The discharge, taken two days later (on April 3rd), had a putrid odour, and contained numerous large and small bacteria.

On the following day (April 4th) it presented the same appearance. Sixteen days after this second operation (on April 17th) there were still numerous bacteria present

Case 6.—Take again a case of Syme's amputation performed on March 9th, 1880, for disease of the ankle-joint. Several sinuses were included in the flaps. Free drainage was employed, and salicylic or boracic ointments and boracic lint. This case went on very well; *i.e.* there was at first a little odour, but this was very slight and soon almost entirely disappeared. The discharge got less, and the wound came to look somewhat like an aseptic wound.

Fig. 7 (March 15th, from drainage tube) shows chiefly streptococci in pairs; no typical micrococci, nor the colony form of micrococci; small bacteria; a few long rods.

On March 17th the discharge taken from the drainage tube contained chiefly oval bacteria; also streptococci (*i.e.* spherical bodies in chains); no typical micrococci; a few long bacteria.

On April 12th the organisms were much less numerous, there being only a few streptococci and bacteria.

April 14th, very few organisms—streptococci.

April 16th, rather more organisms than in the last—only streptococci. There had been a little retention of the discharge.

May 14th, a considerable number of streptococci; also a few oval bacteria: drainage not quite perfect.

Here we see that organisms were present, but so long as the discharge flowed freely away, they did not develop. When tension occurred they grew. The wound did very well, and forms of micrococci were the chief organisms present.

So much for examples of cases not treated aseptically. In all cases organisms were present, and these were almost always *bacteria*. The more putrid the discharge, the more numerous and the smaller were the bacteria (Bacterium termo?). The better the progress of the wound, and the better the drainage, the fewer the organisms; but nevertheless there was always some form of organism present, and had I inoculated infusions from them, I should certainly, according to my former extensive experience, have got bacteria, as well as micrococci, to develop in all cases. The significance of the diminution in number of the bacteria in the last case is a point which I shall not discuss here. I will merely state that in some wounds following a

very satisfactory course *micrococci* only can be found by this method of examination.[1]

Let us now look at cases treated aseptically. I shall only mention a few instances, but I may state that I have examined, in almost all cases, specimens of discharge taken at every dressing with the same results as are illustrated here.

In the first place, I will give two cases which show that all forms of organisms may be permanently excluded by strict aseptic treatment.

Case 7.—Take first the most testing case of all—one of empyema. Here at each change of the dressings air is sucked in with every inspiration, but when the dressing is done with aseptic precautions, this air has been acted on by carbolic acid. We shall therefore see whether the spray is efficient in destroying organisms.

The case of empyema to which I refer was one of considerable standing, and was opened aseptically on March 7, 1880. The cavity of pleura was not washed out, and during the whole of the treatment no carbolic acid or other antiseptic was applied to the interior. Hence if organisms got in, they could develop just as freely as in a flask. There were no organisms in the pus when evacuated. The dressing was changed daily.

Fig. 8 is a specimen taken on March 15th, eight days after the thorax was opened. This contains no organisms of any kind, neither bacteria nor micrococci. Hence for eight days the spray had been efficient.

Fig. 9 was taken on April 13th, *i.e.* thirty-seven days after the incision. Specimens examined in the interval were free from organisms, and here it will be seen that there are no organisms of any kind. This result is the more convincing, as for some days there had been a difficulty to the exit of the fluid, and some discharge was pent up in the lower part of the thorax. This was let out on April 13, and the specimen was taken from this fluid. Now my invariable experience has been, that when such accumulation occurs, if organisms were present before, they will be found in large numbers in the retained fluid; in fact they develop just as freely as if the fluid were in a flask. A specimen taken on April 19th—*i.e.* forty-three days after the incision—was also free from organisms.

This case seems to me an absolute proof of the efficacy of

[1] In these cases, though micrococci alone could be found, yet cultivation experiments would in all probability have revealed the presence of bacteria as well.

the spray in destroying the activity of the particles in the air which give rise to organisms and fermentations; for here the action of the living tissues, to be afterwards discussed, could not come into play—the fluid was under the same conditions as if it had been in a flask placed in an incubator. The conditions exactly correspond with my spray experiments (p. 26 *et seq.*).

Case 8.—Take next a case of incision into the knee-joint in a case of gelatinous degeneration of the synovial membrane before suppuration had occurred. Mr. Lister has found that, in these cases, free incisions on each side of the patella, and the insertion of a drainage tube into the joint, often brings about a cure without suppuration and without the necessity for further operation. It was so in this instance. The incision into the knee was made, and drainage tubes inserted, on May 10th.

On May 14th *no organisms* were present in discharge taken from the drainage tube.

On May 16th, same result. Fig. 10 is a specimen taken on May 20th from the drainage tube: *no organisms*.

A specimen was also taken on May 20th from a plug of lymph in a small chronic abscess beside the knee, opened on May 12th, and here also there were no organisms.

On May 22nd there were still no organisms.

I might mention a number of cases to show that where the dressing is frequently changed, organisms may remain absent for a long time, or even altogether. Therefore where the dressing is changed frequently, and where the various aseptic precautions are thoroughly carried out, organisms never develop in the discharges.

As a rule, however, the dressing is not changed so frequently, and then, though organisms are absent at the commencement of the case, they frequently appear towards its termination. In that case, however, the organisms which appear belong to the group of micrococci.

The following cases illustrate this.

Case 9.—I will take first a case treated strictly aseptically, and following a typical 'aseptic course.' This case illustrates the entrance of micrococci after some days.

The patient, a young man æt. 26, had suffered for a long time from a sore on his leg, which had now become epitheliomatous. The

patient was very weak. Amputation was performed through the middle of the thigh. The case followed a typical course. There was no rise of temperature. The patient felt at once relieved by the removal of the disease, and his appetite and strength began to improve from the day of the operation. The wound healed by first intention, except where the drainage tube was. When this was removed the sinus became filled with lymph, and this becoming vascularised, healing took place completely without the occurrence of granulation. The amputation was performed on April 8th.

Fig. 11 was taken on April 9th (first dressing) from the drainage tube. *No organisms*, but there is a good deal of granular matter.

Fig. 12, taken on April 10th from the drainage tube (second dressing). *No organisms*. Less granular matter. Much less discharge. The dressing was now left unchanged for two days.

Fig. 13, taken on April 12th from the drainage tube. *No organisms*.

The dressing was again changed on April 14th, and one or two bodies were then seen which might be micrococci, but of this I could not be certain.

Fig. 14, taken April 16th. A piece of lymph was clipped away and rubbed over the surface of a cover glass. There was almost no discharge. Line of incision soundly healed. The piece of lymph filled up the place where the drainage tube was. (The drainage tube was removed on April 14th.) *Distinct micrococci*; no bacteria; almost no leucocytes—those that are present being badly formed. The dressing was now left on for three days, and in a specimen taken on April 19th from the little bit of lymph there was *nothing but micrococci*. No bacteria and no leucocytes. The dressing was now left on for four days.

In another specimen taken on April 23rd, also from the lymph, which had by this time become in the main vascularised, *micrococci* were present in great numbers. No bacteria.

Here we see the typical result in a case where the ordinary rule was followed of not changing the dressing till the discharge comes to its edge. In this case displacement of the dressing was the cause of the frequent changing of the dressing latterly. For six or eight days no organisms appeared in the discharge. When they did appear they were micrococci. Bacteria never got in. Further, the micrococci, though latterly present in enormous numbers, never caused suppuration, nor did they apparently interfere with the healing of the wound.

Case 10.—Case of excision of the mamma and axillary glands for scirrhus, done on March 19th.

Fig. 15, taken from the drainage tube on March 20th, contained *no organisms.*

A specimen taken from the drainage tube on March 21st contained *no organisms.*

A specimen taken from the drainage tube on March 22nd contained *one or two micrococci.*

These micrococci were more numerous at the next dressing on March 26th, and they were present in large numbers on March 31st and on April 2nd; no bacteria having appeared, as will be seen in the next specimen.

Fig. 16, taken on April 4th, when the wound was almost completely healed. Here there were *numerous micrococci*, but no bacteria.

In this case the micrococci got in earlier than we have yet seen—viz. on the third day after after the operation—but nevertheless bacteria never appeared, and the wound did not seem any the worse for the presence of the micrococci.

That micrococci may get in even earlier than this, if there is but little overlapping and much discharge, is evident from a case of removal of a small epithelioma from the cheek, where only a small dressing was applied, which was left on for two days. The discharge obtained on the second day—*i.e.* at the first dressing—was found to be full of micrococci. The edges of the wound were not brought together, but it became filled with blood-clot, and healing occurred under this without any suppuration at all, and more rapidly than I have ever known it take place in such a wound, and yet numerous micrococci were present even from the first.

Case 11 also illustrates this. A keloid was removed from the back of a man's neck on March 24th. A small dressing was applied, but there was a good deal of discharge, which reached the edge of the dressing a few hours after the operation. Specimen 17, taken at the first dressing on March 25th, shows *a few micrococci.*

A specimen taken on March 28th (third dressing), and one taken on March 31st, showed the presence of micrococci in large numbers, but no bacteria appeared at any time.

And now I come to two cases illustrating very important points as to the source of these organisms. In these cases I

have examined the discharge, not merely in the drainage tube, but at some distance from the wound, under the gauze dressing, and I have found that, though there might be no organisms in the wound, yet they might be present at the edge of the dressing, and that micrococci had generally advanced nearer to the wound than bacteria.

Case 12.—Excision of the mamma and axillary glands, done on March 27th.

A specimen taken on March 28th from the drainage tube (first dressing) contained *no organisms.*

Discharge was taken on March 31st (third dressing) from the dressing, *at a considerable distance from the wound.* The dressing had not been changed for two days, and the discharge had reached the edge some hours before the visit. *This specimen contained both micrococci and bacteria.*

A specimen of the discharge taken at the same time from the *drainage tube contained no organisms.* (See Fig. 18, Plate III.)

Examined again on April 2nd (from drainage tube, fourth dressing). *No organisms found.*

Discharge taken on April 4th from the *dressing*, at some distance from the wound, contains *bacteria and micrococci.* (See Fig. 19, Plate III.)

Fig. 20 is from a specimen of the discharge taken at the same time from the drainage tube, and contains *no organisms.*

A specimen taken from the sinus on April 6th contained *no organisms.*

A specimen taken from the sinus on April 8th contained *a few micrococci.* Wound almost healed.

A specimen taken at the next dressing from a piece of lymph over the orifice of the sinus showed *numerous micrococci.*

Here we see that on March 31st organisms had penetrated for a little distance under the dressing, but had not yet reached the wound.

The same was found on April 4th; but on April 8th a few micrococci had got in, and having once got in they multiplied rapidly. *Bacteria did not get in.* There was no change in the appearance of the wound to show that anything hurtful had entered.

Case 13.—This was a case of disease of the knee-joint treated like Case 7, but here there was necrosis of the patella before operating, and extensive disease of the bones. As no improvement followed the

incisions, excision was performed on April 2nd. The drainage tube on the *inner* side passed in between the bones, and one was also introduced into a hole gouged in the bone; that on the *outer* side passed into an abscess cavity in the soft parts. The case followed the typical course.

A specimen was taken on April 2nd from some curdy material found in the interior of the joint. (It must be remembered that the interior of the joint had been in communication with the outer world for some weeks by means of a drainage tube, but there had never been any suppuration in the cavity of the joint.) *No organisms* were found.

A specimen taken on April 3rd from the *drainage tube* on the inner side contained *no organisms*.

Fig. 21, taken on April 4th from the gauze at some distance from the wound on the inner side. *One or two micrococci; no bacteria.*

Fig. 22, taken on April 5th from the *inner drainage tube*, contained *no organisms*. Contrast this with Fig. 21, taken from the gauze on the previous day. In it there were a few micrococci at some distance from the wound, but, as we see from Fig. 22, they did not get in.

Fig. 23, taken on April 8th from the *inner drainage tube* contained a *few micrococci*. They had now reached the inner wound, and in later specimens they were found in large numbers.

Fig. 24 is a drawing of a specimen taken on April 15th from the *outer drainage tube* leading into the abscess cavity. This contained *no organisms*, although they were present on the inner side of the knee on this same day in large numbers. This shows that the organisms could not have come through the blood or developed spontaneously in the wound; otherwise they ought to have been found in the outer side as well as in the inner.

From these results—and these are only a sample of what I have got by this method of investigation—and from my former cultivation results (each method very important in its own way), the difference which I have been led to establish between wounds treated aseptically and those not so treated will be evident.

Wounds treated aseptically are either free from organisms or, if the latter are present, they are only micrococci. The others always contain organisms, and, in the great majority of cases, these organisms are bacteria as well as micrococci.

III. If, under any circumstances, organisms do enter wounds treated aseptically, what are their peculiarities?

The facts just stated under the second heading imply that we have to deal in wounds with two great groups of organisms—rod-shaped organisms, or bacteria; and spherical organisms, or micrococci.

Some, however, assert that there is no specific difference between micrococci and bacteria; and these observers would say that the micrococci found in aseptic wounds are simply bacteria altered in form by the new conditions in which they are placed. Prof. Billroth, indeed, has gone so far as to assert that there is only one species, coccos, in the group of Schizomycetes; that this may under varying circumstances assume the form of bacterium or coccos, these two being transmutable into each other. That micrococcus is an organism distinct from bacterium, is denied by Hallier and doubted by Klebs, while it is strongly affirmed by Cohn, Rindfleisch and others.

I am now thoroughly satisfied that micrococci are really a class of organisms quite distinct from bacteria. I have observed them and worked with them for four years, and I have never yet met with an instance in which a micrococcus has become a bacterium, or *vice versâ*.

Before considering the evidence on this point, I may define what I mean by micrococci. They are (following Cohn) colourless or coloured round cells, very small, generally under one micro-millimetre in size, with or without movement, growing in pairs, triplets arranged in triangular form, short chains or groups of smaller or larger size, not derived from bacteria nor developing into them. Other living spherical bodies may be found in cultivating fluids, such as spores of fungi or, indeed, of some forms of bacteria, as pointed out by Koch [1] and Ewart [2]; these, however, when fresh nutriment is added, develop again into fungi on the one hand, and into bacteria on the other. The life history of micrococcus seems only to consist in development from pairs to short chains or groups of larger or smaller size, this cycle being repeated on the addition of fresh pabulum.

I need not here enter into the general characteristics of these organisms, but I may mention some facts which tend to shew that they are distinct from bacteria.

[1] *Beiträge zur Biologie der Pflanzen*, Bd. ii., 1876.
[2] *Microscopical Journal*, vol. xviii.

Tiegel [1] has pointed out, that if a fluid containing organisms be made strongly alkaline with carbonate of soda, *bacteria* quickly disappear and only a few *micrococci* remain, which also ultimately vanish. This indicates a chemical difference between the two forms.

A similar chemical difference has been incidentally referred to by Koch [2] viz., that while *micrococci* are stained by hæmatoxylin, *bacteria* are not.

I have found that micrococci, when acted on by a strongly peptic solution at the temperature of the human body, remain unaffected, in contrast to ordinary albuminous granular matter, which, as a rule, soon disappears. Many forms of *bacteria*, similarly treated, become aggregated into clumps, or may for the most part disappear, only a few irregular rods and granules remaining. Here again a chemical difference is evident between the two groups of organisms.

Then as to their mode of growth. I have mentioned the triangular arrangement of micrococci, and said that this is typical of these organisms. This is supposed by Cohn to be due to a looseness of the intercellular substance, allowing the cells to become displaced. But then this arrangement is constant, and Mr. Lister[3] has by direct observation made out that it is due to longitudinal division of the cells (Fig. 25). This is a method of division which never occurs in *bacteria*. Here again, then, in their mode of growth we have a marked difference between the two.

Micrococci prefer acid fluids; most bacteria prefer alkaline or neutral fluids.

Micrococci grow readily, as we shall presently see, in fluids containing proportions of carbolic acid in which bacteria only grow with difficulty.

Then, lastly, direct observation has failed to show any transformation of one into the other. I have specimens of micrococci which have remained in cucumber infusion for ten months, and they were just as perfect micrococci at the end of the time as at the beginning. There was no transformation into bacteria.

[1] Virchow's *Archiv*. Bd. lx.
[2] Traumatic infective diseases.
[3] *Transactions of the Royal Society of Edinburgh*, vol. xxvii. 1875.

I figure three specimens to illustrate the same point, and in the note on the next page I give a table of the series of experiments.

The micrococci were obtained from a case of acute abscess in the groin. When this abscess was opened some of the pus was introduced into flasks containing meat and cucumber infusions, but nothing developed. On the third day after it was opened, the dressing having been left on for two days, another flask of meat infusion was inoculated, and in this micrococci developed. From this flask were obtained the micrococci in the series of experiments tabulated below. They were cultivated for several weeks in a variety of fluids, but always remained micrococci of the same kind and with the same effects on the various fluids.

Fig. 26 represents the discharge from the wound from which the micrococci were obtained, and is seen to contain micrococci alone.

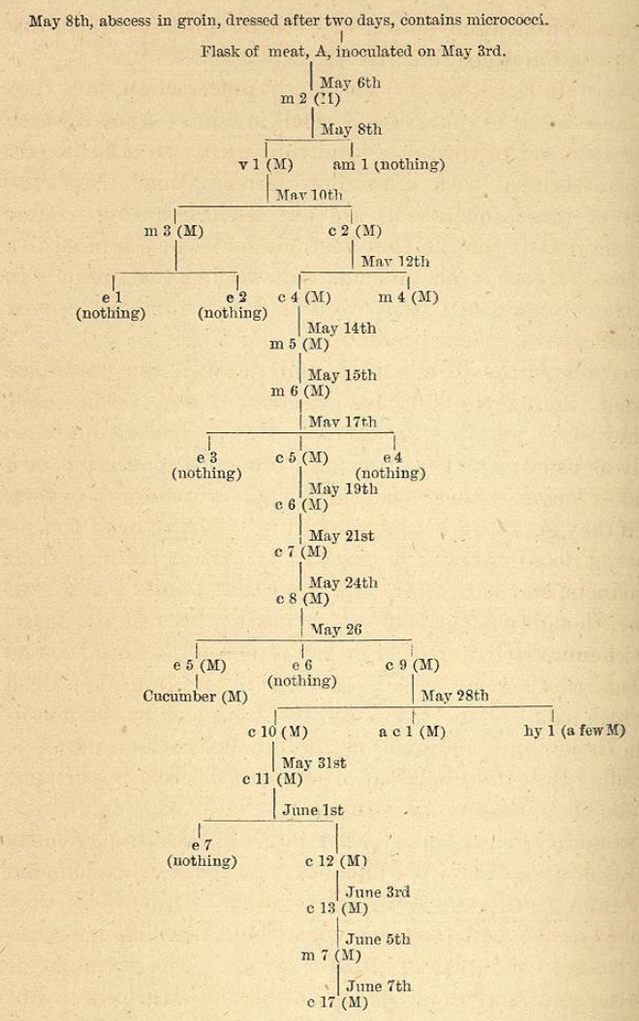
Fig. 27 is a drawing of a specimen taken from a flask of vitreous humour, the third in the series, and here we find only micrococci.

Fig 28 is taken quite at the end of the series (from c 17, see note), after the organisms have grown in a variety of fluids (eighteen in all), and yet here we have only micrococci, and these are similar in appearance to the others. There was here no development of micrococci into anything else. (I may just call attention in passing to the proof of the efficiency of the method of experimentation afforded by these results, and also to the numerous arguments which can be drawn from them in favour of the views I am advocating.)

Such are some of the facts which seem to me to show that micrococci are distinct from bacteria, and they are a sufficient answer to the question as to whether there is anything special about the organisms found in wounds treated aseptically.

It is only one well-defined class of organisms which enter wounds treated aseptically, while in other wounds all forms may be found.

I will not here enter on the question of the effects of these micrococci nor will I stop to enquire why it is that no bad



Lost from having allowed four days to elapse before inoculating again.

In this list m = meat } infusion.
" c = cucumber }
" v = vitreous humour of sheep.
" e = fresh egg.
" am = alkalised meat infusion.
" hy = hydrocele fluid (very concentrated).
" M = micrococci present.

effects result from their presence. I shall content myself just now with the following remarks.

It is certain that they do not cause putrefaction, but they always cause a sort of sour, sweaty smell in fluids—a smell which can be recognised in whatever fluid they grow: in other words, they are associated with a peculiar fermentation. Now, the products of this fermentation are but little irritating. They have no acrid taste, nor do they feel pungent when applied to a cut surface. Hence, probably, it is that we find that wounds in which these organisms exist, even in large numbers, appear often unaffected by their presence.

Nevertheless, they can hardly, under any circumstances, be indifferent, and I think I have observed that, in some cases, after they have got in, the wounds do not behave quite so typically as usual; *i.e.* there may be a trace of suppuration, or a sinus takes longer to heal than one had any reason to expect. Again, if they get into a wound containing a piece of dead bone—say, not yet loose—they will grow in its canals, produce their sour products, and irritate the parts in the vicinity; and thus the bone, though not mechanically irritating, because not loose, nor yet chemically irritating if it is quite aseptic, does become somewhat irritating and loses its character of an innocuous dead piece which may be slowly removed by absorption by the neighbouring tissues, and becomes a foreign body which must be thrown off. In such cases, then, it would be of great importance to exclude these micrococci if possible.

An instance which, I believe, illustrates this, occurred recently in Mr. Lister's practice. We know that formerly, when hempen ligatures were used, they always came away. If, however, they are applied aseptically, they remain without causing suppuration, as has been shown in Mr. Lister's cases. The wound heals over them, and they may indeed ultimately disappear. But here, as in the case of the dead bone, a necessary condition for obtaining this result is, that the ligatures be perfectly unirritating. In the case I refer to, Mr. Lister excised the thyroid gland aseptically, having previously ligatured the vessels, somewhat after Watson's method, with strong hempen twine. The wound healed entirely by first intention, except where the drain was, and this also had almost healed by the tenth day. For