed "to increase the efficacy of the fumigations" in the human organism.[18]

A key question accompanying this method concerned whether the fumigant operated simply on the surface of the skin and its symptoms or if "the minutely divided sulphur find[s] its way into the circulation."[19] Emerson argued that the latter was the case, as the application of the apparatus to the body, excluding the head, also cured skin disorders on the latter. Indeed sulphuric fumes were said to "give increased energy to the functions of the cellular tissue, stimulate the languid circulation, and modify, in a very remarkable degree, the functions of the lymphatic system."[20]

Galès's invention was submitted to extensive scrutiny by a medical tribunal, including luminaries like Pinel and Dubois, who were so satisfied with the results that they declared it as advantageous over all other existing methods in the cure of scabies.[21] A similarly positive evaluation was secured from a committee set up to examine the method by the Faculty of Medicine in Paris, resulting in its adoption in warships and public hospitals by order of the government. The apparatus was further technically improved by Dr. D'Arcet. This was done by separating the furnace from the main body of the box, and by adding pipes with which to introduce the fumes in the latter, so as to disallow carbonic acid byproducts from affecting the patients under treatment.[22] Soon, an apparatus capable of carrying twelve patients at once was built at the Hôpital Saint-Louis, while the method enjoyed great international acclaim and was widely adopted in hospitals across Europe. Throughout the continent, and as far away as Odessa or the United States, the method was tested on several ailments, including arthritis, herpes, tumors, and paralysis. Physicians like Jean De Carro, the Viennese doctor known for his introduction of vaccination in the Austro-Hungarian Empire, perfected the method and even, in the case of David Luthy in Switzerland, redesigned Galès's machine (figure 1.3).[23]

Fumigation's Double History

The history of the antiscabies fumigator shows us how, already by the beginning of the nineteenth century, technological innovation and experimental science had come together in exploring the uses of sulphur for the

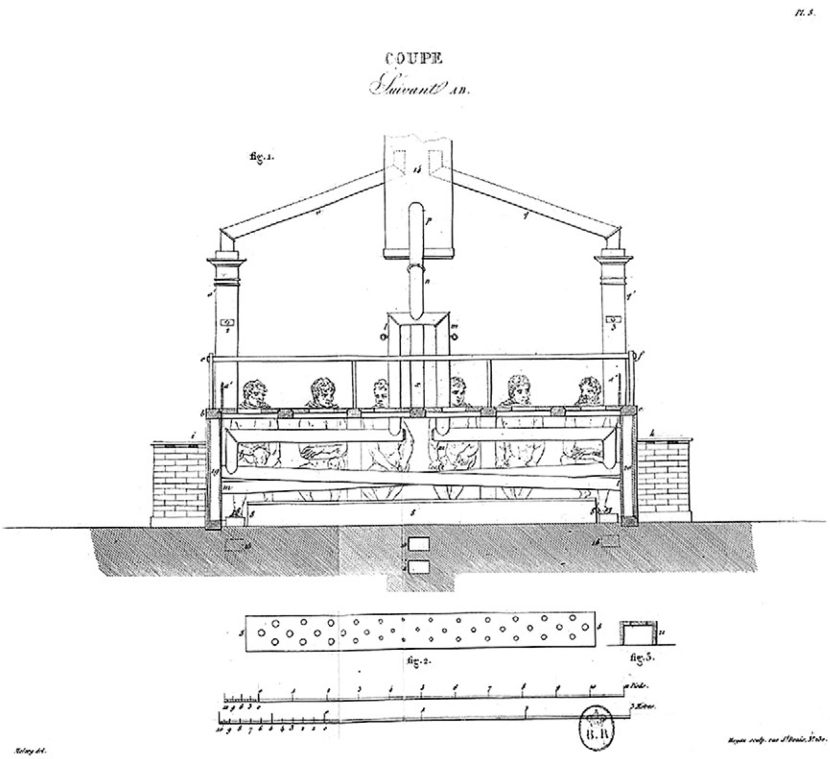

Figure 1.3
Illustration of amended fumigatory box with separate furnace, accommodating six patients.
Source: Conseil général d'administration des hospices, *Descriptions des appareils à fumigations, établis, sur les dessins de M. D'Arcet, à l'hôpital Saint-Louis, en 1814 et successivement dans plusieurs Hôpitaux de Paris, pour le traitement des Maladies de la peau* (Paris: Impr. des Hospices civils, 1818). gallica.bnf.fr / Bibliothèque nationale de France.

benefit of human health. Yet we believe that its history also contains a much more important insight. What is striking is that whereas in the case of scabies, unlike that of syphilis, the causative agents of the disease were known to the inventors, operators, and users of the fumigation technology, the latter was never aimed at *killing* these agents. Instead its imagined impact was believed to be internal—with the fumes said to have a constitutional effect on the patient. This is important insofar as this was the first time that a fumigation technology was used against a disease *in the* *knowledge of its ability to kill its agent*, and yet this fact seemed to be of little importance to its advocates or users.

This is a case that clearly demonstrates a historical distinction that we need to keep in mind when examining the development and application of fumigation technologies: the distinction between therapeutic and hygienic fumigation. This is notably not a distinction between fumigation practices applied to the human body versus fumigation practices used on nonhuman animals, inanimate objects, or built space. Hygienic fumigation, by which we mean fumigation not aimed at curing but at disinfecting, is used on humans to our days. What defines the distinction between these two modes of fumigation is that the first (therapeutic fumigation) is aimed at individual health, whereas the second (hygienic fumigation) is concerned with communities or, in modern days, "populations," and their health.

If this sounds like a modern distinction, we should point out to a foundational moment in the separation between individual and population/community health. As is well known, this was no other than the Hippocratic differentiation between, on the one hand, individual ailments, and, on the other hand, epidemics. What is less noted, but worth retaining our attention here, is how this distinction relied on the differentiation of a notion that would prove pivotal for the development of certain applications of fumigation in the sphere of human health: miasma. Historians generally agree that miasma first emerged as a magico-religious idea, referring to a form of pollution resulting not from the mere existence of matter out of place (as hasty readers of Mary Douglas may assume) but from ritually inappropriate acts in space and time.[24] Miasma was believed to be a cause of illness and was, paradoxically to our modern ears, experienced as fundamentally contagious: a property or state that was transmitted, among other things, by means of instruments used to purify someone suffering from such a pollution.[25] Yet, at the same time, as Jacques Jouanna notes, miasma and magico-religious medical practice were connected by another phenomenon, not that of individual but of collective illness—*loimos*, or pestilence.[26] As famously portrayed in Sophocles' play *Oedipus Rex*, where the plague of Thebes is caused by the miasma that is embodied by the homonymous tyrant as a result of patricide, the solution to pestilence is also ritual purification, a process portrayed in the *Odyssey* as including fumigation.[27] What Jouanna underlines is that while, as an opponent of such approaches, the Hippocratic corpus ridiculed the individual application of miasmatic etiology (famously in the case of epilepsy, or "the sacred disease"), it actually endorsed and elaborated on it in the case of its collective or "pestilential" application. In Hippocrates's *Breaths*, epidemic fever was seen as caused by miasmata. Used in the plural rather than in the singular, this no longer referred to a ritual pollution but to a natural phenomenon: morbific vapors that enter the human body.

We will not dwell here on the cosmological and indeed political-theological impact of this displacement for Greek society, but rather stay with Jouanna's emphasis on how it affected medical treatment: by shifting practice in the face of epidemics away from purification (and, in turn, from ideas of contagion) and toward the removal of patients from the afflicted location or "environment." What is interesting, from a medical historical perspective, is that, in light of this, in the Hippocratic corpus fumigation was a technology applied not in the case of epidemics but of individual ailments, most famously gynecological ones.[28] It was, in other words, a method used on the human body rather than its environment—a technology aimed at curing the former, and not at halting the progress of epidemics.

Given this extensive historical legacy of fumigation as a practice of treatment, nineteenth-century medical luminaries like Pinel were right in claiming that, "the use of fumigation as a medical agent, is by no means a modern invention, but is almost coeval with the history of medicine." What they overlooked, however, was that, even when considering Europe alone, this use was far from historically uniform.[29]

We can thus already see here what may appear as paradoxical today. On the one hand, fumigation was part of a medical system that gave rise to ideas about the etiological importance of bad air or environmental miasmata. And yet, on the other hand, fumigation was originally radically disassociated from this etiology, and was rather applied to a pathological sphere that was seen as unrelated to the latter. This forces us to reconsider the historicist identification of anti-epidemic fumigation practices in modern times as an etiologically reformed practice or an antimiasmatic technology that was only salvaged from obscurity by an epistemological shift that adapted it to "germ theory." Instead we need to admit that fumigation had always been a far more versatile and multifaceted technology than one defined by or contained in any single etiological framework.

We turn our attention to the hygienic uses of fumigation, but do not for a moment assume this to be a watertight category, unaffected by what we have identified as the sphere of its therapeutic uses. Indeed it may be claimed that if fumigation managed to achieve the hygienic status it did in the decades examined by this book, this was only made possible by it borrowing from and adapting the technoscientific turn already assumed in the therapeutic sphere of its application.

Hygienic Fumigation

The origins of fumigation as a technology aimed at halting or dissipating epidemics are blurry. What is certain is that, in the course and aftermath of the Black Death, fires were used with the purpose of purifying the air from "pestilential stenches," not just with smoke, but also with heat and smell.[30] Such methods, which seem to be based on a hybrid of pre-Hippocratic understandings of miasma as individual pollution and Hippocratic ideas of "bad air" as the cause of epidemics, were endorsed by authorities like King Joao II in his efforts to halt plague in the city of Évora in 1490.[31] In early modern times, as the classical notion of miasma was rediscovered in Europe, plague epidemics were met with the increasing use of public fumigation. Celebrated cases, such as Nathan Hodges and his use of resinous smoke to fumigate plague-stricken houses in 1665 London, largely relied on no more than copper torches, thus demonstrating that by the mid-seventeenth century technological innovation was already evident in antiplague measures. In 1657, during an outbreak of plague in the city of Genoa, the Capuchin friar Maurice devised a simple apparatus in order to purify 430 graves attached to the church, which according to the prevailing medical doctrine at the time were believed to be polluted by the corrupted air emanated by the great number of plague corpses buried within.[32] The apparatus consisted of a large tent built of a wooden frame inside of which was placed a pan containing a flaming substance: a "perfume" made of sulphur, antimony, cinnabar, cumin, pepper, arsenic, and other substances. Two square openings on either side of the tent allowed for a wooden beam to be entered, which would then latch onto a cord attached to the tomb's lid, allowing its operators to lift it. Having filled the tent, the fumes trapped in it were thus forced to enter the sepulcher through its opening and purify it of its pestilential vapors.[33] After one hour of exposure, and after pouring soil on the cadavers, a similar "perfume" was lowered into the tomb with the addition of pulverized sulphur.

If Maurice's method was to all accounts only used once, a few decades later, in the course of the 1721–1722 plague epidemic in southern France, another fumigating machine was invented to deal with the supposedly pestilential vapors of the victims of the disease—one that Sylvain Gagnière tells us was then adopted across Provence.[34] Judging Maurice's method to be both too cumbersome and too dangerous for those operating it, on October 22, 1722, under the directions of the illustrious Avignonese architect Jean-Batiste Franque, a technologically more sophisticated machine was thus built.[35] Embodying both design and engineering in a manner proper to its age and time, this apparatus consisted of a metallic box filled with coals and perfumes; attached to it through an iron pipe were large double bellows, operated manually with the help of a suspended lever.[36] The fumes generated by this machine entered the graves by means of a hole created by a drill. The machine was put in operation in Avignon for at least one month, disinfecting graves until, on November 11, 1722, all antiplague operations ceased.

If these two machines point to a significant output in the early modern development of fumigation technologies against the supposed corrupt air generated by plague corpses, the history of the use of fumigation onboard ships whose crews suffered from disease is more blurry. What is certain is that, with the intensification of medical concern over maritime travel, by the mid-eighteenth century a more systematic study of these methods and their effects becomes evident. This would coincide with and indeed be fueled by a much broader fascination, first scientific and then also popular, about gases and their chemistry. A passion, as Steven Connor has shown, that would engulf Europe in a chemical revolution that relied on the development of an experimental culture and an association of gas chemistry with social reform.[37]

A pioneer of the maritime application of fumigation was James Lind, the Scottish physician best known for his discovery of citrus fruits' effect on scurvy and his work on typhus. In his influential lectures before the Philosophical and Medical Society in Edinburgh in 1761 (published 1763) he relayed how, upon being appointed at the Haslar Naval Hospital near Plymouth three years earlier, he observed the way in which the smoking of the *Revenge* with "the vapour of tar" had led to the abeyance of the infection that had been afflicting its crew after its return from the Mediterranean.[38] Lind further noted that three methods prevailed in purifying ships after the removal of their crew. First, the burning of tobacco, by placing the latter on fires made of old pieces of rope placed across the ship. Second, charcoal and brimstone fire, which Lind noted was effective in "purify[ing] . . . all tainted apartments, ships, cloaths [*sic*] etc.," but was unable "to destroy some species of vermin, particularly lice"—a fact that led him to conclude "that contagion is not propagated from animalcules."[39] Third, by the addition of arsenic in the charcoal and brimstone fumigants in the following manner:

> After carefully flopping up all the openings, and every small crevice of the ship, (as was also necessary in the preceding processes) a number of iron pots, properly secured, are to be placed in the hold, orlope, gun-deck, etc. Each of these are to contain a layer of charcoal at the bottom, then a layer of brimstone, and so alternately three or four layers of each; upon which the arsenic [*sic*] is to be sprinkled, and on top of it, some *oakum*, dipped in tar, is to be laid, to serve as a match. The operators, upon setting fire to the oakum, must speedily leave the place, shutting close the hatchway by which they came up.[40]

Lind was confident that the use of fire and smoke (in terms both of heat and fumes) was "the most powerful agents for annihilating infection; and, it may be presumed, even the plague itself."[41] He, however, dismissed the common practice of using bonfires in the streets of cities as a method against plague and other diseases as based on groundless and erroneous principles. He reasoned that such practices were in fact harmful, for they deprived cities of fresh air "fully impregnated with that principle of life" and so much needed "in the inner, foul and pent-up chambers of the tainted sick."[42] If, on the other hand, people were to be removed from such spaces, Lind reasoned, then the benefit of fire and smoke (he did not, it must be noted, use the term fumigation) could not be matched: "In a word, a judicious and proper application of fire and smoke, is the true means appropriated for the destruction and utter extinction of the most malignant sources of Disease."[43]

A year later, in 1762, in the second edition of his essay on the health of seamen in the Royal Navy, Lind provided further discussion of the use of smoke and fire. This included among other things evidence in support of such methods derived from proto-ethnographic narratives. It is here that we come across the first mention of fumigation used for the control

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of vermin, though these were not associated with any disease at the time. Lind proposed the use of sulphur for killing rats, mice, cockroaches, ants, and weevils. In particular, he advised "that the Fire be at first gentle to draw the Rats towards it, that for they may be stifled in the Hold by the Smoke there, and not at once suffocated by a quick and violent Steam, when dying and afterwards rotting betwixt the Ship's Timbers, they are apt, for a considerable Time afterwards, to occasion a poisonous and noxious Stench."[44]

In 1777, in his groundbreaking book on prisons, the philanthropist John Howard provided a concise summary of Lind's proposed method, derived from their correspondence:

> Charcoal fires should be lighted in the morning, and allowed to remain till evening, and half a pound of brimstone thrown upon each, their smoke in the mean time being closely confined. They may be in iron pots. This fumigation should be repeated every day for a fortnight. Every evening after the fumigation, the ports and hatchways should be opened, and the inside of the ship washed with warm vinegar: and after the last fumigation, before the men return to the ship, the decks should be thoroughly scraped and cleaned.[45]

At the same time, across the Channel, another medical luminary, Louis-Bernard Guyton de Morveau, was the first to experiment with a new method of fumigation on *terra firma*. In 1773 he was confronted with the question of disinfecting the air of Dijon's cathedral. At the time, the cathedral was believed to be polluted with "impure" gases derived from human cadavers kept in it due to the fact that the harshness of the winter season made digging in the church's graveyard impossible.[46] Taking the gases to be the cause of a "contagious fever" in the surrounding area, Guyton sought to counter the pestilential effects of the polluted air by means of muriatic acid (the then-prevalent name for HCI, or hydrochloric acid), in the belief that the latter would counter the "ammoniac" of the putrid decompositions, which were believed to be "the vehicle of the fetid miasmata."[47] Muriatic acid had first been identified as a possible air purifier by Dr. John Johnstone of Worcester in 1758 in a treatise titled *An Historical Dissertation on the Malignant and Epidemical Fever which prevailed at Kidderminster in 1756*. Yet it was Guyton who, basing his work on Antoine Lavoisier's revolutionary understanding of combustion, procured experimental proof of the gas's properties:

> I had several times rendered this phenomenon visible, by placing under a very large bell-glass, tilled with common air and immersed in water, two small gallipots, one of them containing concentrated muriatic acid, or common salt sprinkled with sulphuric acid: the other ammoniac in a liquid state, or even a solution of the carbonat of ammoniac [*sic*]. White fumes were instantly seen to ascend, fill the capacity of the vessel so as to render it opaque, and then become condensed so far as to permit the inclosed air [*sic*] to resume its transparency. But it is a fact particularly worthy of attention, that on removing, and replacing it after renewing the air, the fumes will recommence, and the same phenomenon may be produced repeatedly.[48]

Deciding to hold a trial with his fumigating gas on March 6, 1773, Guyton used six pounds of salt and two pounds of concentrated sulphuric acid; "The whole was put into a capacious bell-glass inverted and placed on a bath of cold ashes, which were gradually heated by means of a large chafing-dish."[49] So powerful was the gas said to be, that an individual who ventured near the sealed church's main door keyhole was reported as being affected by the escaping fumes. The church was reopened the following day, and four days later services were resumed with the putrefaction having been supposedly extinguished. Content with the results of his trial, Guyton was glad to find an opportunity to repeat it a few months later in the Dijon Jails, where thirty-one inmates had come down with "hospital fever," and then again in 1774, in the course of a cattle epizootic. The latter was aimed at the purification of the affected stables, with the government officially endorsing the use of muriatic fumigation.

It was not long before experiments aimed at the invention of new fumigating methods took place in Britain too. In July 1780, James Carmichael Smyth, a physician in Middlesex Hospital, was sent to Winchester's prison where an outbreak of "fever" was raging among Spanish prisoners of war. There he observed that the disease did not follow Thomas Sydenham's rule of epidemic dissipation, but rather increased in force by the day.[50] Unable to observe any petechial spots, as originally reported by the prisoners' clergyman, Smyth complained that the "distemper" was particularly deceitful, and that even individuals who appeared to be only slightly indisposed quickly perished.[51] Convinced that, in spite of its appearance, the disease was both malignant and dangerous (a judgment seemingly confirmed by himself falling ill with the "fever"), Smyth attributed the outbreak to the general living conditions imposed upon the Spanish prisoners: "in every situation, where a number of people are crowded together, whether in ships, hospitals of prisons, unless the strictest attention be paid to cleanliness and to a free ventilation or circulation of air, a fever sooner or later breaks out amongst them, of a very contagious nature, and attended with very fatal effects."[52]

Smyth entertained the notion that "contagious fevers" were "of two very distinct classes." The first, called "specific contagions," were said to arise not "from any general quality, or process of nature" but to have a "peculiar origin" and thus to "excite diseases of a peculiar kind."[53] Such diseases, like smallpox and measles, were believed by Smyth to be able to afflict an individual only once in his or her lifetime. The second class, called "general contagions" or otherwise "putrid" contagions, was said to result from putrefaction: "That the contagion, or miasma, of the jail and hospital fever," such as the one supposed to be afflicting King's Holds in Winchester, "is of this kind, admits of every species of evidence a matter of fact and of observation can do."[54] Following the long-held opinion that perspiration of bodies held in close quarters was a cause of putrefaction, Smyth generally advocated that the latter might be prevented by the renewal of air. And whereas Smyth, followed John Haygarth in being sceptical about "the risk of propagating the contagion" by means of clothes or furniture lying in an atmosphere where diseases like smallpox prevail, he was confident that this was in fact the case for putrid contagions, like "jail fever" and "hospital fever": "Indeed, wherever a vapor can be distinguished by the smell, we have the demonstration of our senses for what a length of time, not only clothes, but furniture, and even the boards and walls of houses will retain it."[55] Smyth's interest thus lay squarely with a singular question: What was able to destroy the "putrid contagion"? The answer, in his opinion, was "mineral acids in the state of vapour."[56] But while he acknowledged that, in the past, sulphur and muriatic fumes had been successfully used on clothes and furniture, he argued that their danger to animal life made them inappropriate for use in hospitals and prison wards. By contrast, the solution was to be sought in another substance: nitrous acid.

Smyth was confident regarding the efficacy of the particular substance, which was obtained by mixing niter and heated vitriolic acid, on the basis of a private experiment he had conducted (he did not state where or when):

> We put a mouse, confined in a wire trap, under a glass cylindrical jar, capable of holding about 25 pints beer measure, or 881 cubic inches; the jar was inverted upon wet sand, contained in a flat earthen trough or pan; it was then filled with

> the fumes of the smoking nitrous acid, introduced by means of a crooked glass tube, until the animal could not be very distinctly perceived. The mouse was kept in this situation for a quarter of an hour, when the jar was removed, and the animal exposed to the open air—it immediately ran about the wire trap, as usual, and had not the appearance of having suffered the slightest inconvenience from its confinement. After a few minutes, the mouse was again put under the glass jar, which was now filled with the vapour of pure nitrous acid, detached from nitre by the vitriolic acid. It remained much about the same time as before, and when the jar was removed, seemed perfectly well.[57]

After repeating the experiment with the use of different minerals on a greenfinch, Smyth finally applied nitrous acid to himself and his friend and collaborator Mr. Hume in a small room (1,040 cubic feet), experiencing no discomfort from the produced fumes.

Although not mentioned in Smyth's own treatise on the Winchester outbreak, Robert Lulman, a Commissioner of the Sick and Wounded Board, recounted the way in which Smyth employed his nitrous acid fumigation in the ward. It had been the first time that Lulman observed the employment of this method: "The vessels in which it was contained were placed on the floor, between the patients beds and in other parts of the wards. . . . The Nitrous Acid was used in a fuming state, while the patients were in their beds, and was kept there night and day."[58]

Following the publication in 1791 of Smyth's treatise on the Winchester events, an official trial of the method was ordered by the Admiralty in November 1795 on His Majesty's hospital ship *The Union*, anchored in Sheerness, which had been recording cases of "petechial fever."[59] Fumigation was applied twice a day on the ship in the following manner, with all patients aboard until February 3, 1796, when the "contagion" was declared extinct: "The articles used in the fumigation are nitre purified and oil of vitriol; which is placed in a pipkin two-thirds full of hot sand, and carried from place to place; a cloud of steam arising from its being stirred, fills the wards."[60] To the great enthusiasm of the Surgeon of *The Union*, during that period only two persons were taken ill. This was attributed to fumigation. Moreover, the process was said to have caused no problems to patient or doctor: "The people bear it exceedingly well, and I frequently stand in the midst of a cloud, arising from fumigation, as thick as fog, without the smallest inconvenience; a circumstance of great consequence, as the sick are all in the wards during the fumigation, and their cloaths [*sic*] &c. are consequently impregnated with the acid vapour."[61]

Used consequently to great acclaim on a number of ships and hospitals (including the Russian ship *Pamet Eustaphia*, the Forton Hospital, and Yarmouth Naval Hospital) Smyth's nitrous fumigation was hailed as both effective and pleasant. This led Paterson of the Forton to describe the method as "of all other remedies extant, the most convenient, the most elegant, the most ingenious, and the most efficacious."[62] In following years, the method was used in a growing number of vessels and hospitals, again with salutary results. It also attracted considerable attention on the international stage, with French and Spanish translations of Smyth's work appearing, alongside endorsements by leading scientists such as Louis Odier.[63]

In 1802 Smyth petitioned the House of Commons for recognition of his discovery. In spite of James Lind's son's objections and an antifumigation testimony by the Scottish naval physician Dr Thomas Trotter, following the consultation of letters and reports from a number of cases where Smyth's method was employed, the Committee of the House of Commons provided its endorsement, awarding Smyth £5,000.[64] The Committee declared that it was convinced "that the efficacy of the Nitrous (or rather Nitric) Fumigation, in preventing the communication of the most virulent contagion, has been fully established."[65] Nitrous fumigation was ascertained to be superior to "other means of preventing infection," such as by use of sulphuric and hydrochloric acids. It was also said to "be used in places the most crowded with sick, without injury to any class of patients":

> Its benefits may be therefore enjoyed, under circumstances wherein it may be extremely difficult or even impossible to maintain the cleanliness and ventilation, which in all cases of infectious diseases are so eminently desirable, and in situations, such as ships of war and transports, where the removal and separation of the sick may be impracticable, and where it may be impossible to cut off all communication between them, and still more, between the persons who attend on them, and others who are in the same vessel.[66]

This was indeed the first official endorsement of a fumigation method by the British government. Yet this success was not bound to England. Encouraged by the reception of Smyth's method and troubled by recent epidemic urgencies in Genoa and in the course of Napoleon's campaign in the Middle East, in 1801 Guyton made a grand return. This took the form of a treatise that by way of thirty-seven experiments reviewed the comparative efficacy of different fumigating agents on "putrid exhalations."[67] Received with great enthusiasm by the French medical community, it elicited the interest of the Ministry of Interior in relation to "contagion" on board of ships, and enjoyed translations in many languages, including English.[68]

Before two years had elapsed, Guyton's muriatic acid method and two fumigating apparatuses, designed by the famous-at-the-time Dumotiez brothers, were not only endorsed by France, but also adopted in Spain in the combat against yellow fever.[69] The machine consisted of a glass bottle contained in a wooden casing, including a wooden cap, which by use of a large screw could be used to loosen the cap and allow gases to escape into the room meant for fumigation.[70] As noted by the historian Elana Serrano, "the fumigation machine embodied two essential features of Lavoiseir's system of chemistry: the theory of acids and the theory of combustion. . . . According to Guyton de Morveau, the fumigating machine supplied a highly oxygenated compound of muriatic acid—oxy-muriatic acid—which destroyed contagious participles in a process akin to combustion."[71]

Serrano has argued that Guyton's idea that "the contagion cannot be born and spread if only by the most culpable negligence" set the stage for fumigation being included within a larger political process, which transformed the relation between the state and its subjects.[72] In Serrano's reading, this entailed a shift from hitherto dominant "military" or "sovereign" measures to more "democratic" ones, which "appealed to citizens' moral responsibility, by asserting their responsibility for their own health and that of their peers."[73] The historical material presented by Serrano do indeed point at an unprecedented public dissemination and state endorsement of fumigation against epidemics. But do they also point out to, or form part of, a shift toward a properly speaking biopolitical paradigm, as Serrano proclaims? Serrano recounts how, in 1804, the Spanish Prime Secretary Manuel Godoy ordered the manufacture of 30,000 such machines for distribution among the general population in southern Spain in order to halt the ongoing yellow fever epidemic. Initially the machines were too expensive and the scheme folded. But after an ingenious redesign that reduced their production cost, they were finally employed a year later "for the 'complete disinfection' of Cartagena."[74] Within the general political atmosphere of reform, anti-absolutism, and the Spanish–French alliance at the time, the apparatus was promoted both in print and by means of public experiments, forming what Antonio García Belmar and Ramón Bertomeu-Sánchez have described as an "imperfect consensus" on the method.[75] This involved its promotion not only as an anti-epidemic technology but also as an enlightened and economically beneficial measure. However, if there is something striking about the emergence of hygienic fumigation at the turn of the nineteenth century, and its dissemination across Europe, this is indeed that, for an age that was increasingly preoccupied with quarantine as a technology of protecting cities and nations from "contagion," the discussion of fumigation seems to be not correlated with the one about quarantine. To thus interpret, as Serrano does, its employment as a process that opposed or overcame the latter would be to superimpose questions and notions from the late nineteenth century to 1800. The employment of Smyth's fumigation in military hospitals and prisons in Britain or Guyton's machine in Spanish households certainly points to a new age when hygienic fumigation would begin to feature among state-endorsed methods of epidemic control. However, as we can see, for example, in Serrano's exposition of the employment of Guyton de Morveau's method in the lazaretto of San Joseph in Cartagena, at the time these were technologies not used to shift the paradigm of what we may call the sovereign power of epidemic control, as embodied by quarantine, but rather to perfect it.[76]

This dynamic between fumigation and quarantine was to change as a result of the rising tensions between proponents and opponents of the latter in the context of consecutive waves of cholera epidemics, beginning with the first cholera pandemic of 1816–1826.

Cholera, Quarantine, and Fumigation

In 1825 the Prussian physician Friedrich Schnurrer presented one of the most eloquent defenses of a geographic view of cholera. His fascinating pamphlet against the existence of any disease independent of the human host—a manifesto against contagion theories—was accompanied by one of the earliest global maps of disease distribution.[77] With this map, and through a vast collection of observations, he demonstrated how various quarantines, put in place throughout the world against the spread of cholera, had failed in achieving their purpose: not a single quarantine had effectively stopped the cholera morbus on its devastating march. To Schnurrer, and to many of his contemporaries, quarantine was deemed to be ineffective for the simple reason that, in their opinion, cholera was not a communicable disease.

However, in the long nineteenth century of disease–etiology disputes, theory and practice often diverged. Only a few years later, the Prussian authorities reacted to the 1830 cholera epidemic with drastic measures aimed at halting the transmission of the disease among districts, buildings, and government departments. A sanitary cordon was put in place around suspicious areas, isolation stations were erected to separate those suffering from cholera, and the authorities set up strict rules for movement across infected areas. Cholera, now thought to be highly transmissible, was supposed to be contained by a drastic regime that combined quarantine and disinfection. Among the measures applied to both the garments and belongings of travelers, as well as goods and merchandise, was systematic fumigation with chlorine. Furthermore, as the Prussian government remained concerned about cholera infiltrating its bureaucracy, every letter, every official *Amtsblatt*, and every file in government possession was supposed to undergo fumigation in order to protect the royal authority.[78]

In the same year, the eminent physician Professor H. Scoutetten of Strasbourg was sent to Berlin to investigate the raging epidemic of cholera. Among his findings, which sought to corroborate an individual disposition rather than a rampant contagion, he presented a new device to treat cholera in individual patients. As fumigation seemed to have enjoyed success in halting the disease in the Prussian countryside, his device proposed a reinvention of the old tradition of therapeutic fumigation for the purposes of epidemic control. The specially prepared bed enabled the treatment of patients with both heat and fumes. A funnel-shaped device at the foot of the bed connected a spirit lamp with four wicks. A tripod and a bowl could be placed over the lamp to vaporize aromatic herbs or sulphur.[79]

For the first half of the nineteenth century, the concurrence of contradictive measures to combat cholera was quite characteristic. Some countries insisted on the effectiveness of strict quarantine, while others focused on local or social conditions. As much as the nature of cholera and its distribution were subject to extensive dispute, so were practices of disinfection and fumigation seen as controversial, with varying prospects of success. After the devastating epidemics of the 1830s, both French and English authorities became increasingly aware of the unsystematic nature of the practices applied. Local quarantine systems came under suspicion of being but masked attempts at obstructing trade. At the same time, intrusive disinfection campaigns led to resistance, as they yielded only very limited effects on the actual spread of cholera. Against this background, and driven by the epidemic pressure of the disease, the first initiatives to arrive at transnational conventions of how to apply disinfection and quarantine were brought forward by the French government. As the second half of the nineteenth century would reveal, the aim was nothing short of sorting, once and for all, the intricate and complicated relationship between quarantine as a system of time-consuming detention, and disinfection as a system of instantaneous chemical protection.

The history of infectious diseases and epidemics has hardly ever been confined to national or regional perspectives. The long history of quarantine, the development of principles of protection through exclusion, isolation, and segregation, shifts the perspective inevitably toward the intimate relationship between local measures of protection and the perception of a dangerous global interconnectedness. Other than hygienic and therapeutic practices of fumigation, quarantine has been an extensive object of study in historical scholarship. As is widely known, the word quarantine stems from the Italian *quaranta giorni*, forty days. It was used in the fourteenth century by the Venetians to describe the length of detention that was deemed appropriate for arriving ships to remain at sea before entering the harbor of Dubrovnik. Despite this original application being driven by the fear of plague and applied to maritime trade, it is crucial to acknowledge that the development of quarantine was neither just a history of infectious diseases nor of maritime sanitation. As scholars have emphasized in recent years, the history of quarantine is an impoverished story, if its deep and integral ties to commerce, economic rationalities, and trade tactics are ignored.[80] Of equal importance is the appreciation of quarantine as a larger system of thought—a system through which a variety of political, economic, and medical institutions, practices of immunization, and structures of regulation have been established on both land and the sea.

The larger environment of the history of quarantine encompasses isolation stations, lazarettos, the long and winding history of the pesthouse, practices of demarcation, spaces of observation and surveillance, and instruments of integration as much as of exclusion. Only recently has Guenter Risse proposed to think of the pesthouse as both a place and a parable in which multiple histories of diseases converge with the historical development of citizenship and public health in the modern USA.[81] Similarly, John Henderson has described the early modern lazaretto in Florence as a place of conversion, where the social and economic structure of Italian societies is laid bare.[82] Howard Markel has portrayed the plight of quarantine in the New York Harbor as a system of exclusion, in which racial stereotypes persisted despite newly available methods of diagnosis and disease identification.[83] And in her account of the "English System," Krista Maglen has shown how the sanitary zones that were crafted around nineteenth-century quarantine stations impacted local and international trade and politics. Throughout history, practices of immunization have yielded to the development of veritable political concepts, whereas figures of immunity align themselves with envisioned communities and their imagined other.[84] Equally, the history of quarantine expands directly from an epistemological history of concepts about contagion to the political story of borders, buildings, and islands to the history of ideas about states, global fabrics, and—crucially—the regulation of trade and commerce.

Mark Harrison and more recently Alison Bashford have emphasized the pivotal significance of the "global archipelago" of quarantine stations as a fundamental condition for the emergence of global trade networks. Harrison wrenched the history of infectious diseases from that of war and the emerging nation state, so as to usher in an almost transhistorical conflict of interest between freedom of trade and the control of disease.[85] For a long time after plague established this paradigmatic conundrum, the world was clustered along the lines of those favoring rigid quarantine for the cost of commerce, and those—like England—who protected their liberal regime as a promercantile, antiquarantine conviction. Harrison thus traces the spread of disease "along the arteries of commerce" so as to foreground the establishment of quarantine systems as corridors of power, in which the liberation of trade was negotiated against the threat of disease.[86] Bashford, on the other hand, sees the global network of quarantine stations coming into new historical light against the development of a perspective in transoceanic history. An icon of world history, the quarantine station thus assumes its significance precisely in its locality, separated from the place of protection but organized as a gateway for global intersections and connections. As a "portal" to world history, the vast network of stations, lazarettos, and ships built to regulate the relationship between trade and disease at the threshold of local and international harbors invites careful interrogations and comparison of the *longue durée* of the geography of diseases, politics, and power.

For both Harrison and Bashford, the history of quarantine cannot be disconnected from the emergence of globalization and of economic markets that transgress the nation-state, nor from the development of an early version of international, or rather, imperial hygiene.[87] Reinvigorating the contours and borderlines of nation states, quarantine stations became thresholds of the political and geographical authority of empires in the late eighteenth century. At the same time, Harrison argues, we see the development of a concept of balance to structure the relation of trade and contagion. Trade interests, along with early humanitarian sentiments, began to define the contours of early global agreements—or rather alignments—about the importance of disease control in the shadow of economic interests. And here, as Ackerknecht has made clear, a new ideological frontier emerged, in which the rationality of quarantine, the particularities of its implementation, and the coherence of its systematic application became subjects of heated controversy.[88] This approach would establish two new guiding principles that structured the majority of nineteenth-century quarantine stations. First, with the 1851 Paris sanitary conference, an international system of corroboration and collaboration was set up in order to align international policy and practice. And second, these new channels of early international considerations of questions of health, disease, and trade would become pipelines for a new kind of political authority, which aimed to make quarantine scientific while asserting imperial economic interests.[89]

The history of nineteenth-century international sanitary conferences revolves largely around the changing particulars of cholera. But the political pressure from which the impressive and unprecedented initiative of global cooperation developed was erected on a shared frustration toward existing practices of quarantine. The British diplomatic delegate to the 1851 sanitary conference, Anthony Perrier, summarized the concerns of those participants, who had no faith in the possibility of cholera's importation. He condemned the quarantine established in some states against the disease, as this continued a "routine path of practices that are outmoded, useless, ruinous to commerce, and harmful to public health."[90] If the majority of the delegates supported a ruling in favor of quarantines against cholera, the result was never ratified by any of the participating states, and was never turned into practice. If anything, the first as well as the second sanitary conference, in Paris (1858), demonstrated the deep epistemological divide on the etiology of cholera. An agreement on standardized quarantine systems was thus out of reach.

By 1874, Russia's frustration over arbitrary quarantine detentions by the Ottoman Empire led to a fourth conference, this time held in Vienna: "practically the whole shipping trade of Russia passing through the Bosporus has, since 1866, been at the command of the quarantine agents of the Porte and their fancies."[91] Although numerous meetings were dedicated to the formalization of international conditions for maritime sanitation, the differences between those preferring quarantine and those favoring medical inspection seemed unresolvable. As the eminent German medical geographer August Hirsch proposed, it was agreed by all to consider all measures viable to the protection against cholera.[92] States were thus free to choose whichever procedures they preferred. In the meantime, Robert Koch's discovery of the causative bacillus of cholera boosted the faction favoring the communicability of the disease. Still, an international agreement was far from reached. In 1892, the seventh international sanitary conference, in Venice, came close to establishing a consensus on the mode of destruction best suited for cholera and, for the first time, delegates were moved to consider the success of steam sterilizers on ships. Still, disagreement prevented a unified proposal for methods of destroying the "pathogenic germ," as sterilization of merchandise and the hulls of vessels did not tackle the issue of the human carrier. Where the conference succeeded was in proposing a classification of ships as "clean," "suspect," or "infected," a classification that, although it remained in place for the decades to come, caused extensive debates over the definition of its categories.[93]

Disinfection: A New Frontier

It would take until the tenth international sanitary conference, which took place in 1897 once again in Venice, for discussion between the world's great powers to consider diseases other than cholera, with the conference being exclusively concerned with plague. This was also the first time international delegates would take into account the necessity of a unified strategy of maritime sanitation across national and etiological divides. In Venice, plague was discussed with surprising unanimity. Although outbreaks of the disease in North Africa, the Middle East, and Russia had not ceased throughout the nineteenth century, it was the 1894 outbreak of bubonic plague in Hong

Kong that brought the disease back on the international stage. As by 1896 plague proceeded to spread across British India, the fear of a global pandemic made it the central subject of the conference.[94] Delegates accepted that the disease was caused by a bacterium, as Alexandre Yersin had shown in 1894, and that outbreaks of human plague were often preceded by epizootics in rats, but not that rats were the actual source of the disease.[95] Still, the role of insects remained ambiguous, and although the American delegates pointed toward the significance of yellow fever, the disease was hardly discussed. The conference succeeded in establishing an internationally binding convention of dealing with plague, adopted by the eighteen participating states and their corresponding port authorities. This detailed the measures deemed necessary to halt transmission over both sea and land. The quarantine for ships suspect or infected with plague was set to ten days; rigorous measures of disinfection were made obligatory for suspect and infected vessels; regular inspections were encouraged, especially for ships dedicated to pilgrimage, and the sanitary station at the Suez Canal was improved and modernized.[96]

The French delegate Adrien Proust considered the regulation of disinfection to be the most important achievement of the conference. In his detailed report, the practice of disinfection was now globally defined as a suite of escalating measures: whereas fire should be used for objects of no value, steaming was decreed as best to clean fabrics, washing with lime-solutions for surfaces and walls of inhabited places, and finally, aeration of spaces with liquefied sulphurous gas was proposed. “It has long been thought, and it is still hoped,” Proust wrote, stressing the necessity of fumigatory equipment, “that the best method of letting an antiseptic penetrate everything is the controlled release of a microbicidal gas.”[97]

It thus took until the Venice conference in 1897 to arrive at the foundations of an international agreement about systematic measures of disinfection to be trusted with the task of aiding and, in certain circumstances, replacing quarantine stations. It is noteworthy that most of the agreements reached in Venice were exclusively bound to the question on inanimate objects and their relationship to the transportation of disease. In the case of plague, this extended to animal vectors and the possibility of the rat being a carrier of the disease, but by and large, human bodies were taken out of the equation. These bodies remained subjugated to detention times, while goods and merchandise were increasingly considered to be safer if treated with extensive disinfection. Accordingly, the measures agreed upon at the 1897 conference were solely directed at objects and their surfaces and textures, as well as agricultural products.

This is not in itself surprising as recent scholarship has shown that throughout the nineteenth century debates around and practices of disinfection were singularly focused on inanimate objects, fabrics, and goods. Since the first sanitary conference in 1851, objects of daily life, and especially those involved in maritime trade, were categorized, scrutinized, and tested for their susceptibility to infection of any kind. To this end, infection was not clearly defined and was subject to extensive controversy. And yet, as David Barnes has argued, it was precisely this mutable notion of infection that allowed quarantine doctrines and practices to persist across the globe within a timeframe where epistemological and political rejections of notions of contagion were peaking: "What worried medical men and laypeople alike was not contagion but infection, in its pre-germ-theory sense: an invisible, often (but not always) malodorous contamination, potentially transportable over long distances in goods, vessels, or bodies, that was capable of causing disease unless neutralized or dissipated."[98] Long before bacteriological paradigms were applied to define the role of fabrics, organic matter, and inanimate objects in the retention or transmission of agents of disease, these had become pivotal targets of disinfection as part of what Barnes calls an "interpermeable world."[99] Regardless of the failure of sanitary conferences to arrive at an agreement about the usefulness of disinfection until 1897, Barnes has shown for the case of the lazaretto and quarantine station of Philadelphia in the United States that disinfection practices and the application of various chemical substances had long been considered to be effective against "infection," which was often, but not exclusively, understood to be carried (or indeed self-generated) in fabrics, coffee, tobacco, or any other goods that crossed the oceans.[100]

The historian Owsei Temkin has considered the nineteenth century as having brought a secularization of the age-old concept of infection. In his account, the term had been redirected to acquire a scientific content and to develop a "new moral force."[101] Replacing older notions of staining and impurity, according to Temkin, the new medical concept of infection emerged steadily in the course of the nineteenth century through various concepts, proposals, and theories that eventually led to the work of Pasteur, Lister, and Koch. Barnes's portrait of disinfection in the United States suggests there was indeed a "tacit consensus about infection"; a rarely specified but widely applied category that was considered both a process as well as a quality that was bound to certain local conditions.[102] Much of its veracity, Barnes proposes, was earned through it being applicable to polemics in favor and against the idea of the contagious transmission of diseases. But unlike in the positivist reading of Temkin, Barnes sees the concept of infection as remaining largely undefined. He furthermore suggests that much of the particular notion's impact on the early landscape of global health was owed to its status as an uncertain object at the center of practices and strategies of containment: "Diffuse and invisible but deadly, infection in the pre-bacteriological era can ultimately be defined only as that which was neutralized or removed by whitewash, chemical solutions, fumigation, steam, ventilation, and flushing with fresh water."[103]

The history of disinfection, which developed over the nineteenth century, both in tandem with and in disjuncture to quarantine, is often curbed of its rich implications and entanglements, when looked at only through the lens of its bacteriological reinvention in the 1870s. Historical scholarship has overwhelmingly focused on the second half of the century and the impact of bacteriology on the reinvention of the field.[104] Yet, as indicated above, already in the first half of the nineteenth century, we see a large number of experimental procedures put in place to evaluate the effects of chemical and organic substances for the purpose of disease prevention. Various indications for the widespread disinfection and fumigation of mail in the early nineteenth-century containment of yellow fever outbreaks in the northern United States demonstrate another field, in which disinfection practice was thought to have substantial impact.[105] In contrast to the above-discussed development of hygienic fumigation practices up until 1800, the question that arises here is at what point the application of disinfectants became a practice in which a chemical agent was understood to have a direct impact on the properties of an infectious agent.

Andrew Mendelsohn argues that much of the early bacteriology in Paris should be seen as focused on the chemical manipulation of the virulence of pathogenic agents.[106] Pasteur, in his own original research on wine, had investigated the possible role of microorganisms in the process of fermentation. To halt the spoilage of wine, in 1861 Pasteur then famously proceeded to suggest three different methods of eliminating the responsible microorganism: filtration, exposure to heat, and application of a chemical substance. For the latter, he experimented and ultimately relied on a substance that had been discovered in 1834 by Friedlieb Ferdinand Runge, originally called Phenol and later established as carbolic acid. The substance, which was derived from coal tar, had been used to treat railway ties, as it appeared to prevent rotting. It had also found various uses in sewage and garbage processing, as it seemed to prevent the production of supposedly noxious gases and stinks. Influenced by Pasteur's research on fermentation in wine, it was Joseph Lister who famously began to apply the chemical as a disinfectant on the human body in surgery. He began to wash instruments, soak pads, and clean hands of the surgeons with a 5 percent solution of carbonic gas and observed a drastic reduction in the incidence of gangrene, the most common cause of death after surgery in the nineteenth century. In a series of six articles in *The Lancet*, Lister published his results in 1867 and proposed the paradigm of antiseptic surgery, which—after some controversial back and forth—became rapidly standardized across European and North American operation theaters.[107]

The American physician Robert Bartholow summarized disinfection practices developed over the mid-nineteenth century in his 1867 treatise on "the principles and practice of disinfection."[108] Bartholow argued that the ravages of cattle plague and the disastrous experience of cholera since the 1830s in North America and Europe sparked a renewed interest in disinfectants as weapons against the "mysterious animal poisons" that seemed to be driving the epidemics. The "strictly modern science" of chemistry had supplied society with numerous new agents that could be employed for systematic disinfection.[109] These agents were supposed to show effect against two entirely different categories of substances against which they were employed. First, the products of putrefaction, which created a powerful morbid agent, were considered. Second, Bartholow wrote of a "peculiar organic matter: to which we apply the terms virus, *materies morbi*, morbific matter, diseased germinal matter."[110] When it comes to disinfecting agents, he saw the field as divided between those of chemical nature, employed to destroy a noxious compound (heat, ozone, chlorine, bromine, iodine, nitrous acid, and sulphurous acid), agents such as antiseptics and colytics, which were useful in arresting the chemical change of morbid matters, and agents that were used to physically restrain the noxious substance. Sulphurous acid was to Bartholow in 1867 a common deoxidizer, which had the capacity to abstract oxygen to pass on to sulphuric acid. As such it ranked high and was understood to be both a brilliant destroyer of infectious matters, as well as a high-functioning antiseptic. As had been long observed in the age-old tradition of winemaking, sulphurous acid "prevents change, decomposition, or fermentation, by abstracting oxygen and by destroying those minute living organisms necessary to this process."[111]

In the decades following Bartholow's publication, and in parallel to the success of bacteriology, disinfection became a blossoming field of experimental study and theoretical exploration. But again, reducing the success of disinfection practices to the development of the bacteriological laboratory would miss a crucial point: the continued application of disinfectants was not inherently bound to a clear definition of the microbe it was supposed to act upon. Rather disinfection was itself an experimental practice through which the shape and nature of infectants was supposed to be illuminated. Rebecca Whyte has argued that, for this reason, disinfection did become a popular public health practice in the second half of the nineteenth century in the United Kingdom in, as well as outside of, the laboratory. Day-to-day disinfection did mostly take place outside of laboratories. And although the bacteriological paradigm achieved a model character in explaining the efficacy of disinfecting agents, "there were myriad debates about how to create a mutually understandable scientific standard for testing" the compounds on the "epidemic streets."[112] Where the laboratory and "germ theory" succeeded in redefining and reframing disinfection as a "germicide," a range of methods remained in place despite the inability of the laboratory to prove their efficacy against germs, microbes, or any infectious matter.[113] Whyte explains this historical disjuncture through the differences between laboratory practice and practical application. Missing a theory that would sufficiently explain how chemical substances effected bacteria, rejecting the comparability of the laboratory and the interior of vessels led to a research field that was in its entirety carried by an experimental system that operated vastly without a comprehensive theoretical understanding of the supposed efficacy of gases, solutions, and substances in the field.

In the last two decades of the nineteenth century, this development opened the floodgates to a vast amount of experimental setups, which were put in place on both sides of the Atlantic to establish standardized hierarchies of disinfecting substances, as well as to arrive at a consensual theoretical understanding of how modern methods of disinfection were supposed to overcome all shortcomings of traditional practices of quarantine detention and medical observation. What spearheaded this process was the rapid development of a range of disinfection apparatuses.

Disinfection Apparatuses

The history of the development of mechanical contraptions for disinfection spanned the nineteenth century. Back in the 1830s William Henry had conducted the first scientific experiments with disinfection, as a result of rising anxiety in his hometown, Manchester, about the importation of plague from Egypt inside bales of raw cotton and subsequent fears of the arrival of cholera in England's key merchant hub.[114] In his letter to the *Philosophical Magazine* (October 14, 1831) Henry drew authority from Alexander Russell's *Natural History of Aleppo* (1756, and revised edition by his brother Patrick, 1794), where summer heat was considered as a palliative of plague and which had an impact on Henry's ideas of disinfection.[115] Henry proceeded to test the effect of heat on smallpox vaccine lymph, which was neutralized after being exposed to 140 degrees Fahrenheit, while also showing that "items of clothing made of cotton, silk, wool, and fur were unharmed after exposure to a temperature of 180F for three hours."[116] He concluded that a temperature of 212 Fahrenheit was the minimum "capable of destroying the *contagion* of fomites."[117] Graham Mooney has argued that Henry's experiments "provided no more than analogous inference for the action of heat," so that, by "directing his lymph-contagion toward the impending cholera threat, Henry recommended the construction of dry-heat chambers at seaports."[118] Henry envisioned already in the 1830s that his apparatus (an enlarged metal boiler, which he soon modified, "for cholera-hospitals, lazarettos and stations where large quantities of articles are intended to be disinfected") would, if installed in every port, eventually overcome the unreliable and widely mistrusted practice of quarantine detention.[119]

Henry defended the necessity of his method on account of the need to "substitute" quarantine, and in the knowledge that substances like chlorine were inapplicable as disinfectants to a wide range of products, fabrics, and goods as it discolored and damaged them.[120] By the 1870s such methods would be widely employed in the construction of disinfection apparatuses, which, as Graham Mooney has shown, enjoyed great popularity. Following

Mooney, in 1870 George Fraser's disinfector, "was designed as a brick oven, heated from underneath by a coke fire. The iron carriage used to transport the clothes was driven directly into the disinfecting chamber, meaning that employees did not have to handle infected clothing and the carriage itself was disinfected during the disinfecting process."[121] What was crucial to these machines was their ability to be "self-regulating," a task confounded, Mooney tells us, by the fluctuating temperatures in the disinfecting chambers when in operation. Though dry-heat machines that approached this ideal were in fact achieved (see for example William Ransom's disinfection apparatus, 1870), the inability of heat to penetrate denser or larger items led to a move toward steam as the preferred medium of disinfection.

Mooney's research on the history of such apparatuses confirms the opinion that this shift was catalyzed by the endorsement of steam or "moist heat" by Robert Koch in 1881.[122] Steam was not only more evenly distributed in the disinfecting chamber than dry heat, it could also penetrate objects thoroughly at lower temperatures. Moreover, a key element to the apparatuses that ensued was their portability.[123] Machines like Washington Lyon's steam disinfector, patented in England in 1880, "had wheels and could be carted around by just one horse."[124] Mooney's study of the history of disinfection in England has stressed how confidence in heated steam was fostered by experiments conducted by Franklin Parsons for the Local Government Board in 1884: "Parson's three-way experimental matrix of bacteria, disinfection method, and materials established a sort of sliding scale for disinfecting efficiency. Using both laboratory methods and operational disinfecting machines in situ, he assessed the impact of dry heat, boiling water, current stream, and steam under pressure on anthrax, swine fever . . . and tuberculosis."[125] Parson's experiments showed steam under pressure to be the most efficient method of disinfection, leading to the adoption of Lyon's machine, and at the same time to the invention and manufacture of competing steam-based disinfecting apparatuses.[126]

In England, the principles of "easy use, portability and effective means of destruction" were linked to experimental systems that came to merge and entangle laboratory and domestic spaces.[127] At the same time, the development of regimes of maritime fumigation required the inclusion of vessels into experimental systems that form the subject of this book. Fumigation, with its long and versatile history of cross-fertilizing humoral and hygienic ways of thinking about the body and its environment, merged in the last three decades of the nineteenth century with the increasingly biopolitical landscape of disinfection. The vapor, known for centuries to be therapeutic in supporting bodily balance and to promise a fortified, hygienic atmosphere against ailments, was slowly transformed into a chemical substance with dedicated effects on organic forms of life. As fumigation became a method of disinfection, it advanced into a powerful agent that enabled and encouraged the possible replacement of unreliable and controversial quarantine routines by a thorough system of maritime sanitation, which promised for the first time enduring safety to fuel a sulphuric utopia of trade and travel free from disease transmission and time-consuming detention. Never totally disentangled, but retaining a material and epistemological exchange allowing for their relative autonomy, by the end of the nineteenth century, domestic disinfection and maritime fumigation regimes formed part of a broader biopolitical, political-economic, and imperial world system that assumed the chemical battle against infectious diseases as a key goal of technoscientific, economic, and social transformation.

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Sulphuric Utopias

A History of Maritime Fumigation

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