Appendix

Alexander Ogston ON ABSCESSES

Gentlemen,

Once again I venture to appear before you in order to communicate the results of an investigation which I completed last winter for the British Medical Association. For the sake of brevity I must dispense with all details and only describe the principal results.

As you know, Robert Koch's fine investigations into the infective pathology of wounds have aroused new hopes that the dark area of medical science, the field of infectious processes, will soon be conquered. Something has been done in this direction, more particularly in Germany; in general, however, deplorable confusion still reigns—and nowhere more so than concerning the causes of septicaemic processes and the way they work. It is obvious that until we acquire a closer understanding of the basis and the fundamental elements of this question, very few of the preparatory studies on the subject can be properly exploited. The simple things must be known first. We must first of all know the properties of the different organisms and the power of each one to bring about pathological processes, before we are in a position to understand the complicated picture of so called blood poisoning.

Guided by this idea I undertook a study of micrococci. Ewart's observations have led to the point where nowadays we have to distinguish four main kinds of micro-organisms; Bacilli or little rods; Bacteria, which are shorter than bacilli and the ends of which are rounded, so that they are shaped like short sausages; Spirilla; and Micrococci or spherical bacteria.

Micrococci are round or slightly oval; they occur singly, in pairs, in chains or in groups, but in all circumstances they keep their rounded shape; they are never drawn out in filaments and form no spores. They are found most easily and most purely in the pus which exudes from a closed abscess when it is opened. Using the methods of Koch (which I followed exactly),

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they can be dyed purple very nicely with methyl-aniline; and they can be recognized with complete certainty in the tissues and fluids, by using Abbé's lighting and oil immersion lenses. When using other methods, however (and I have used many, in order to check my own findings as carefully as possible), they are very easily overlooked.

It is true, as Wolff recently emphasized, that in the tissues and fluids there are granules, which become strongly coloured with aniline and cannot be distinguished from single micrococci, but in practice this causes no embarrassment. Micrococci which play a serious role and start pathological processes never occur singly; on the contrary they are always growing and form unmistakable groups, chains or at least disc shapes, the appearance of which clearly indicates a purpose. Single micrococci occasionally found are of no importance, and can thus be disregarded. Since they occur so frequently in pus, I have examined 88 cases of abscesses with the greatest care; they were all quite typical and up to that time had not been opened. Among them were 70 acute abscesses in the most diverse parts of the body and in all of them micrococci were present in the pus in quantity. Four others were cases of abscesses progressing more slowly, connected with processes which caused impurities in the blood, as they followed erysipelas, abdominal inflammatory disease, pharyngitis and pulmonary inflammation, and in these too, I have always easily been able to observe the presence of micrococci. In the remaining 14 cases, all of which were cold abscesses, originating from caseous processes in the bones or lymphatic glands, I could never discover any organisms even after the most careful and exact observations. Attempts at cultures, too, always proved negative.

These facts in themselves are significant, and I could not help thinking that it might be possible to discover a causal connection between acute suppuration and micrococci, as Kocher in Berne had suspected. Everything supported this assumption. The micrococci always showed signs of growth. Very rarely did they occur singly, but rather arranged in the shape of discs and in chains or groups. Their diameter varied between $1/750$ th and $1/1480$ th of a millimetre. They moved spontaneously,* and once I saw a chain of 11 links work its way through an otherwise motionless environment for three times its own length in the space of 25 minutes.

In order to determine in what quantity these organisms occurred, I counted the number of pus cells and then, having made dried preparations, I drew conclusions about the number of micrococci from the preparation between the two structures. From 400 estimates by means of a haemacytometer with 10 specimens of acute pus I found, on an average, 917 775 pus

* subsequently noted in 1881 to be an artefact.

cells in every cubic millimetre, and therefore one might reckon the number of micrococci as being, on average 2 121 070 per cubic millimetre. That was the mean figure of 57 different specimens of pus but the variations were enormous. Twice there were only 900 micrococci and again on another occasion there appeared to be 45 million per cubic millimetre. It also seemed to me that in the same pus the organisms were not uniformly distributed, that in an abscess which was kept closed they gradually sank down and that even at the base they were by no means spread out uniformly.

It was apparent too, that either there are different kinds of micrococci, or that they show different types of growth. Sometimes they were to be seen only in the form of chains—as can be seen in fig. 1—and in this case, even when they formed zoogloea-like masses, the chain form was still discernible (fig.2). Evidently this formation was produced by division and always proceeded in the same direction—towards the poles; this was proved most clearly by the arrangement of the long chains, where every stage of this division was represented.

In other specimens again, no chains were to be seen, at most three cocci were lined up; but everywhere large groups and masses lay spread out which appeared to have originated from an entirely different kind of division. Two cocci side by side occurred frequently, indeed three could be found in line occasionally, but normally they formed a kind of triangle. Four formed a square, and from these the large irregular masses appeared to be formed by division in every direction (compare illustration, fig. 3). An intermediate substance could not always be detected; before being stained they appeared to be surrounded by a light coloured halo, but after staining nothing of the sort was to be seen. Only in some spherical bacteria in groups—larger ones, as it seemed to me—I could not see through in between the individual spheres and the masses looked like bunches of grapes* (und die Massen sahen Weintraubenartig aus) while in another pus sample quite light coloured interstices were always noticeable, either because the cocci were less clearly crowded together, or because there was no intermediate substance that would take up the stain (fig. 4).

In some abscesses there were relatively large micrococci to be found, clearly egg shaped only arranged in pairs. Among 64 abscesses, 31 contained only the micrococci in groups, 17 contained only chain forms, while in 2 they existed in pairs only, and in 14 both in chains and in groups. Whether the forms I have mentioned represent different micrococci or merely variations in their mode of growth I would not at present dare to decide. At any rate, no difference was observable in the abscesses containing them.

* later called Staphylococcus (1882).

Occasionally other organisms occurred as well. On three occasions they were only bacilli, and on two occasions bacteria, bacilli and spirilla (fig. 5). But the micrococci were never absent. Such abscesses emitted a fetid smell; they were mostly located near the anus or in relation to decayed teeth. The bacteria were mostly placed in clumps in and on large cells, the rods and spirilla lay between the cells, almost without exception the micrococci lay unattached between the cells (figs 6 & 7).

Now in order to find out whether micrococci really cause inflammation I carried out a series of 68 injections in guinea pigs, mice and white mice. Twenty different experiments with pus from cold abscesses, in quantities from one to ten drops remained without effect causing no inflammatory reaction; the animals remained quite healthy and within five or at most ten days the injected matter had vanished without trace. Pure pus was thus powerless to cause further suppuration. But when I used pus containing micrococci in quantities ranging from one quarter of a drop up to two drops, then an abscess always developed at the point of injection. During the first few days the animal was unwell, crouching and would not eat; the mice in particular, showed symptoms of blood-poisoning mentioned by Koch, and when I examined the blood during this period, usually—though not always—I found paired micrococci in fairly large quantity, floating in the blood serum between the corpuscles. In the course of the first week, the symptoms of blood poisoning disappeared, the animal became quite bright again, the blood in most cases contained no more micrococci, but the abscess grew bigger and bigger like an ordinary human abscess. If I killed the animal during the first period I found a small cavity of pus with progressive purulent breakdown of its walls, and the surrounding area was thickly strewn with micrococci. The cocci proliferated in the tissues, forced their way into the interstices of the tissues and, according to the kind of grouping mentioned before, formed into chains and cloudlike masses (figs 8 & 9), round which the tissues looked more transparent than normal as if coagulated. The pus in the cavity was pervaded by masses of micrococci; instead of an average of 2 million their number had risen to 13 or 18 million per cubic millimetre. In later stages instead of an infiltration of micrococci, a wall of granulation tissue without organisms was formed, this to all appearances had the effect of preventing or reducing the infiltration of micro-organisms into the blood. Pus from such abscesses, when transferred to another animal again produced abscesses and so on.

However, if I injected the same animal in a different place, subcutaneously, with the same amount of pus, mixed with an equal quantity of a 5 per cent carbolic solution, not once did an abscess ensue. The matter disappeared without leaving any trace like that from a cold abscess, while at

the point of the first injection there was a flourishing abscess. Using 1/16th of a drop or less, and using a drop of pus which had been much diluted with blood on opening the abscess, the injections caused only a transitory red inflammatory infiltration which did not end in suppuration, with temporary symptoms of blood poisoning. The animals' resistance seemed sufficient to render such a small quantity innocuous. I must mention, too, that injection into the abdominal cavity in quantities of one or two drops caused neither suppuration nor adhesions, but only passing symptoms of blood poisoning.

Although it is true that the effect of the injections in causing an abscess was practically constant, it appeared that there was, even in animals from the same litter, a certain predisposition on the one hand and a resistance on the other. Sometimes they died—the mice especially—on the second or third day with every sign of septicaemia before a well developed abscess had appeared, and locally I found extensive infiltration of micrococci with deficient pus formation. Occasionally—but only extremely rarely—the process did not go beyond the first stage and then regressed, as if the animal's resistance had got the upper hand, and yet the same pus caused a typical abscess in a different animal. And, sometimes again, probably because the local irritation was too strong or the tissues too weak—the result, instead of an abscess was a gangrenous destruction at the site of injection including the skin over it. When finally the sloughs had come away, there remained a granulating ulcer in that place; under its whitish surface the micrococci continued to proliferate though to a lesser degree.

Finally, I tested the influence of heat on the organism and found that as soon as the pus had been heated to a temperature of 55 degrees or more the injections produced no result. But in this direction my experiments are by no means complete.

Everything I was able to observe in human subjects tallied with these results; I will only add that repeated examination of the point where an abscess breaks through has convinced me that the gradual thinning which takes place is brought about not by infiltration of cocci but by absorption of the granular wall as it advances.

I had now reached the point where I had to assume an intimate connection, indeed a causal connection, between micrococci and acute suppuration. Perhaps you will not be unaware that very recently, Dr Watson Cheyne, Lister's assistant, has advanced the thesis (based on observations of wounds) that micrococci are innocuous organisms, and because they are able to live in diluted carbolic solutions they frequently penetrate from outside into wounds treated according to Lister's method, and can be found there without having any particular significance.

My observations, as well as those of Koch, Israel and others, contradicted, I will not say his facts, but his conclusions, and therefore I was obliged to repeat his experiments; which then led me to undertake new experiments supplementing my previous work into the occurrence of micrococci in suppurating wounds, and in acute suppuration generally, which do not come into the category of abscesses.

On a series of investigations of vesicles, blood extravasations, haematomas, and the most diverse pathological cyst fluids as well as fluids from cavities of the body, I convinced myself, first of all, that micrococci never occur in them unless they have passed into a state of purulence and these facts were confirmed by numerous experiments with cultures.

Next I examined a fairly considerable series of suppurations as well as gonorrhoea, pustules, purulent sputum in bronchitis and caseous pulmonary consumption, and also suppurations from the various apertures of the body and whenever the suppuration could be called in any sense acute the presence of micrococci was clearly observed. Only in one case of chronic *acne vulgaris* there were no micrococci to be found in about half the pustules.

Watson Cheyne did not use Koch's methods in his observations of wounds; I on the other hand always used Koch's methods as well as other methods. As regards the wounds, I arrived at results which (apart from individualities and peculiarities of cases) fully confirmed all that had transpired from the investigations of abscesses. In fatal septicaemia, proceeding from deep and poorly drained post operation wounds as in a case of removal of a goitre, I found micrococci in the wound and also in the blood which, in accordance with Hueter's idea, was taken from a lip vein on the inside of the lower lip. Here I could not but suspect an acute process of invasion by the micrococci which gained access to the bloodstream with a rapidly fatal result although I was denied the opportunity of proving this at post mortem.

In a compound dislocation of the ankle joint which was not treated by the Listerian method, rich colonies of micrococci proliferated in the cavity of the joint which was filled with clotted blood; in the torn saphenous vein they were mixed with the pus, lying there in the extravasated and oedema fluids, they proliferated in the subcutaneous layers of connective tissues which bordered the deep fascia; they were present in the blood of the popliteal vein at removal of the limb thus appearing to be in the process of being washed away into the general circulation. In the lymphatic glands I have not so far found them but I do not doubt that they occasionally occur there. The subcutaneous connective tissue in the vicinity of the skin wound was pervaded by a dense network of colonies of micrococci, and the

excretion of these vies with the absorption of their poison, in as much as the kidneys constantly excrete the cocci, which is demonstrated by their presence in the urine. This excretion, which I have had occasion to observe only in human subjects, includes bacilli as well as micrococci. Forms of *Bacterium* I have never seen in urine. In operation wounds which have been treated from the start strictly in accordance with Lister's method, organisms are never to be found, even after months of treatment, and the same applies to cold abscesses, which as I have pointed out before did not originally contain any. In such cases there was no real suppuration, but only a serous exudation.

If treatment is careless, however, the micrococci creep in because they can live in weak carbolic solution as Watson Cheyne has proved.

In the case of newly opened abscesses the familiar micrococci are found in pus. Gradually, as the abscess heals the micrococci in the exudation diminish, although they live on under the thin whitish surface of the granulations (as long as this remains), dispersed through the superficial layer of granulations (fig. 10); they are also to be found in the pus. As soon as the loss of tissue substance is made good, they become increasingly sparse until finally, when the wound contracts and becomes clean and bright red, it is only with difficulty that the odd solitary micrococcus can be found.

Ordinary ulcers which did not start from an abscess and which were not treated antiseptically show the same characteristics. In the two cases just referred to one finds other organisms only exceptionally. However, when one examines a part of a wound which shows undermining of the edges and deepening of the base, forming a kind of pocket where the pus stagnates, one finds *Bacteria* and *Bacilli* with their characteristic putrid smell.

Where one must presume that faulty antiseptic measures during an operation has allowed hidden suppuration to occur deep in the tissues one finds in the pus a content of micrococci like that in acute abscesses while other organisms are usually absent.

Injections of pus from wounds will easily produce abscesses. If a wound is once affected with micrococci it is extremely difficult to get rid of them. The ordinary antiseptic bandage is insufficient; moreover, they seem to live quite happily under bandages of potassium permanganate, thymol, salicylic acid, boric acid and carbolic oil in a strength of 6 per cent, at least when these are applied in the normal way. They can be removed most effectively by cauterizing the wound with zinc chloride; once this is done the ordinary Lister bandage is sufficient to keep them out.

There are probably micrococci which do not have the property of causing suppuration; for after an operation on a flat foot, where a bandage had remained unchanged for over six weeks and gave off on removal a familiar

cheesy smell, I found colonies of micrococci in the secretion of the wound, apart from other organisms, although the wound looked aseptic, showed no suppuration and was on the point of healing under a moist scab and organizing blood clots.

The preceding statements are based on 96 examinations of wounds.

It was bound to appear surprising that the micrococci seemed to be so innocuous in superficial wounds; although in abscesses they played such an important role. The explanation is provided by the results of my experiments with cultures. Only 118 cultures were attempted, almost exclusively with pus from abscesses, i.e. with micrococci without any admixture of other organisms. I tried cultures in many liquids, for example, in urine, ascitic fluids, the contents of ovarian cysts and hydroceles, blood from the umbilical cord, Pasteur and Kohn fluids and in fluid from the anterior chamber of the eye. The latter succeeded best of all; but the results were extraordinarily varied. Sometimes the micrococci grew quite nicely and luxuriantly in chains as well as in groups, but more often the experiment was unsatisfactory, and there were even occasions when the micrococci I had introduced died out completely. The temperature I applied, from 37°C downwards did not explain the results, and injections of the micrococci produced in this way almost invariably produced negative results.

I therefore abandoned cultures in glass cells and tried deep culture bottles, which, suitably protected, still admitted air. All sorts of experiments served to guard against deception. Now I observed that forms of *Bacterium* always produced putrefaction and that fluids impregnated with them turned alkaline and contained ammonia, while the organisms themselves proliferated on the surface like a lawn and the sediment showed only motionless, apparently dead forms.

In the bottles containing micrococci things were quite different; even after months they remained unclouded and acid or neutral, their smell did not change; in the layers near the surface there was nothing to be observed; only lower down and in the sediment micrococci developed but not in such large numbers as I should have expected after my experience with abscesses. Since the culture of micrococci succeeded best in the layers removed from the air, I suspected that perhaps they might be 'Anaerobes', in Pasteur's sense.* On this assumption I filled a few cells with oxygen and tried the cultures again. The results however, did not come up to my expectations.

Finally I hit upon the idea of producing a culture in eggs. To this end I took new-laid eggs, and proceeding as in all my experiments with strict antiseptic precautions I made a small hole at one end and with the aid of a long

* Pasteur, L. 1878, *Bull. Acad. Méd.* no. 18.

hollow needle, injected the micrococci into the white at the opposite end. They were placed in a Lister type bandage and kept in an incubator at normal body temperature. After a fortnight the eggs were filled with the most beautiful micrococci and I was able to check and confirm my earlier observations regarding motion and development. The yolk was fragmented but otherwise the egg was unchanged and smelt entirely fresh, whereas eggs which had been treated with other organisms instead of micrococci gave off a foul smell and showed the white changed and the yolk blackened. In this way I succeeded in keeping micrococci pure and active in white of egg—micrococci which had been taken with antiseptic precautions from previously unopened abscesses and which had been cultured for seven weeks in urine, and finally for a fortnight in an egg. A drop injected under the skin of guinea pig again produced an abscess, while a simultaneous injection of fresh white of egg on the other side of the same animal disappeared without trace within ten days.

Such experiments convinced me that micrococci developed best without air, and explained why they remain innocuous in shallow wounds. Probably the micrococci which are exposed to air develop so badly and lose some of their virulence so that the tissues can resist or expel them easily before they get a good hold locally, whereas in places where the influence of air is excluded their virulence can be fully developed. Thus abscesses develop, or, under appropriate circumstances favourable to the micrococci a process of blood poisoning may take place and this may even on occasion end fatally without there being any obvious local suppuration.

On the basis of what I have said the following conclusions seem to me to be justified.

(1) Micrococci are the most frequent cause of the formation of acute abscesses.
(2) The occurrence of acute suppuration is everywhere very closely connected with the presence of micrococci.
(3) Micrococci can produce blood poisoning, and
(4) The individual constitution plays an important role in poisoning by micrococci and strongly influences its intensity and speed.

I regret that I have only been able to give the main outlines of my investigations, however, I have brought the relevant preparations with me and shall be glad to show them should that be desired.

I cannot do better than conclude with Kocher's words: 'There is only a difference of degree, a quantitative difference between a simple localised acute inflammation and cases of the most acute pyaemia.'

Fig. 1 Micrococci in chains, enlarged, ×2600.
Fig. 2 Bunches of micrococci in the form of chains in pus. ×1600.
Fig. 3 Micrococci in groups. ×2600.
Fig. 4 Groups of micrococci in pus. ×1600.
Fig. 5 Organisms in pus. ×1600. (a) Pus cells; (b) Bacteria; (c) Bacilli; (d) Spirilla; (e) Micrococci.
Fig. 6 Organisms in pus. ×1600. (a) Bacilli; (b) Intercellular micrococci; (c) Micrococci in or on large cells; (d) Large cells or mass of protoplasm; (e) Pus cells.
Fig. 7 Micrococci in extravasated blood. ×1600. (a) Intercellular micrococci. (b) Micrococci in or on large cells; (c) Red blood corpuscles; (d) Large cells or masses of protoplasm; (e) White blood corpuscles.
Fig. 7A Bacilli and micrococci in urine. ×1600.
Fig. 8 Micrococci in the form of chains in the wall of an abscess. ×1600.
Fig. 9 Micrococci in groups in the wall of an abscess. ×1600.
Fig. 10 Micrococci on the surface of an ulcer. ×1600.