

oculation or by feeding. And the case which I have shown proves that the animal is highly susceptible to a natural infection.

This rarity of tuberculosis in the sheep contrasts strongly with the excessive prevalence of the same disease in certain classes of cattle, and is probably explainable by the habit of life of the sheep.

The incidence of tuberculosis amongst different classes of cattle appears to be principally determined by the conditions under which they live. The disease is most common in dairy cattle, which are crowded together in confined byres which have no adequate means of ventilation, the proportion of infected cattle in different herds kept under these conditions being anything between 20 and 90 per cent. Amongst Aberdeenshire cattle, for instance, which live almost entirely in the open air, tuberculosis is, on the other hand, extremely rare. And it is almost certainly to their open-air habit of life that sheep owe their freedom from tuberculosis.

DISINFECTION OF THE HANDS.¹

By CHARLES W. CATHCART, F.R.C.S., Surgeon to the Royal Infirmary, Edinburgh.

IT is a somewhat humiliating reflection, and yet a salutary one, that the enemies which the surgeon has most to dread in his endeavour to keep his wounds aseptic are just his own hands and those of his assistant.

Halstead² was among the first to throw doubt on the possibility of absolutely sterilising the hands. Lockwood³ afterwards showed that pieces cut from the skin which had been carefully prepared for operation by washing and soaking with strong antiseptics were capable of infecting gelatine culture tubes with numerous organisms. He pointed out also⁴ that the contents of sebaceous glands included all sorts of micro-organisms, and that the sweat as it came to the surface seemed to bring organisms along with it. In 1899 Freeman⁵ published the results obtained after disinfecting his hands by various methods. In each case he removed the antiseptics from his fingers before inoculating the nutrient gelatine. The finger to be tested was dipped into a bottle containing melted gelatine, and kept there for about ten minutes, being freely moved about and rubbed against the sides of the bottle all the time. The details of four important experiments recorded by him are as follows:—

Experiment I.—Hands scrubbed in warm soap and water, nails cleaned, hands re-scraped, washed and soaked in alcohol and then in bichloride, rinsed in boiled water, finger dipped in ammonium sulphide, and then brought into gelatine. About thirty cultures were obtained.

Experiment II.—The hand was then wrapped in sterilised towels and thoroughly perspired for some minutes in a Beck's hot-air oven. Another immersion of the same finger in gelatine furnished about

¹ Reprinted from "The Scottish Medical and Surgical Journal," April 1902.

² "John Hopkins' Hospital Reports," Vol. II.

⁴ *Ibid.*, 1892.

³ "British Medical Journal," 1896.

⁵ "Annals of Surgery," Vol. XXX.

sixty cultures, just double the original quantity, although, the same finger being used, the number should theoretically have been less.

Experiment III.—The member was then re-scraped and re-sterilised, and the finger again placed in gelatine. But fifteen cultures were obtained.

Experiment IV.—The sweating process was again gone through with, following which but two cultures appeared in the nutrient medium.

In this way he tested "several processes of sterilising the hands which were in common use—the chloride of lime method, the mustard method, and the permanganate of potassium and oxalic acid method. With the first two I obtained so many cultures that I could not count them. . . . With the permanganate of potassium method between fifty and seventy-five cultures grew; hence this process, according to my experience, stood next in efficiency to alcohol and bichloride of mercury."

Other experimenters have made cultures from the skin in many different ways, but it is unnecessary to say more at present with regard to them except this, that they all bear witness to the great difficulty of completely freeing the skin of the hands from micro-organisms. As might have been expected, the result of doubt having been cast upon the value of the former methods of cleansing the hands has caused numerous inquiries; and strenuous efforts to be made in order, if possible, to eliminate from the treatment of wounds the risk of contamination from the surgeon's hands. A formidable array of papers have appeared on the subject, especially in Germany, besides several treatises, some of which almost deserve the title of books. One of these, published at the end of last year, is by Shaeffer,¹ and is a very valuable contribution to the subject, as it gives evidence of accurate reasoning and careful experiment. From this, from Hægler's treatise,² and from papers, the chief of which will be mentioned in due course, the present review of the subject of hand disinfection has been drawn up.

In order to concentrate opinion upon some of the more important practical points, we may arrange our remarks under the head of definite questions.

1. *Is it possible to render the hands absolutely sterile?*—Although some have claimed that they have been able to do so, others, in testing their results, have shown that there has been a fallacy at some stage or other in the experiment, and we may take it that in the present state of our knowledge the answer to that question is "No." Of course it will be understood that the expression "absolutely sterile" is to be considered in a strictly scientific sense, while the method to be employed must be one which is available in daily practice. The reasons which enable us to understand why the difficulty is so great are, briefly, that organisms may lie so deeply in the crevices and cracks in the epithelium and in the interior of sweat and sebaceous glands that their complete dislodgment cannot be ensured, while the attempt to destroy them *in situ* by powerful antiseptics injures the epithelium just as much, if not more, than it injures the

¹ "Experimentelle und Kritische Beiträge zur Händedesinfektionsfrage," von Dr Richard Shaeffer (Frauenarzt in Berlin). Berlin, 1902. S. Karger.

² "Händereinigung—Händedesinfektion und Händeschutz," von Dr Carl S. Hægler (Basel). Basel, 1900. Benno Schwabe.

organisms themselves. Hægler has devised a simple method of demonstrating the difficulty of removing fine particles from the surface of the hands. The hands are rubbed over with lampblack or Indian ink suspended in water. After the ink has dried in for ten or fifteen minutes, the hands are washed and scrubbed. The removal, however, of all the marks visible to the naked eye will be found surprisingly and instructively difficult, while a simple lens and then the microscope will reveal fine particles in the deeper cracks and crevices of the epithelium where the cleansing process had apparently been complete. The experiment is as important as it is simple. It impresses us with the difficulty, if not impossibility, of removing all the fine particles lodged in the crevices of the epithelium by the method of hand-washing available before an operation, although they may be retained so firmly in their places that they do not become free during the operation, or only to a very limited extent; while it brings home to us the immense importance of avoiding contamination of our fingers by pathogenic organisms.

In spite of the discouraging answer to the first question, we must pass to consider—

2. *Is it possible to render the hands so free from organisms during an operation that the danger of wound contamination is exceedingly small?*—From numerous records of clinical experience, as well as from Shaeffer's experiments, the answer to this question is, "*Yes, if the necessary precautions are taken.*" Besides Lister's and Watson Cheyne's well-known admirable results with soap and water and 1 to 20 carbolic acid, Kelly's permanganate of potash method has been found most satisfactory, although Freeman showed it to be distinctly faulty by his experiments. By the chloride of lime method which Freeman found to be much inferior to Kelly's, Stimson¹ reported that he had had no suppuration for two years. Bull and Coley² in hernia operations report 95 per cent. of primary union using green soap, hot water, alcohol, and perchloride of mercury. Lockwood's percentage in non-strangulated hernia³ was 96 per cent. of primary union in his last series of fifty cases, and he considers the "operation of radical cure to be one of the severest tests of aseptic surgery." Hahn⁴ states that he has had no wound infection of any kind in 136 consecutive operation cases by the method which he describes of soap and water scrubbing, followed by 1-1000 of sublimate alcohol, and then by 1-2 per 1000 of sublimate in water. Lastly, Kocher⁵ in 1899 reported that out of 255 operations he had had only one case of suppuration due to wound infection at the operation. His method of hand-cleansing was practically that of Ahlfeld, and, although gloves were used, he states that he had had equally good results before they had been introduced.

As to the relative merits of various methods, Shaeffer decides in favour of Ahlfeld's hot-water-alcohol method as the one which, when efficiently carried out, gives us the greatest confidence in answering this second question in the affirmative. Mikulicz's spirit-soap method

¹ Discussion following paper by Weir, "New York Medical Record," Vol. I., 1897, p. 469.

² "Annals of Surgery," Vol. XXVIII.

³ "Aseptic Surgery," by Charles B. Lockwood, 2nd edition, p. 242. Young J. Pentland, 1899. Edinburgh and London.

⁴ "Centralbl. f. Chir.," 1900, p. 993.

⁵ "Transactions of the American Surgical Association," 1899.

ranks, in his opinion, next to it, and most of the others a long way behind.

The chief virtue of alcohol is shown by Shaeffer to consist in its power of removing organisms clinging to the surface of the skin. He tested this both with the "day's hand" and with hands artificially infected with a non-pathogenic yellow air-germ of about the same resistance as the staphylococcus. After scrubbing with soap and water with much greater vigour than would have been done at an operation, he found that he could always obtain a large number of colonies in plate cultures from the fingers. He then scrubbed his hands twice or thrice in 96 per cent. of spirits (brushes and spirit changed each time), and found that the number of colonies was very greatly reduced or that they were absent. The spirit which had been used for scrubbing the hands was filtered, and numerous colonies were obtained from the filter paper. This experiment showed that the spirit had loosened and removed great numbers of germs which the simple mechanical scrubbing process had left behind, although it had not killed them. The antiseptic property of alcohol he does not, however, consider to be of much importance. Another property to which some have attributed the value of spirit to the surgeon is that of shrinking the surface and holding down the organisms which it does not get rid of. Although it may be difficult to explain why any one agent should, at the same time, loosen epithelium and cause it to contract, Shaeffer's experiments, which we have not space to detail, seem to prove that spirit actually fulfils this double function. Possibly it may act on the cement material in one way and on the cells themselves in another.

Upon the action of spirit in setting free the organisms from the skin depend several of the details of the *hot-water-alcohol method*, as *Shaeffer recommends it*.

For an important operation the hands are to be washed in (not over) a strong solution of green soap in water as hot as can be borne. All the scrubbing is to be done *in* the water, in order that both hands may benefit by the soaking, which encourages perspiration and loosens epithelium. The water should be changed several times, and fine sand, powdered pumice stone, or marble dust may with advantage be used, as well as a nail brush, which is imperative. This stage of the process should last ten minutes. The nails having been well cleaned all round with a nail cleaner, the hands may be firmly rubbed with a dry sterile towel, although this latter detail is not insisted upon. The hands are then to be scrubbed again *in* two separate quantities of spirit with a fresh nail brush. This spirit scrubbing should take three and preferably five minutes. Finally, the hands are to be bathed for a short time in a reliably sterile fluid in order to wash away any remaining organisms which have been loosened although not removed. For this purpose 1-1000 corrosive sublimate solution is recommended, although not for its antiseptic effects so much as for its being a reliably sterile fluid.

Mikulicz's Spirit-soap Method.¹—The agent is the spirit-soap of the German Pharmacopœia, 3rd ed., p. 291. On analysis it contains 10·2 per cent. of potash soap, 0·8 per cent. of free oil, 1·0 per cent. of glycerine, 43 per cent. of alcohol, and 45 per cent. of water. It is, in

¹ "Deutsche Med. Wochenschr.," 1899, No. 24.

fact, an over-fatted potash soap dissolved in nearly equal parts of spirit and water. The visible dirt is first rubbed off with gauze soaked in the spirit-soap; next the nails are cleaned with a Braatz nail cleaner, and the hands are then scrubbed for five minutes with the spirit-soap and a nail brush. A thin film of the soap is left on the hands, which makes them slippery as soon as they become moist. This disadvantage is diminished by bathing them in sublimate lotion and rubbing them with dry gauze, and is removed by wearing thread gloves. Mikulicz claims for this method that it saves time, that it does not irritate the skin, and that, besides being cheaper than the hot-water-alcohol method, it produces a more loosening disinfectant effect upon the hands. The last of these assertions as to disinfection is, of course, the most important, and it has been carefully tested by Shaeffer. Using hands artificially infected with the yellow air-germ, and giving the spirit-soap method the benefit of about double the amount of scrubbing that Mikulicz prescribes, Shaeffer found that he was able to obtain from six to eight times as many colonies after the spirit-soap method as he could after using the hot-water-alcohol method, the conditions being otherwise the same. The latter method he therefore considers to be distinctly the better of the two.

Of the other methods tested by Shaeffer we may mention the following:—

(1) *Sublimate Disinfection, i.e.*, thrice changed hot water, soap and fine sand, afterwards from five to ten minutes in 1-1000 sublimate solution; results much inferior to those obtained with the spirit-soap, although the sublimate was purposely not neutralised before the inoculations were made from the hands.

(2) *Schleich's Ground Marble and Soap Method, i.e.*, purely mechanical.—Tested in the same way, and also with more than the prescribed amount of scrubbing, this method yielded an enormous number of colonies. This only confirmed the previous criticisms of this method by Paul and Sarwey, Krönig and Blumberg, and Schenk and Zaufal. Shaeffer explains the unduly favourable view which Schleich took of this method by showing that his laboratory experiments were not nearly severe enough in their tests, and that the good clinical results reported after its use were due to Schleich's plan of operating with a dry, polished hand, a plan which becomes highly dangerous as soon as the hand gets moistened in the wound.

(3) *Disinfection with Mercurial Æthylendiamin Solution, 4 per Cent.*—This, although more expensive than 1-1000 solution of corrosive sublimate, Shaeffer does not find any to be more efficient.

(4) *The Lysol Method.*—Shaeffer used a nail brush and a hot 1 $\frac{3}{4}$ per cent. solution of lysol, thrice changed, for fifteen minutes, then bathed his hands for four minutes with sterilised water, which only partially removes the carbolic in the lysol. Although the effect upon the hands was more severe than could be borne in actual practice, the result was no better than that obtained by disinfection with corrosive sublimate.

Lysoform and chinisol, which were also tested, were not found to be as good as corrosive sublimate.

We have confidence in accepting Shaeffer's conclusions not only from the apparent intrinsic merits of his work, but also because so many others have realised the value of alcohol as an agent for cleans-

ing the hands, although they do not all seem to have grasped its real mode of action, and therefore have not employed it in the most effective way. Apart from the relative merits of Ahlfeld's and Mikulicz's methods in removing organisms from the hands, there are one or two other points which are worth considering. Mikulicz claims that spirit-soap is cheaper than alcohol, and gives 38 pf. per kilogram (litre) as the price of spirit-soap, and 45 pf. per kilogram as that of spirit. Without entering into the question as it affects Continental surgeons, we find that this advantage in price does not apparently hold good for spirit-soap in Great Britain. On inquiry at the headquarters of one of our leading Edinburgh chemists, the writer was told that spirit-soap made in this country according to the German Pharmacopœia would be much dearer than methylated spirit; and that even if cheaper materials were used than those laid down in the German Pharmacopœia, the advantage as to price would still be on the side of the spirit. The wholesale price of methylated spirit at present is 2s. 9d. per gallon (imperial). Bought in small quantities from a chemist it would cost a medical man about 6d. per imperial pint. For an important operation probably a quart would be required for each pair of hands, while for a minor operation a pint would suffice.¹ The smell of the 10 per cent. of wood naphtha used to "denature" methylated spirit is comparatively slight, and soon passes off the hands, while it probably increases the cleansing effect of the spirit. Even the odour of the $\frac{1}{200}$ part of paraffin oil added to the ordinary commercial methylated spirit may be neglected when the other is not available. Shaeffer in his experiments used a cheap denatured spirit of 96 per cent. Our methylated spirit is issued at 91 per cent. (64 o.p.) and 88 $\frac{1}{4}$ per cent. (61 o.p.), but this difference seems to be immaterial.

As to the other points of difference between the two methods, the slipperiness of the hands left by the spirit-soap is a distinct disadvantage in operating, unless gloves are worn, which is not the question at present. If the slipperiness were removed by further washing and dry rubbing, probably the value of the spirit-soap method would be diminished, as many believe that the layer of soap left upon the hands is of service in keeping organisms embedded in the epithelium from escaping into the wound. The gain of ten or twelve minutes at the beginning of an operation, and without heating the hands, would therefore not help the spirit-soap method much in its competition with the hot-water-alcohol method. Lastly, methylated spirit can be obtained anywhere, while spirit-soap would have to be specially made up.

Before passing to the vexed question of gloves, there are one or two points as to the appliances used in washing the hands which require a brief notice.

Should Running Water only or Hand Basins be used?—Many consider that the water ought to be constantly running in order to carry away the organisms set free from the skin. Shaeffer, while admitting this advantage, prefers a hand basin with the water several times changed. In this way we obtain the benefit of a strong solution of

¹ In hospitals with large laboratories the cost both of spirit and of spirit-soap would be greatly reduced if Government permission were obtained to re-distil the spirit. After being used for the hands, the spirit is available for burning purposes.

soap, which is impossible with running water, and still more of a thorough soaking when the plan of washing all the time *in* and *not over* the basin is carried out. It is needless to say which method is most convenient in general practice. Doubtful hand basins, if scrubbed out with black soap and scalded with boiling water, will probably be rendered safe for all practical purposes, although some think that they should be sterilised by steam.

Nail brushes should always be sterilised, and separate ones used for the water and for the spirit scrubblings. Boiling for eight minutes in water is considered sufficient, or they may be sterilised with the dressings by steam, which does not soften them so much as boiling does, or kept constantly soaking in 1-1000 corrosive sublimate or 5 per cent. carbolic acid. Good serviceable nail brushes can be bought for 3d. or 4d. each. The fine sand or pumice stone used can easily be boiled, and then kept dry or soaking in an antiseptic fluid.

Should Gloves be used during Aseptic Operations?—A great deal has been written about them, and we shall try briefly to indicate what seems to be their value. Three different kinds have been recommended: rubber gloves by Halstead, thread gloves by Mikulicz, and leather gloves by Wölfer. Rubber gloves are a perfect protection so long as they remain intact, but when made so thin as not to hinder greatly the sense of touch, they are very apt to be torn in pushing in needles, etc. Since they encourage sweating, the fluid which accumulates within them towards the end of a long operation will be charged with any organisms that the hand may have retained, and this fluid escaping through some small puncture would be highly dangerous. They are, moreover, much more expensive than either leather or thread gloves, and not so durable, nor so easy to work with. Thread gloves seem certainly to act by delaying the passage into the wound of any organisms which the hand may contain. When they become damp with blood and perspiration, however, the fluid which can be squeezed out of them carries such organisms with it, and constitutes a danger. Such gloves, therefore, require to be changed several times in the course of a long operation. For such work as of lifting up slippery viscera, in abdominal operations, or for grasping the larger class of instruments, thread gloves are considered to be of advantage, but for fine dissection and where delicate touch is wanted they are a decided disadvantage if not an absolute hindrance. Kocher considers that the chief value of thread gloves is in tying ligatures to prevent the silk (which he uses) from picking out organisms from the deeper layers of the skin, as the knot being tightened. Much the same may be said of leather gloves; only that they are better filters, and require to be sterilised by soaking in antiseptics, instead of by heat, which shrivels them up. Shaeffer considers that the advantage of gloves during an operation are counterbalanced by their disadvantages in prolonging the operation, in increasing the risks of some slip in the manual work, and in exposing the tissue to greater risk of bruising, in addition to the special risks of rubber gloves already referred to.

Frequent rinsing of the hands during the course of the operation would probably serve the same purpose as changing thread gloves, and takes up less time; while one finger in each hand might be protected by a firm rubber finger-stall, and made to bear the chief strain in drawing the ligatures tight.

In all that has been said about disinfection of the hands, it has been assumed that the hands were in a healthy state. It is necessary, therefore, at this stage of the discussion, to refer to the possibility of sores on the fingers. All authorities who allude to this subject are emphatic that *no method of disinfection can pretend to protect a wound against an inflamed or suppurating hand*. Lockwood¹ says: "It would be most reprehensible to operate with a suppurating sore upon the hands. I have recently seen a terrible disaster follow the breach of this rule." The organisms are scattered broadcast throughout the wound during the course of the operation, with the inevitable result of extensive infection at the most dangerous time—*i.e.*, when the surfaces are raw. Slight cuts or grazes, if not inflamed, do not seem actually to contra-indicate a surgeon's operating, but they must be well covered up with collodion, or preferably celloidin. This must be applied after the hands have been prepared, for spirit will dissolve and loosen either substance—or a *firm* finger-stall should be used; the thin stalls are so apt to give way that they constitute a danger. From the evidence furnished by experiments the probability is that most surgeons have hitherto under-estimated the danger of slight scratches on the hands, and especially on the fingers. Blumberg² was often able to obtain numerous colonies from the slightest scratches when no development could be obtained from other parts of the hands or fingers. Shaeffer, again, made it a rule never to experiment upon hands on which there was the slightest visible injury or chap (*die kleinste sichtbare Verletzung oder Schrunde*).

This leads us to a most important precaution—*i.e.*, the preservation of the surface of the hands. Lockwood, Hægler, and others have drawn attention to the ease with which a smooth hand may be cleansed as compared with a rough one, and everyday experience confirms their conclusions. Hence the use of very powerful antiseptics, such as Lockwood's 1-500 of biniodide in spirit, Lister's 1-500 of corrosive sublimate in 5 per cent. carbolic acid, or even 5 per cent. carbolic acid, do more harm than good by roughening the hands and leading them to crack, except for the favoured few whose hands can stand them. Even the hot-water-alcohol method, which is so relatively unirritating, damages the hands by removing the natural fat of the skin. It is therefore necessary to compensate for this by rubbing into the hands some simple preparation of lanolin or oil at bed-time, and, if possible, also at the end of every operation. Hægler emphasises the need for thus caring for the hands, and considers that it should be as regular a part of the surgeon's daily routine as the winding up of his watch. In order to facilitate the cleansing of the finger-tips, *the nails should be kept as short as possible*.

But this is not all. From what has been said as to the impossibility of rendering the hands absolutely sterile, and of the trouble required to prevent them from conveying mischief during an operation, two precautions naturally suggest themselves. (1) That of keeping the hands as free from pathogenic organisms as possible throughout the day, or "hand prophylaxis." Many ways of assisting to fulfil this object have been suggested, such as using forceps instead of fingers in removing dressings from suppurating wounds; wearing

¹ "Deutsche Med. Wochenschr.," 1899, No. 24, p. 179.

² "Centralbl. f. Chir.," 1900, Surgl. Congress Report, p. 20.

thread gloves at ward visit; and protecting the hands with rubber gloves when opening abscesses, and such like (where fine work is seldom required); and washing off pus before it dries in, if it should touch the hands. Moreover, it is of great importance to wash the hands very thoroughly at the end of even an aseptic operation, so as to leave no culture material upon them for the benefit of any chance organisms which they might pick up during the day. (2) That of rinsing the hands frequently during the course of an operation, and touching the wound with them as little as possible, using instruments instead.

It will be seen from the preceding brief discussion of the subject that disinfection of the hands, as now understood, means trying to remove organisms *from*, rather than hoping to kill organisms *in*, the hands, and that improved methods running on this line still justify our operating with bare hands. At the same time it will have been evident that care and trouble at the operation is only one part, although a very important one, of the total number of precautions required to ensure success.

THE INTERCOMMUNICABILITY OF HUMAN AND BOVINE TUBERCULOSIS.¹

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THE past decade has seen the awakening of a widespread interest in the study of tuberculosis, the spirit of Oriental fatalism which has for so long led us to view with equanimity the awful loss of life annually inflicted by this great white plague having given way to an active campaign against its ravages, a campaign so largely one of education, in which we strive to spread far and wide the fundamental facts that tuberculosis is a communicable disease, and, from that fact, preventable. If preventable, why not prevented? With these precepts firmly implanted in the minds of the medical profession, as well as of the general public, we have reason to hope that each year will see a more careful study of the methods by which tuberculosis is spread and the means to be adopted for its prevention. On every hand societies for the prevention of tuberculosis are being formed, whose object is to teach the truth concerning the disease and to dispel those false notions, chief among which may be mentioned belief in the hereditary character of tuberculosis, which in the past have led us to regard the tribute of human life as inevitable.

The intelligent prophylaxis against any disease demands a thorough understanding of the methods by which it is spread. The whole world is in accord in assigning the chief rôle in the propagation of tuberculosis to the inhalation of particles of sputum thrown off by phthical persons, the majority of the profession agreeing with Cornet in the belief that sputum is most dangerous when dried and pulverised, while others follow Flüge in regarding the moist floating particles

¹ An Address delivered at the Annual Conversational Meeting of the Pathological Society of Philadelphia on Thursday evening, 24th April 1902. Reprinted from the "University of Pennsylvania Medical Bulletin," May 1902.