wisdom of a policy having for its object the removal of this source of infection, which is dangerous for man as well as for animals. It should be possible, by rigid cleansing and disinfecting of byres, and by the condemnation of all carcases or animals known to be tuberculous, to stop this source of infection.

5. It is not for us to prescribe the mode in which the infection should be dealt with in the case of man. The Council has skilled officials whom it can consult on the matter. But we venture to suggest that a beginning should be made with a definite attempt to stay the infection. If the public were authoritatively informed of the harmful nature of all discharges from tuberculous persons, and more particularly from cases of Consumption of the Lungs, and if they were encouraged to have these discharges rendered innocuous, and also to submit their houses and clothing to disinfection at intervals during the currency of the disease, and again at its close, it is believed that much good would result. With the splendid sanitary organisation which Glasgow possesses, it should be possible to do much to cleanse our city from some of the principal causes of the widespread prevalence of this, its greatest plague.

On behalf of the Society,

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CHAPTER XI.

ON DISINFECTION.[1]

Gentlemen,—First let me explain the scope of this paper. I have dropped from the title the subject of Infection, and confine myself to Disinfection, which affords material enough. I have read pretty well all that has been written about disinfection—both theoretical, or experimental, and practical. I am familiar with the various so-called disinfectants and disinfectors as placed in the market, and pressed by travellers and advertisements upon the public. I have had a large experience of the practical difficulties in the way of the effective use, even of genuine disinfectants, in detail, in private or on the largest scale in public operations. I do not pretend to treat my subject scientifically. I propose to submit merely a few general conclusions which, during the observation and direction of the practice of disinfection in an extensive field for a good many years, have grown up in my mind. They are only the formulated impressions left by the multitude of facts which pass under the eye of a busy man, whose first duty is to get through a vast amount of daily work, and who has no time for that precise record of data which is necessary to a scientific disquisition.

If we begin the study of disinfection in the laboratory, the problem before us seems very simple. We learn there that if we take a certain contagium, which is definitely associated with a certain disease, if to a determined quantity of that contagium we add a certain chemical agent in known proportion, and after admixture and the lapse of a certain time, we introduce a certain amount of the mixture into the body of some animal, we find that the specific morbid process is not established; or if we attempt to cultivate it in some suitable medium it will not grow. The contagium has thus been

[1] Read at a meeting of the West of Scotland Branch of the British Medical Association, held at Kilmarnock, 13th November, 1884.

disinfected, and we know that the chemical agent is a disinfectant under the conditions of the experiment. The same method applied to the use of heat enables us to conclude in like manner that a certain temperature maintained for a certain time is disinfectant, length of time compensating diminished temperature, and moist heat being more active than dry. Setting aside the fact that the number of contagia which can in this way be submitted to precise experiment is small compared with the number of diseases which have specific contagia, so that we are left largely to analogy in the application of such experiments to practice; there are other more serious difficulties which meet us in practice. Even supposing that all contagia had been subjected to exact experiment, and that we knew that under certain conditions obtained in the laboratory the specific energy of each could be destroyed, how are we in practice to control and secure these conditions? We have to attack these contagia in the whole environment and products of the patient. The media in which those contagia reside are innumerable, and as varied and opposed in their physical character as they are numerous. Even in the same medium the contagium varies in concentration, or quantity, and the same contagium, according as it is moist or dry, in seed or germinated, presents different degrees of vital resistance. The air, the excreta, solid and fluid, the bedding and clothing, the furnishings of the room, the utensils for the service of the sick, all are more or less impregnated with the contagium of the special disease. In each case there is a separate and different task before us, and the case changes with the disease. Even if we had nothing else to think of but the destruction of the contagium, the same disinfectant applied in the same way would not meet the physical necessities of each case. Still, the laboratory would seem to overcome this difficulty by supplying us with disinfectants adapted to the various physical conditions under which the contagia exist in each medium. We have gases for the air, a choice of solids and liquids for the excreta, solutions adapted for the furnishings, and heat, dry or moist, for the bedding and clothing.

But this mere necessary variety brings with it practical difficulties. Every single act of disinfection is a scientific process. There must be precision in use as to quantity and time, there must be unfailing uniformity, there must be perpetual vigilance to apply the exact process, either continuously, as in the case of aerial disinfection, or on each occasion when the dangerous matter is produced, as in the case of the abdominal excreta. In short, the sick-room must become a scientific laboratory, and that under the control of persons usually unskilled and even if intelligent, unless in the com-

paratively rare case in which a trained nurse is in charge, always with minds disturbed by solicitude, and in a condition as far removed as possible from the calm, cool domain of reason. As for the application of heat, as hitherto understood, that is beyond private resources. Certainly this is not the character of disinfection for the million, even if disinfectants could be had for nothing. On the contrary, they are all more or less costly, and when we consider the straitened circumstances which are most common in sickness, this element is in itself fatal to systematic effective disinfection on the lines of laboratory experiment

This criticism of disinfection from a laboratory point of view has hitherto gone on the supposition that in disinfecting the various media we have nothing to think of but the destruction of the contagium. This is far from being practically correct. What are these media? They are for the most part not like mere decoctions of hay, or cultivation fluids or solids, interesting solely from their vital and chemical relations to the contagia which they contain. They are either literally of vital importance to the patient, as the air which must at all risks sustain his life, or figuratively, as his property, possessed of economic value. The abdominal excreta may be left to the chemist to treat as he pleases, or rather, to be treated as the intelligence and means of his agents at the bedside will permit. But the air of the apartment must first of all be respirable; and if it is respirable, it cannot be disinfected. You may deodorise it by faint evolutions of chlorine or sulphurous acid, or dissemination of carbolic acid, or by the more aesthetic and agreeable aromatic vinegar, or eau-de-Cologne, or you may follow the fantastic suggestion of another author and moisten the heads of matches so as to liberate ozone! but this is the mere delusive ghost of disinfection. There is probably little harm done by saucers with chloride of lime placed about the apartment, or sheets soaked in carbolic acid draped over the doorway, or Condy's fluid sprinkled on the floor, or any other of these inane proceedings. The worst that can be said of them is that they may give a sense of false security, and divert attention from free ventilation and scrupulous cleanliness. The sensations of the patient and attendants will keep them within the limits of innocuousness. Still, they partake of the same character as much of the more serious public practice of disinfection which Simon has described as a "futile ceremony of vague chemical libations or powderings, . . . savouring rather of superstitious observance than of rational recourse to chemistry."

It is in the disinfection of bed and body clothing, mattresses, and the like, that the restraints of economic considerations upon the endeavours to attain theoretical perfection are most felt. Yet this is undoubtedly the department of disinfection which it is of the highest practical importance to carry out efficiently. I suppose at least 75 per cent. of all the contagia thrown off in our commonest infectious diseases is one way or another detained in those personal belongings of the patient. At any rate if this overstates the fact quantitatively, it certainly does not as an estimate of the risk of effective infection arising from the proportion of the total contagia conveyed to the bedding and clothing, as compared with that sent into the air or down our sewers. Therefore, we have to attack the most dangerous and insidious infectiveness lodged in personal property of the greatest value to the owner. It so happens that of all the disinfectants, that which is most applicable to bed and body clothing and bedding is also that which is experimentally proved to be the most certain, and under conditions, the best known and the most easily controlled—viz., heat. All contagia are destroyed by boiling, and a dry heat of 230 deg. F., or even 220 deg. F., maintained for a longer time, is equally certain in action. Yet it is also true that this disinfectant is the most difficult of all to apply without injury to the textures submitted to it. The material is derived from many sources, animal and vegetable, and varies, therefore, in power of resisting heat. The value of the manufactured article depends sometimes on form and elasticity, which may be lost through heat, or on colour, which may be impaired. Every one knows that blankets and other woollen articles cannot be boiled without serious injury. Even the most cautious washing changes gradually the white, fleecy, new blanket into the yellow, dense, bare, comparatively comfortless old one. With cottons and linens there is no trouble. They may be boiled with impunity. Wool, hair, and feathers are most troublesome. They all depend, for their value and utility, upon form and elasticity, which again depend not only upon the hygrometric moisture, but upon the presence of animal fats. When we begin to deal with such articles, we find that we are involved in all the technical knowledge of several trade processes. If you wish to realise the truth of my words, read pp. 497-508 of Vallin's *Traite des Disinfectants et de la Desinfection*, the most recent work on the subject of which I am aware, and one which is pervaded by a minute practical knowledge and common sense which are unique in their application to this branch of sanitation.

In short, then, in the application of all processes of disinfection to articles of value, we are controlled and guided not by considerations of what is theoretically necessary, but by the effects of our processes upon the articles in question. And to whose judgment must these effects be submitted? We have the guidance of many and valuable experiments, as to the limits within which we may avoid discolouration, increase of friability, loss of elasticity, diminished resistance, and lowered breaking point of fibre. But we are not judged by scientific men like Ransom, De Chaumont, or Vallin. Our judges are women and exacting householders, generally backed by the opinions of upholsterers, hair and feather cleaners, and the like, who entertain a secret grudge against sanitary intrusion into their technical domain. It does not avail to quote Ransom as against the judgment of a housewife, who detects that her blankets are returned a shade yellower than they were when they left her custody. Dynamometric experiments on the breaking point of wool or hair fibres will not avert the claim for damages which is supported by the fact that the upholsterer charges so much for the wool or hair necessary to make up the original weight of a mattress or a pillow. The practical result is constant friction in carrying out disinfection, temptation to public officials to scamp the work to avoid censure: constant private efforts to escape interference by concealment, or appeal to fictitious domestic processes; or, on the part of the wealthy, to resort to the general cleansing and renewing operations of the upholsterer and hair and feather cleaner.

Is there any way out of these practical difficulties, any method of simplifying our conceptions of the general requirements of disinfection, so as to substitute a lower standard which we may reasonably expect to maintain in place of a high one, which we know in practice will never or seldom be acted up to? It is instructive to take formulated codes of disinfection of recent date, such as those issued by Central Sanitary authorities, or for the armies of different countries, and observe how they meet the practical difficulties of which I have spoken. They represent the essence of the wisdom of these countries as applied to the solution of those difficulties. In the case of military codes, the property is treated by the owners, who have absolute control over its disposal, and it is treated by subordinates under the strictest discipline. Yet, even in these circumstances, Vallin says, and says truly, "If we wish disinfection to be practised, we must simplify the operation to a maximum, so that it may become habitual, daily expeditious, and may not deteriorate the material entrusted to the care of the administrative officials." The French Army Hospital regulations are very simple. Everything that can be washed is washed, but with unusual thoroughness. After a first washing, the articles are steeped in pure water for 24 hours. Next day they are again washed, each article being taken separately, and scrubbed with Fuller's earth, then rinsed in clean water and dried. *Finally*, they are fumigated with sulphur, and hung out in the open air. The wool of beds is similarly washed and soaked; but in the place of a second washing, it is passed through an alkaline solution to restore elasticity, dried and fumigated. In the English Army regulations, the disinfection "by dry heat or any other means" precedes the washing; but such articles as cannot be washed are to be fumigated, exposed to air and sun for a week, beaten and brushed. Hair mattresses are to be exposed to the air, beaten, and, if possible, subjected to dry heat of not less than 212 deg. for two hours. In "Instructions for Disinfection," issued by the "National Board of Health," of the United States, after a startling instruction to boil "flannels, blankets, &c.," in a solution of sulphate of zinc and common salt for at least half-an-hour,—they proceed: "Heavy woollen clothing, silks, furs, stuffed bed-covers, beds, and other articles which cannot be treated with the zinc solution, should be hung in the room during fumigation, pockets being turned out, and the whole garment thoroughly exposed. *Afterward they should be hung in the air, beaten and shaken.* Pillows, beds, stuffed mattresses, upholstered furniture, &c., should be cut open, the contents spread out and thoroughly fumigated. Carpets are best fumigated on the floor, *but should afterwards be removed to the open air and thoroughly beaten.*" In certain regulations issued quite recently by the State of Illinois for the prevention of small-pox, there is a still more pronounced appeal, after every sort of technical process of disinfection to ordinary washing, to exposure to sun and air, and to beating and shaking of articles which have received some dry treatment. It is especially noted that no security is to be obtained but by free exposure to the air of every garment which has been exposed to infection; and that after fumigating an apartment it must be left empty; with every door and window open for a week or a fortnight, and all the furniture, if possible, placed in the open air.

These are but illustrations from the highest sources of what meets one in any attempt to codify and regulate disinfection on a large scale. In all, two facts are conspicuous: (1) That either in conjunction with technical processes of disinfection or as a sort of last resource when these are inapplicable, recourse is had to the free use of the great natural disinfectants —open air and sunlight. If these are enjoined as sequents to technical disinfection, there is displayed a want of confidence in that disinfection; if these are substituted, then it is obvious that they must be held to be sufficient alone. In either case aeration and insolation are either sufficient or insufficient by themselves. If the former, why not be satisfied with them? If the latter, why enjoin them? (2) The other fact is that

what we shall, for the present, call nothing more than *mechanical* disinfection, also forms either an adjunct to or a substitute for all the ordinary technical processes. The contagia are removed by the common process of washing with soap and hot water, by beating, shaking, brushing, and rubbing surfaces with damp cloths or soap and water, all of which are simply ordinary operations in domestic cleansing.

I feel that I am becoming very heretical, and that my heresy will, like all heresies, become dangerous if half apprehended, or, through imperfect expression, misunderstood. I know that *perfect* disinfection means killing the contagium before getting rid of its material substance. To take a shovelful of small-pox crusts and throw them into the ashpit, or to shake the debris from the flannels of a scarlatinal convalescent over the window sill, are not processes of disinfection. In a sense you disinfect the room which has been swept and the flannel which has been shaken, but you start the contagia on a fresh career of mischief. You must adapt your procedure to the case in hand. You must burn the small-pox crusts in the fire, and you must simply wash the flannel in the ordinary way with soap and a plentiful use of water. It is of no use fumigating it. Let us follow out this process of washing. I believe that the contagia, though in their naked condition microscopic, or probably as spores, sometimes minute beyond the powers of any microscope, are as they leave the body comparatively gross, wrapped in faecal envelopes, in effete animal matter. They are, in short, physically associated with dirt. It may be microscopic, as in the case of the breath and urine; or minute, as in the case of the finer debris of the skin; or tangible, as in the case of the discharges from the alimentary canal. Their inherent vitality and longevity are proportioned to the associated moisture. What Baxter thought was probable many years ago, I believe is certain, "that all contagia disappear sooner or later under the influence of air and moisture." The contagia which impregnate the breath are moist, and if they float out into the open air their career as living forms soon terminates. So with the cutaneous exhalations. Hence typhus, which spreads like wildfire, with personal uncleanness and overcrowding, is absolutely disarmed by cleanliness and ventilation alone. The contagia of the urine and fæces are still more moist, and so farther on the way to destruction at the outset of their career. If their moisture is rapidly evaporated, so that the solid ingedients become dust, then they are endowed with the longevity and far-reaching infectiveness of all dry contagia. The most dangerous and long-lived of all contagia are those which begin their external career in this state of dryness; of these scarlet fever and small-pox are the most striking illustrations. They impregnate the atmosphere of the room, and make it highly infective. Yet we can do nothing to destroy this infectiveness, but trust to the natural disinfectants—air and moisture—which, in this climate, any hygroscopic body soon acquires. We may, however, by applications to the patient's body, clog the wings of the contagia, and retain the debris to be removed by the bath. In the water all contagia are drowned at once, in the sense of being imprisoned, and if the bulk of water be sufficiently large in proportion to the organic matter, decomposition proceeds apace, and they soon cease to exist as vital entities. There are only two circumstances which may give them another opportunity of infection, one is if they contaminate the water supply, the other is if from defect of bulk of water and stagnation gaseous bubbles project them into the air, or the filthy solution smears the sides of sewers above water level, or deposits mud which is exposed to the sun and the sweep of currents of air.

Let us return now with these ideas in our minds to washing regarded simply as a mechanical process of disinfection. The contagia in a washable garment are bulky from their attachment to animal debris. If we take a new sponge, by continuous washing in water we get rid ultimately of every particle of sand. If we take a sheet, for example, or a blanket, smeared with the pus of small-pox, and, carrying it to a freely-flowing stream, soak it, beat it, rinse it back and forward in the stream, wring it, and again immerse, and so proceed for a sufficient time, there can be no doubt that ultimately we shall completely disinfect it. The pus and variolous contagia will flow down stream, and be effectually disposed of by dilution and oxidation; and by the mere mechanical use of water the article is disinfected. This is the rudest form of washing. The ordinary process, I need scarcely say, is even mechanically much more efficient. The element of heat also comes into play. In any degree, with the added soap and soda, it promotes the solution and thorough moistening of the animal debris, strips the contagia, so to speak, of their protecting envelopes, and initiates the final process of destruction. If the nature of the tissue to be washed permits boiling, then we have perfect disinfection, as no contagium survives a moist temperature of 212 deg. F. Therefore, whenever we can subject any article to the domestic process of washing with boiling, we can perfectly disinfect it.

So much by way of reasoning on general principles in proof of the efficiency of simple washing as a disinfecting process. I am able to establish my opinion from the experience of many years, during which this has been the sole method of disinfection applied by the Sanitary Department of Glasgow to all washable articles. We have during the last ten years washed in the same washing-house over a million of articles of every sort, infected by every variety of contagium known in this country. Everything has been done exactly as any good housewife would do it, only in a place provided for the purpose, and with ample supply of water and steam, and recently with mechanical aid. Blankets and woollen articles have not been boiled, all others have. The most crucial fact is this, that there has never been a single case, or suspicion of a case, of interchanged disease, *e.g.* of small-pox, appearing in a house from which clothes had been removed on account of scarlet fever or typhus. In short, I am convinced that in every case the result was obtained for which the operation of washing was undertaken. The only defect is this, that the washerwomen must handle the articles before disinfection or drowning of the contagia in water, and therefore are occasionally infected. To overcome this difficulty, we lately had erected an apparatus to disinfect by high pressure steam before disturbing the bundles; but this at once brought about complaints of injury to the clothing, which would soon have wrecked our popularity with the housewives and obstructed our operations. We found that the steam fixed all sorts of stains from animal matter. A sheet stained with blood comes out a dull red colour which nothing will remove. Indeed, this application of steam is a part of the trade process of dyeing. Every woman knows that cloth stained with blood must be steeped and rinsed in cold water before ordinary washing. The practical result is, that dirty clothes must be disinfected by washing before being disinfected by steam or dry heat, for that also fixes stains. We are, therefore, again disinfecting all washable articles by simple washing.[1]

In spite of this ample experience, in view of the salamander-like behaviour of spores in resisting dry heat, according to the experiments of eminent biologists, it was with a sense of relief that, two year ago, I read the papers of Koch and Wolfhugel, on the comparative disinfecting value of dry heat and steam. They were asked to advise the Government as to the best form of disinfecting apparatus by heat. By experiments of such convincing accuracy as might be expected under such guidance, they proved that, by direct application of steam at 212 deg. F. for five to ten minutes, even the virulence of dried anthrax blood was destroyed. Earth spores, which have a reputation for tenacity of life at high temperature beyond all others, were devitalised by fifteen minutes' exposure to steam, while they resisted the action of dry heat continued for three

[1] The apparatus referred to is that invented by Washington Lyon.

or four hours at 302 deg. F. Koch proved also that the penetrating power of steam, even at atmospheric pressure, was immensely superior to that of dry heat. He therefore reported that, whenever heat can be applied to disinfection, there is no method equal to the use of steam, applied so that it may reach the articles to be disinfected at its initial temperature 212 deg. F. The boiling point of saline solutions is higher than that of pure water, *e.g.* 30 per cent. of common salt raises the boiling point to 224 deg. F. Nitrate of potash and chloride of calcium raise it much higher. The dry heat stoves in Berlin have consequently been reconstructed for the application of steam; and I believe that in Paris the municipality is now effecting the same change in the district disinfecting stoves of that city.

It must be observed, that, though washable articles are so easily disinfected, the process must be carried out either in a private washing-house, or in a public washing-house, devoted solely to that use. Wherever it is done there must be abundance of water, both hot and cold. Therefore, the use of washing-houses which are not private is not permissible; and, in the hands of a slovenly person who makes a puddle of her washing-tub, still more of one who has no tub and no appliances, no washing can be efficient for disinfecting.

As to hair and wool, I am satisfied that mere mechanical disinfection with cold water and soap, which would not remove the natural grease and so impair the material, is thoroughly effective. There must be a constant flow of water, and a thorough disturbance and agitation of the fibres. After this process and washing of the tick, the whole can be sent to an upholsterer to remake.

Any article which is impregnated with dry contagia need not be fumigated, even if the tissue will resist corrosion or the colour not be cast. We cannot have confidence that any gas will penetrate the dry organic envelopes. Our only resource again is mechanical—beating, shaking, brushing, with exposure for as long a period as possible to the free circulation of air and direct sunlight. In populous places this cannot be done at the domicile with safety. In the country it may. Carpets are the chief representatives of this class of articles which come into our hands. We have a carpet-beating machine, which is ventilated into a furnace, to which all dust is conveyed. Afterwards they are dragged over the grass, and hung up in the open air for a time. In the case of mattresses, pillows, and the like, which are not visibly soiled, we employ steam disinfection, which is also useful in the treatment of clothing of good quality which is not soiled, or which cannot with safety be washed.

Chemical disinfection of the abdominal excreta, as usually practised, I believe to be all but valueless. However accurately you have determined the efficient proportion of the agent to be used, what can you expect from passing the excretion into the solution or powder, or putting the solution or the powder on the excreta, and the next minute drenching the whole down the water-closet? How can the agent, while in due proportion, have penetrated the fæcal masses and killed the contagia if we drown it at once in water? In order to meet this difficulty, I had water troughs substituted at Belvidere for ordinary water-closets. These I intended to fill with a 1 to 15 mixture of strong muriatic acid and water, which would be renewed morning and evening. On calculating the annual cost of this procedure, I found it could not be done for less than £500 a year, for a daily average of 150 patients; not to speak of the difficulty of arranging for the safe distribution of such a quantity of corrosive acid. I therefore abandoned the project, and use cupralum in such quantity as will at least keep down the odour. As an endeavour to disinfect fæces on a large scale, I cannot say my experience is encouraging. Use anything you please, but expect only deodorisation, and get rid of the faecal matter into the sewers or into the earth without delay. When thoroughly immersed in water, it is harmless for the present, and an oily pellicle, as of terebene or paraffin, hermetically seals down the contagia.

As to apartments which have been occupied by a patient during an infectious illness, you may fumigate if you will, but a thorough domestic cleaning is the best mode of disinfection, renewing wall-surfaces, which are dirty, washing down paint, rubbing up furniture, burning all dust, and letting the air play freely through the open doors and windows as long as possible.

I believe that the municipal disinfecting apparatus of the future will be a large washing and cleaning establishment, comprising in its various departments, besides a washing-house, provided with the best mechanical aids, a hair and wool-washing and feather-steaming, and carpet-beating apparatus. The processes to which the various articles and materials are subjected in cleaning, as presently carried out as ordinary businesses in towns, are all disinfecting. They merely require to be transferred to places set apart for infected goods outside the inhabited area.

In isolated houses in country districts, it is quite possible by a little ingenuity in arrangement, and fertility of resource in applying the principles which I have been inculcating, for country people to consume their own smoke. I have sometimes thought when besieged, by my friends the rural practitioners in the West of Scotland or their patients, with applications to receive infected washings, or to send out disinfectors to them, or still more, when, as occasionally happens, I intercept consignments of infected bedding at the upholsterers in Glasgow, that they might, without much difficulty, help themselves. I trust that out of this long and rather incoherent paper they may be able to pick some hints which will be of use in aiding them to do so. I shall always be glad to advise them how to meet special circumstances, and to enforce their advice with such weight as my opinion may possess in the event of that advice seeming, as it very possibly may seem to their clients, too homely, not sufficiently redolent of the popular notions of disinfection as an abstruse and mysterious art.

THE PHYSICAL LAWS WHICH GOVERN THE DISTRIBUTION OF INFECTION.[1]

During a course of reading recently undertaken in furtherance of an inquiry into the prevention of tuberculosis, my attention was attracted to the fact that the modern doctrine of tuberculosis rests upon physical laws of the operation of which the circumstances of infection with the bacillus of tubercle are but an illustration—very striking, and, as it happens, peculiarly capable of experimental demonstration—but, still, only an illustration or example. I learned that the bacilli of tubercle were imprisoned in the expectoration, and could not leave it while it continued to be moist. I asked myself, Would any kind of bacillus or microbe not, vulgarly speaking, be in the same box if similarly circumstanced? I learned that there were no bacilli in the breath of consumptives. I asked myself, Are there *ever* any microbes in the breath? I learned that although the breath of persons suffering from consumption was pure, yet the air about them became full of infective dust—*i.e.* dust containing bacilli, and that the source of this dust was their expectoration smeared about on handkerchiefs or otherwise dried and pulverised. I asked myself, Would the same result not ensue with any moist infected material similarly treated? These thoughts expanded into a consideration of the physical laws which govern the distribution of infection. The subject is a wide one, and within the share of your time which I can reasonably ask even the outlines of an adequate discussion can only be suggested. But the doctrine of infection is so distinctly germane to the business of the Section that any part of it seems to be a proper subject for the address with which the President is expected to open your proceedings and to introduce himself to your acquaintance.

[1] Address as President of the Preventive Medicine Section, Glasgow Congress of the British Institute of Public Health (now Royal Institute of Public Health), 1886.

It has long ceased to be disputed that infection has a material basis, that the quality of infection is inherent in a material *substantia*. Positive knowledge now covers such a considerable proportion of the infectious diseases that I am warranted in filling up by analogy the gradually diminishing gaps, and asserting broadly as the doctrine of infection, that its *substantia* is always a microbe—an organised solid. For the present I propose to consider the contagia merely as solid bodies. The possession of the complex quality of life brings them into new relationship to such physical agents as light, heat, moisture, electricity; and profoundly influences the bearing of gravitation, cohesion, and other laws of matter as matter, upon the effective working out of their functions. But in the investigation of the circumstances under which outbreaks of infectious disease occur, in the routine operations about the individual case to prevent infection during its currency, and to remove infection from its environment at its close—in short, in the daily work of preventive service, it is of importance to rise to the conception of a few absolute and universal laws; and, having done so, to apply them rigidly in the interpretation of observed facts, and in the guidance of procedure. There is no property of the contagia from which we can rise to generalisations more widely applicable to the phenomena of infection, more interesting and more useful, than that of solidity. Whatever their form, whatever their size, whether spore or mature organism, whether moist or dry, whether they are naked or embedded in fragments of the material in which they grew, whether they grow with or without oxygen, whether they are wholly or partially parasitic, being solids, we can, without hesitation, predict how they will behave in certain circumstances, in which their behaviour is of supreme practical importance. Let us begin with the consideration of an infected liquid. Within the limits of the liquid the automatic power of locomotion possessed by a few microbes is of no practical importance. They are borne passively in the internal currents so long as the fluid is agitated. They are not uniformly distributed. They exist in shoals. When the liquid is quiescent they subside with a rapidity proportioned to the relation between their own specific gravity and that of the liquid. It is difficult to compel our minds to apply to a particle of matter which is not only invisible to the naked eye but beyond the range of the microscope, the same physical laws as to a pea or a marble. Yet Tyndall has demonstrated by optical tests that particles so fine as to be ultramicroscopic and incapable of being caught by one hundred layers of the best filter paper, still own their allegiance to the law of gravitation by subsiding, though, as it were, reluctantly, "after a few weeks' quiet." Even these particles can be caught mechanically in the finer meshes of a porcelain filter.[1] The contagia, compared with such particles, are gross bodies. Here it may encourage in the popular mind that confidence in the application of physical laws which supports the man of science in his inferences, to say, with reference to the entire deportment of the contagia, regarded merely as solids, in gases (air) as well as in liquids (water), that this deportment has been proved to attend sub-divisions of matter far beyond the lower limit of their bulk.

The relation of infected liquids to the process of infection is of superlative importance. Contagia are passive. A fly alighting on a foul liquid may rise therefrom and transport microbes to a congenial soil, but the microbes are not auto-motors. They only move when they are moved. Can they be moved by evaporation? The daily operations of the chemical laboratory answer—No. The chemist evaporates down his solutions of non-volatile salts and never loses even a molecule. Distilled water contains no particles. It has been proved by experiments, oft repeated by different hands, that microbes cannot leave a liquid surface by evaporation; not even when foul-smelling gases arise with the watery vapour. I am content to rest upon the ordinary experience of the chemist. He conducts his evaporation at a temperature much higher than that at which, in nature, infected liquids are evaporated especially within inclosed inhabited spaces and from our own bodies. If ever by such means solids could be lifted from a liquid surface he would have discovered it. Although in a calm day the sea does not give to the air a single molecule of salt, we know that in storms the wind becomes charged with spray, and a white deposit is visible on windward-facing windows far inland. This observation points to the only circumstances under which a liquid can give up solids to the air. When gas is being formed in volumes, as in the case of rapid decomposition beneath the surface, then the resulting bubbles rise, burst, and may scatter particles into the air. These may be caught up before they can fall back into the liquid and be borne along by atmospheric currents. This may take place in a quite limited collection of fluid. If we have any wide area of infected water, as in a river or pond, sufficiently extensive to admit of agitation into waves before a gale, we may then have an infectious spin-drift borne along from the surface. A foul river falling over a weir or running down a rapid may toss up an infectious spray. These, however, are but the rare incidents which might liberate microbes from liquid. Barring such incidents, microbes submerged are imprisoned. Evaporation is equally powerless to raise solids into the air when it takes place from moist substances or surfaces. Solids and liquids are mingled to all degrees of consistency, but whether the water predominates, or whether the mass is pultaceous or stable in form, the watery vapour can be driven off by the application of heat, and the matter, in so far as it is not volatile, can be desiccated, and still not a particle or even a molecule takes wing. The chemist trusts to this in his analytic work every day. Moist substances or surfaces may be loaded with microbes, but mere evaporation will not raise them into the air.

[1] *The Floating Matter of the Air*, p. 97.

Yet, as everybody knows, the air swarms with microbes in the strata nearest the sea level, in populous places, and they are most numerous in overcrowded rooms. Among these, and in the dust of those localities, we recognise individual microbes which must have somehow got free from liquids or moist substances. The bacillus of tubercle is a typical example. It abounds in the environment of the consumptive, in the air and in the dust. It is not in the breath, it is not in the dusty exuviæ of the skin. It abounds in the sputum, but the sputum is not merely a moist but a very viscid substance, and until it dries and is broken up into dust can yield nothing but watery vapour to the air. If we wish to dry any substance we spread it out. We ted our hay. This viscid sputum smeared upon the folds of handkerchiefs soon dries. When dried it is mechanically broken up by every rearrangement of the folds, and the restless air bears away the infective particles, which pursue their amphibious existence—now afloat, attenuated and invisible; now stranded, aggregated and visible dust. *Mutatis mutandis;* this is the intermediate stage through which all microbes contained in liquids, or moist substances, or on moist surfaces, must pass before they can infect the air. In consumption it is the viscid sputum which must be evaporated to dryness and reduced to dust. In other diseases, according to their nature, it is the sputum, the evacuations from the bowels, from the "rice-water" of cholera through all the degrees of consistency, the urine, the ejected contents of the stomach, the tears, the perspiration, the viscid sputum from the lungs, the watery sputum from the mouth, the perverted secretions of other mucous surfaces. If you consider the physical properties of these infected substances you cannot fail to remark how varied they are, and how those varieties facilitate or obstruct the mechanics of aerial infection. The general law of these differences is very simple. Take the least complicated case in which minute solids may be involved in a liquid—viz., in distilled water. Imagine a film of this spread over a horizontal impervious surface and exposed to the sun. When the water has evaporated, each minute solid will be left lying upon a surface over which it is free to move with the impulse of the slightest air current, or from which it may roll when the surface is made vertical. Contagia are in these circumstances at once yielded to the air as dust. If our minute solids are involved in solutions of crystalloids, evaporation leaves them fixed in a layer of solid matter which keeps them stable but which is brittle and readily crumbles into dust. If again, they are involved in solutions of colloids, they part with their water less readily, and they remain included within a cohesive mass which must be tedded out before it will dry, and which, even when dried, becomes dust only under severe mechanical treatment. It is unnecessary for me to occupy your time applying these hypothetical cases to the constitution of the various secretions and excretions of the body. They all are more or less of the nature of colloids—those originating in mucous membranes more, and those in the skin and kidneys and lachrymal glands less. The cutaneous exuviæ begin as dust, and the cutaneous secretions being spread over an extensive evaporating surface, pass necessarily and at once into dust.

The case of the breath as a medium for the conveyance of infection is so special and so important as to demand separate consideration. It is the popular medium. It is to the breath we all turn with a natural and reasonable suspicion the moment we discover that the air surrounding an infectious person is infected. Yet if we scrutinise the circumstances in the light of the laws just expounded, we shall discover that we are entirely mistaken, and that the conditions under which the contagia pass to the air directly from the mouth are rare and accidental in their occurrence. There have been many experimental demonstrations that in the natural breath of health there are no solid bodies. The very latest is contained in a report on "The Composition of Expired Air and its Effects upon Animal Life," by Drs. Billings, Weir-Mitchell, and Bergey.[1] Their conclusion on this point is the following: "In ordinary quiet respiration, no bacteria, epithelial scales, or particles of dead tissue are contained in the expired air. In the act of coughing or sneezing such organisms or particles may probably be thrown out." The fact is that the mouth and air passages are a perfect illustration of my general statement that moist surfaces do not give off solids either by evaporation or under the influence of air currents. Here we have a complicated air-surface, which in health is kept perpetually moist, which is covered with microbes either borne in with the air and left sticking there, or as in the cavity of the mouth, finding there an appropriate habitat and breeding place. Yet when means are taken to free the inhaled air of all solids, the exhaled air is found to

[1] Smithsonian Institution, Washington, 1895.

contain none. Such is the condition of matters in health; and unless disease alters the physical circumstances, the breath must continue to be germ-free. Apart from the mechanical expulsion of particles by such acts as sneezing and coughing, what we have to contemplate is such a change of those physical conditions as will tend to the production of dust in the mouth. The febrile state parches the mouth and tongue, festoons the palate with strings and films of agglutinated mucus, covers the teeth with sordes; but even so we have to deal with colloidal matter, and I believe it must rarely, if ever, happen that the out-going breath will carry with it more than the gases of putrefaction. Very different, however, is the result when a handkerchief is used to cleanse the patient's teeth and tongue, or when the patient coughs or splutters over his bed-clothes, or if, as I have often seen in the malignant Typhus of olden times and in the Small-pox of to-day, impelled by a sense of suffocation he pulls the shreds of mucus from his throat and smears them upon any convenient material, or casts them upon the floor. These incidents bring us into line with the observations regarding consumption, and add to the great body of evidence in favour of the broad proposition that when air is infective it has been made so by the formation of dust; not directly through the medium of the breath. I need hardly say that the aerial infection which surrounds Typhus and Small-pox originates principally in the skin.

Your time will not permit me to follow those simple and elementary physical laws in detail into all the ramifications of their application. If firmly grasped they will be found not to be mere pious opinions, but clear lights to our path in many circumstances of difficulty and danger. Whenever there is reason to believe that a disease is infectious through the air, look to the conditions under which the specific discharges from the patient may be evaporated and desiccated, not to the breath. If you turn to Dr. T. W. Thompson's contribution to Stevenson and Murphy's encyclopædic work on Hygiene, "The Natural History of Infectious Diseases," you will find this regarding Measles: "The poison of Measles is held to be given off by the breath and mucus, possibly also by desquamating cuticle, though this is less certain. The recipient is no doubt, as a rule, infected through the respiratory tract." (Vol. II., p. 262.) In a previous sentence Dr. Thompson states that the poison of Measles is probably a micro-organism, although it has not been detected. I believe it is most probably a non-spore-bearing microbe. The breath cannot be infectious, unless momentarily after the explosion of a sneeze or under the impulse of a cough. As for mucus "giving off" the poison, it is impossible. But the secretions from the mucous membranes of the air passages, especially from the nose, and from the lachrymal glands, are so copious, so watery, and so smeared and distributed over bed and body clothing and handkerchiefs, that between the production of dust and the conveyance of the material itself by crude contact in the indiscriminate intercourse of childhood, I have no difficulty in accounting for the energetic infectivity of Measles in the catarrhal stage. So with Mumps—Dr. Thompson tells us: "The infection is believed to be given off by the breath" (p. 293). Although in Mumps the secretions of the mouth are vitiated it still presents surfaces to the breath as moist as in health and just as incapable of "giving off" anything of the nature of a solid to the out-going air. You will find in this article numerous references to the breath as "giving off" infectious matter, and in the light of the physical laws which we have been discussing you will be able to satisfy yourself that it can only do so on rare and easily recognisable occasions, and that if the air is habitually infective it is made so by desiccated liquid discharges or cutaneous exfoliations.

These laws have a very direct bearing on our interpretation of sundry phenomena of infection, and consequently upon preventive precautions. If you find evidence that a disease, say Scarlet Fever, or Diphtheria, has taken up its residence—so to speak—in a room after the patient has left it, look for your enemy under the disguise of dust. If you hear of washerwomen being infected, ascribe it to the dust of the soiled clothes, given off in their sorting and distribution previous to being washed, not to microbes being borne up in their faces with the steam of the washing-tub. Indeed, take it as a universal rule, the remembrance of which may confer great peace of mind where vague ideas of infection would tend to hysterical excitement, that microbes under water, or involved in a thoroughly damp substance, are scotched if not killed. We can look at the liquid with equanimity. It may stink, and if we are foolish enough to keep it beside us, it may depreciate our health; but unless we soil our hands with it, and so convey it to our mouths, or pour it out within the drainage area of our wells and drink it, or dip a sheet in it, and dry the sheet and scatter the dust within our breathing area, it cannot infect us. So with the damp substance. It will sooner reach the condition of dust than the liquid; but, until, then, it is innocuous. The inference is a very obvious one, that if the contagia are so effectually drowned and put beyond the possibility of doing harm when either damped or immersed in a mass of liquid, then we have in this expedient the readiest way of making them temporarily innocuous. If mud is harmless so long as we prevent it from becoming dust, then, if, whenever

we encounter dust we make the dust again into mud, we shall make it again harmless. This is the principle upon which the Bradford manufacturers deal with that most virulent and typical dust disease, Anthrax. Before being disturbed, the bale of foul hair is carefully immersed in water; it is allowed to soak, and the bale is loosened out so that the water may gain access to the very heart. The workers are not allowed to touch the hair until the bacillar dust is wet, and they are required to tease and sort it out while it is damp. In this way the dust is turned into mud, and this dangerous process is conducted in safety. In like manner if, instead of pitching infected clothing and changes of bed linen into the dirty clothes basket, where moist stains soon become dry; if, instead of tossing infected articles about on every occasion of handling them, we disturbed them as little as possible, and quietly and promptly plunged them into a tub of water, we might take our leisure about future processes. The infection is harmless not merely so long as the articles are beneath the water, but after they are wrung out of it, so long as they are damp. As to the infective flotsam and jetsam of the air, the dust of apartments which have been inhabited by the infectious sick, I remind you of the principle adopted in the construction of hospital wards and operating theatres—viz., to have as few horizontal surfaces as possible; to have them as smooth and hard as possible, and to make the whole interior of such material that every part of it can be thoroughly hosed down at will. This is again the process of making dust into mud, and if we spray the water through the air we merely imitate one of nature's processes for atmospheric disinfection—the rain. Dust and air infection are reciprocals. The air of a room may be disinfected by simple subsidence. It has been suggested as a part of the process of disinfection of apartments to shut up all doors and windows and keep the air quiet for twenty-four hours.[1] Yet *the room* is not thus disinfected. You must quietly capture and drown the dust. If you throw open doors and windows, toss about bedding, move furniture, bustle over the place with whisks and dusters, you merely chase the dust about and re-infect the air. I speak of dust in closed, inhabited spaces. In the open air that part of the dust which is living and dangerous need give us no further anxiety. Sunlight and rain will soon destroy it or drown it.

I think this is the first time I have used the word "disinfection" in this address, and you will observe I applied it to a process which does not kill the microbes, but simply lands them where they will do no further harm—in the gutter. On the

[1] Du Role et de l'Importance de la Sedimentation des Germes atmospheriques," par le Dr. J. Mareuge. *Revue d'Hygiène*, April, 1896, p. 369.

same principle I did not say that you should soak infected clothes in a 5 per cent. solution of carbolic acid, or that you should spray your walls with a solution of 1 in 1000 of bichloride of mercury. I merely advised you to plunge the clothes in a tub of water, and to hose the walls with water. It seems to me that in dealing with infected liquids and with substances which are moist or can be moistened, we simply waste time in attempts to disinfect which are not only unnecessary but will, in all probability, prove futile. This is eminently true as regards everything of which the final and fit destination is the sewer. Nothing interested or delighted me more in all my reading regarding tuberculosis than the following passage in the report of the experts consulted by the Prussian Government :—" The spittoon is to contain as much water as will not readily spill. The question which is frequently raised (as in the debate at Munich), whether the contents ought to be disinfected before being emptied out, we may answer in the negative. Chemical agents touch the masses of sputum only from the outside, merely coagulate the albumen and penetrate no further. Boiling would be certain, but difficult to carry out. Therefore there is nothing to be done but empty it down the drains or into the water closet, where the sputum remains moist, and, therefore, harmless." In questions of chemical disinfection, Tyndall's account of Schultze's experiment with air drawn through sulphuric acid in order to free it of germs and also kill them, always comes to mind. Tyndall shows that unless the air is passed very slowly through the acid many germs inside the air-bubbles never come in contact with the acid ; and if the air is so passed, he remarks :—" Water will be found quite as effectual as sulphuric acid. . . . The germs were not killed by the water, but they were effectually intercepted " (*Ibid.*, p. 281). The success of all laboratory experiments on the chemical destruction of microbes evidently depends upon so many conditions that failure in practice either on the large scale of public use or in the unskilled hands of private persons is certain. At least, success is uncertain, and confidence without justification may lead to disaster. Therefore, I say if discharges are fluid or moist to begin with get them by the shortest route into the sewer. Dust as dust is invulnerable. If you have to deal with dust turn it into mud and send it also to the sewers. I have no fear that any sort of disease-producing microbe after it once reaches the sewers will ever turn up alive again. Of course, if your sewers discharge into a potable river or your drains leak into local wells, you must take the consequences. All that can be said is that a few germs more or less will in that case make little difference in the results. Otherwise, for pathogenic microbes the sewer

is the broad road which leads to destruction. They speedily perish amid the antagonisms, rivalries, and incompatibilities of nature, which after all are more deadly than all the purposive efforts of man. Imperfect chemical disinfection not merely fails to kill the microbes but it interferes with the operation of the organisms of putrefaction.

I have now meandered along to the close of this somewhat desultory discourse. I wish to mention my obligations to two books : " The Lower Fungi in their Relations to Infectious Disease and Public Health," by C. v. Nägeli,[1] and Professor Tyndall's " Floating Matter in the Air." The former is an old book. It was published in 1877. It seems to be little known. So far as the American Index-Catalogue shows, it has never been translated. As to the details of bacteriology, it is now probably older than its years ; but as to its physics, it deals with immutable laws, the application of which to microbes is merely extended by the progress of bacteriology. I frequently see v. Nägeli's name quoted as an authority in this department of knowledge, but this book is never referred to by writers on practical sanitation. Yet it abounds in the most practical applications of natural philosophy to the modern doctrine of infection, the knowledge of which would correct much that is erroneous in our writing[2] and our practice. Tyndall's book is well known. The study of it will give the student of public health clearer and more scientific ideas of the first principles of the process of infection than any special handbook or treatise on public health known to me. It seems to me that we specialists sometimes grope about the problems which beset us as if we worked in a sphere cut off from the general operations of nature. This not only gives us much needless labour, but it tends to make us deport ourselves as the high priests of a sect in place of acolytes in the ministry of one great temple.

[1] "Die niederen Pilze in ihren Beziehungen zu den Infectionskrankheiten und der Gesundheitspflege, von C. v. Nägeli, Professor in München, 1877."

[2] Even in the last edition of Parkes' *Theory and Practice of Hygiene*, where they have survived the editorial scrutiny of Notter and Firth, as they did of Du Chaumont, we find such statements as these :

"Solid substances lifted into the air by winds, or by the ascensional force of evaporation, fall by their own weight" (p. 130).

"It would appear that the ascensional force of evaporation will lift even animals of some magnitude from the surface of marsh water" (p. 131).

"Besides the organic matter, various vegetable matters and animals, floating in the air, are arrested when the air of marshes is drawn through water or sulphuric acid, and debris, plants, *infusoria*, insects, and even it is said, small *crustacea*, are found ; the ascensional force given by the evaporation of water seems, indeed, to be sufficient to lift comparatively large insects into the air" (p. 137).

There is such a thing as the evaporation of molecules of water, but not of particles, still less of "comparatively large insects" ! There is nothing in the air of marshes which does not get there after evaporation has let it free on the stems of reeds, the leaves of plants, &c., &c., to be blown away as dust.

CHAPTER XII.

DEAD MEAT INSPECTION.

THE DETECTIVE SYSTEM V. THE CLEARING-HOUSE SYSTEM.[1]

THE question of the day is tuberculosis. It is uppermost in the minds of local authorities and their officials, of the farmer and his landlord, of the cattle dealer, the meat salesman and the butcher, of the medical man and the veterinary man. It is before Royal Commissions. It claims the attention of Parliament in clauses of public and private bills and in questions to the heads of Government departments. It is the subject of conference and discussion, deputation and petition. The press is full of it, especially those periodicals which represent the material interests directly or indirectly affected. Indeed, when I say that the question of the day is tuberculosis, I have not so much in my mind the quiet, ceaseless, ever-widening flow of observation and research regarding tuberculosis which began with Villemin in 1864, and has grown beyond estimation in volume and in practical value since Koch's discovery of the bacillus in 1882. In that aspect the question of the day in the bacteriological laboratory and in the pages of periodicals and the proceedings of societies which preserve microscopic and biological results is doubtless this minute but mischievous bacillus. What I wish to point out is the influence of the modern doctrine of tuberculosis upon agriculture and commerce, in the market place and in the butcher's shop, upon the landlord's rent roll and the food of the people. It is always the case. The patient toil of the laboratory is pursued in secret, and the precious items of its results are summed up and carried forward day after day to new pages without noise or excitement. It is the application of these results to the affairs of men which produce conferences and

[1] Address as President of the Sanitary Association of Scotland, at the Annual Congress held at Dumfries, September, 1896.

discussions and deputations, which furnish war cries to political parties, and complicate still more the tangled forecasts of expediency in the deliberations of statesmen.

There can be no doubt that the current agitation among those who breed and feed and sell animals destined for human food, who slaughter them and distribute them to the consumer, as to the where and the when and the how of meat inspection, is one of the manifestations of the interference of the modern doctrine of tuberculosis with the material interests of classes of men. I have not a word to say in deprecation of the agitation of the question of meat inspection with all its numerous side issues, but every party in the discussion speaks from his own point of view. He is more or less a special pleader. This is no disparagement to any body. It is human nature. The farmer wishes to pay his rent, the landlord wishes to get it; the meat salesman desires as big a commission on as large a turn-over as he can obtain; the butcher sees certain meat confiscated which he could sell. These are the common motives which actuate the most righteous and law-abiding of men; but inside every class there are with certainty to be found the few who are not righteous and not law-abiding. The rogues in all trades and callings may not unfairly be described as the parasites of the honest. Their mode of life is to rouse the suspicions and trade upon the good reputation of the majority. You never hear of them or see them at conferences or on deputations. They get the honest men to shout. They convince them that the proposed law or the suggested interference will kill the legitimate trade, whereas the fact is it will only render some nefarious practice of their own impossible. In this matter of meat inspection sanitary authorities speak from the point of view of the consumer. They have no private interest whatever to serve. I represent a sanitary authority which has the misfortune to have adopted a policy and advocated views both as to meat and milk inspection which are very distasteful to each and all of the private interests concerned. From my reading of the evidence given before Royal Commissions of leaders in agricultural journals and veterinary magazines, of reports of speeches made at conferences on clearing-houses, and deputations to Secretaries of State, I have come to think that Glasgow occupies, in the suspicions of some gentlemen, in a small way, much the same position as Lord Salisbury does in the dreams of the statesmen of Europe. They discover Glasgow everywhere mining and countermining, adding a deeper tinge of black to the cloud of agricultural depression, ruining the trade of the meat salesman, thwarting the speculations of the butcher, invading the professional perquisites of the veterinary surgeon. Gentlemen,