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WOUNDS IN WAR

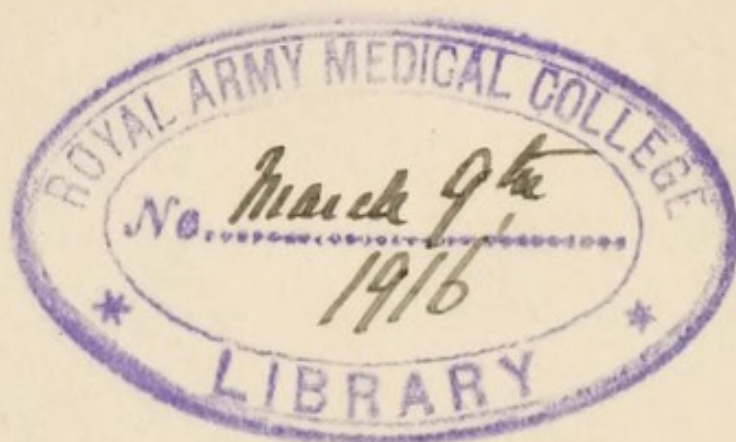
THEIR TREATMENT
AND RESULTS

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D'ARCY POWER
R.A.M.C. (T.)

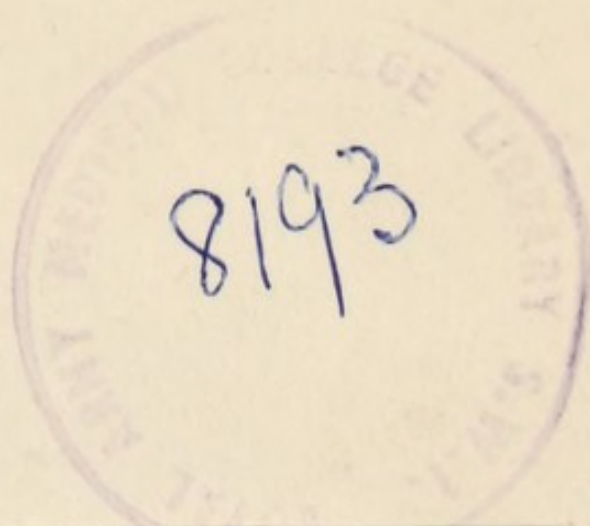
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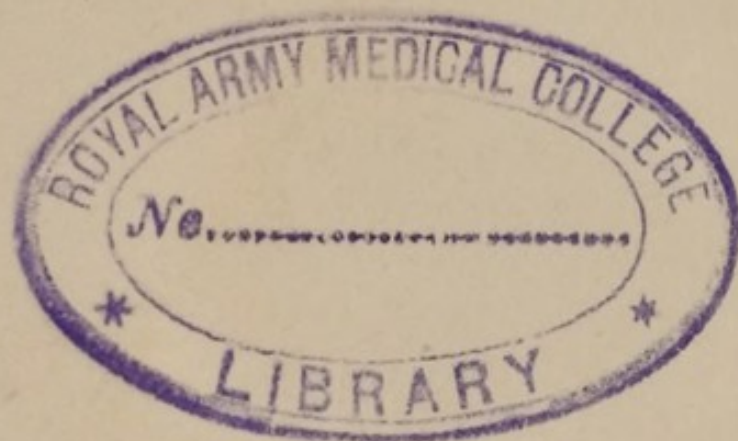


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WOUNDS IN WAR

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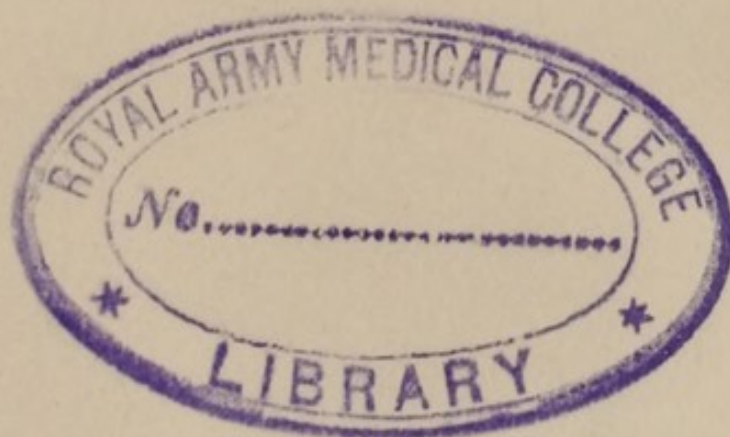
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WOUNDS IN WAR
THEIR TREATMENT
AND RESULTS

BY

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INTRODUCTION

Influence of the Present War on Surgery.—The effect of the present war upon the practice of surgery has been remarkable. It has thrown us back to the time before Lister, when most wounds suppurated. It has taught us that a part of our boasted advance was useless, for the wounds to be treated were already deeply infected before there was any possibility of treating them. It has been the object of surgery for the last thirty years so to treat wounds that they healed by first intention. Success usually followed the attempt to make them do so in civil practice, and many a surgeon could say truthfully that none of the wounds under his care suppurated for weeks or months at a time except in patients who were treated for abscesses, and that even in these cases he had materially shortened the time of cure. Even the South African campaign did not materially shake the general confidence in antiseptic methods, partly because the surrounding conditions were good, partly because the long voyage home allowed most of the wounds to heal before they came under observation, and our surgeons were slow to realize what their original state had been.

Causes of Change in Surgical Practice.—It is far otherwise with the present campaign. The men have been fighting upon very highly cultivated ground which has been manured for centuries. The

earth teemed with micro-organisms, many innocent, some pyogenic, occasionally pathogenic. Life in rain-filled trenches made personal cleanliness impossible, and the clothes and skin of soldiers have been caked with mud. Formerly battles were comparatively infrequent and of short duration. Artillery was less powerful and the guns were fewer. The courtesies of war were more considered. In the present campaign the fighting has been almost continuous, the interval between the opposing lines has been very small, and the whole area both in front and behind has been swept by powerful artillery. It has been impossible, therefore, to render surgical aid to the wounded as soon as has been usual. Where he fell, there he has had to lie certainly for hours and sometimes for days. Nothing could live and move between the trenches so long as the fight was raging, and the wounded could only be brought in when the battle had lulled or when night covered the ambulance parties. The men have fallen, too, in enormous numbers, and it has proved difficult in the front to deal effectively with their injuries. All that could be done was done, and the facilities of modern transport, whether by motor, ambulance train, or barge, were called into requisition to reduce the numbers as quickly as possible. Improved transport, coupled with the nearness of the fighting to our own shores, has brought the wounded to the care of the civil practitioners of this country sometimes within a few hours. It has been possible to watch at home the progress of wounds received on active service in a

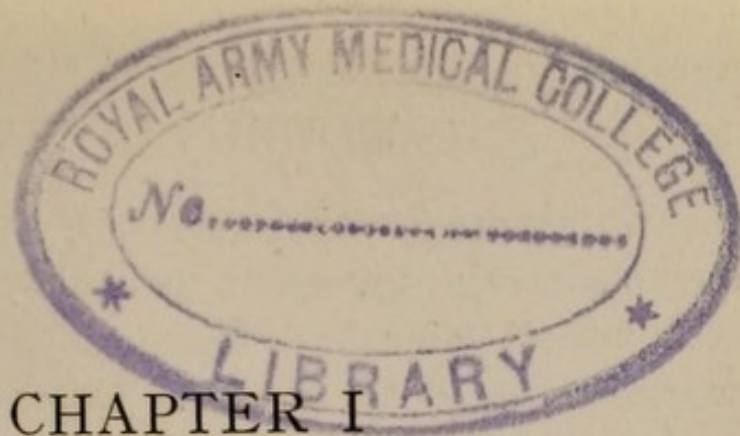
manner which has not been possible since the ' broken times ' under Charles I and the Commonwealth. Much, therefore, has been learnt during the last few months which was known to the older surgeons but has since been forgotten. Some few things have had to be unlearnt. We know, for instance, why our forefathers made such large and deep incisions, why they amputated so freely, and why they preferred simple circular amputations to the more elaborate, and as it seemed to us, the better method of cutting flaps. We know, too, why they valued a sound knowledge of the gross anatomy of arteries and nerves, laying very little stress upon the smaller details, whilst their preference for poultices and wet dressings has been justified.

Effects of Surgical Advances on Treatment of Wounds.

—The experience we have already gained has shown that we are in many respects far ahead of our predecessors. What they did empirically we are now able to give a good reason for. Not only has our diagnosis and prognosis improved but our treatment is better. The employment of X-rays and the application of electricity has made clear the nature of deeply-seated injuries, has enabled metallic substances to be localized, and has rendered it possible to remove them with very little disturbance of tissues. Bacteriology, the direct outcome of Lister's work, has taught us to cope with the worst results of wounds not only scientifically but practically, whilst the doctrine of immunity has materially advanced prophylaxis by introducing the use of vaccines and protective sera. The causes of suppuration being thus known,

where formerly the results were alone known, it is now possible to give a scientific reason for the various methods employed to hasten the process of repair and to arrest in some measure the farther extension of inflammation when it has once begun.

Much still has to be learnt, for Lister's teaching has not yet been able to abolish suppuration under the unfavourable surgical conditions of war. It has shortened the period of suppuration, and it has reduced almost to extinction those dreadful histories which were only too frequent in the Napoleonic and Crimean wars; where suppuration continued in spite of all the surgeon's efforts, until death resulted in pyæmia, or the still worse condition where hospital gangrene caused more deaths than the enemy. But the whole credit must not be taken to ourselves. The Sanitary Service and the Army Service Corps have had a large share in the good result. The physique of the men in the Peninsular War was often inferior: they were badly fed, stupidly clothed, and exhausted by marching and countermarching under very unfavourable surroundings. Our men, at the present time, are usually in the pink of condition, they are abundantly fed, and they work hard under better sanitary conditions than they have been accustomed to at home. It is no wonder, therefore, that they have remained healthy, that in spite of grave drawbacks their wounds have healed readily, and that they have been able to resist the effects of microbic invasion more readily than the civilian population under like circumstances.



CHAPTER I

THE CAUSES OF WOUNDS IN WAR

BAYONET, sabre, and sword wounds have not been met with to any extent among the soldiers admitted into the general hospitals. The vast majority of the wounds have been caused by bullets, shrapnel, high explosive shell, trench mortars, and hand grenades.

Gunshot Wounds.—The bullets usually consist of a solid core of lead covered by a thin casing of nickel, copper, or steel. They are conical in shape, the German and French bullets being more sharply pointed than the Russian, Belgian, or British bullet, whilst the Austrian has a square end. The casing completely surrounds the core of the bullet in some cases, it is wanting at the base of the cone in others. The bullet, therefore, may pass into the tissues in the form in which it left the rifle, or from various causes the casing may separate wholly or in part. The leaden core may then pass on through the wound of exit leaving the casing in the tissues in a more or less crumpled-up condition, or the leaden core may itself be broken up into a number of fine fragments so that under the fluorescent screen the tissue looks as if it had been powdered with metal.

When a bullet is fired from a modern rifle, at least three movements are imparted to it. It passes

forward, it spins on its own axis, and it has a swaying or undulatory movement from side to side.

A variety of causes modifies the character of the wound inflicted by a bullet. Foremost amongst these is the velocity at which the bullet is travelling at the time it enters the tissues. This velocity varies with the weapon employed. The German bullet has the greatest velocity the instant it leaves the rifle, but the French bullet is heavier and maintains its velocity better. During the first 1,500 yards, when the bullet is moving at the highest velocity and has the rotatory and undulatory movements in full force, it produces explosive injuries in the tissues through which it passes, shattering them widely in every direction. From 1,500–6,000 yards, when it has fairly settled down in its course, it may perforate the tissues, making a clean wound of entrance and a larger one of exit in the manner classically described. Beyond 6,000 yards it bruises rather than penetrates and produces the well-known effects of a spent bullet.

Many conditions may modify the action of the bullet. It may have been deflected by striking some object before it wounds, and it may then enter the body at an angle, sideways, or even base first. It may have been altered in shape by a ricochet, or the casing may have cracked, crumpled up, or become wholly detached, giving the impression that a dum-dum bullet has been employed.

It is only in the simplest cases that a gunshot wound presents the typical small wound of entry and the larger wound of exit: the wound of entry being a

mere puncture, the wound of exit being larger and lacerated. The intervening track in such cases may be a straight line drawn between the two points, and it may heal without further trouble. In such cases the bullet often seems to have passed through anatomical positions of great importance without causing appreciable damage. At other times the course of the bullet is extraordinarily circuitous and is probably determined partly by the position of the man at the time he was struck and partly by the state of tension or relaxation of the tissues at this moment. Usually, there is nothing to distinguish the wound of entry from that of exit, both are jagged and irregular, both are suppurating freely by the time he reaches the general hospital.

It is important to remember that the size and appearance of the external wounds afford no indication of the injury done to the deeper structures. A wound which is apparently simple may be associated with a fracture of the underlying bone which is so shattered that the fragments can only be removed with a Volkmann's scoop; a joint under similar conditions may be completely disorganized; an artery may have been made to communicate with a vein to form an arterio-venous aneurysm, or an injury to the spinal medulla may have destroyed its function irrevocably without injury to the vertebral column enclosing it. A careful and thorough examination, therefore, should be made of every bullet wound, however trivial, but under no circumstances should it be probed until the surgeon is assured of the perfect cleanliness of himself, his

patient, his instruments, his dressings, and his surroundings.

When the bullet remains in the tissues it generally lies at some point in the line it was pursuing at the time it entered the body, although it sometimes alters its position very materially, especially when it has entered the thorax or pelvis. It is useless, therefore, to rely upon a skiagram unless it has been taken shortly before the bullet is to be removed.

The worst injuries are produced by bullets which have ricocheted; or which have entered sideways or base first, for they produce huge lacerated wounds with much destruction of soft tissues.

Shrapnel Wounds.—Shrapnel consists of a metal cylinder filled with round leaden or steel bullets which may or may not be enclosed in a metal casing. The cylinder is exploded by a time or percussion fuse, and its contents to the number of 200–400 bullets are driven forwards or, in some of the later forms, backwards, scattering and travelling with a high velocity. The wounds produced by the bursting of shrapnel bear a general relation to those caused by bullets. The laceration of the skin and the tissues is generally greater, and the round bullet is rather more apt to remain in the tissues and to carry in with it fragments of the clothing and accoutrements. It happens, too, that a whole or part of the brass fuse may become buried, thus producing very serious wounds.

Shell Wounds.—The most formidable wounds are undoubtedly those which are produced by high explosive shells. These shells are made of steel or iron. They

are of considerable thickness and are filled with powerful explosives which shatter the shell itself and drive heavy angular masses of metal far and wide, causing terrible injuries.

Bomb Wounds.—Hand and rifle grenades are small explosive bombs which inflict jagged wounds. They are most dangerous at close quarters.

Varieties of Wounds.—Wounds are either abrasions ; perforating (complete or incomplete) ; lacerated. In each case the wound may be simple or may be complicated by other injuries. It is often impossible to classify them according to any system because the character of the wound varies in different parts of its course.

CHAPTER II

THE IMMEDIATE TREATMENT OF WOUNDS

Classification of Wound Treatment.—The treatment of wounds depends very largely upon the time at which they are seen after their infliction. It may be immediately, within the first twenty-four hours; or at a later period. Such a classification seems arbitrary, but it is based upon the assumption that a wound which is seen directly after it has been made may be cured without suppuration, that one which is treated within twenty-four hours ought to be treated as though suppuration could be prevented, whilst wounds which only come under the care of a surgeon at a later period nearly always suppurate.

Difficulties of Wound Treatment in War.—The difficulties encountered on active service in keeping wounds clean are best understood by tracing the course of a wounded man from the front until he arrives home.

Wounded in a charge, the man falls in front of the trenches dirty, sweating, and bleeding. The exigencies of war may oblige him to remain where he lies for hours or even days before help can reach him. He may be able to apply his own field dressing, but the wound most frequently remains untouched. It soon becomes infected with pyogenic organisms from his skin, or with the more deadly pathogenic microbes

from the highly cultivated and manured soil upon which he lies.

The Field Dressing.—Wounded in the trenches, help is forthcoming more speedily. Some friend rips open the first field dressing which is carried by every soldier either in the right-hand pocket, or sewn into the lining, of his tunic. The dressing consists of an outer packet which is sewn up and contains two small separate dressings each complete in itself. Each dressing consists of: (i) a loose-woven bleached cotton bandage $2\frac{1}{2}$ yards long by $2\frac{1}{2}$ inches wide; (ii) a piece of bleached cotton gauze, 36 inches by 23 inches, folded into a pad, 4 inches by $3\frac{1}{4}$ inches, and stitched to the bandage 18 inches from one end; (iii) one safety-pin. The bandage and gauze pad are wrapped in waterproof jaconet, the edges of which are cemented with rubber solution to make the packet air-tight. A portion of one of the corners is turned back and not cemented. The pin is wrapped in waxed paper and fixed outside the jaconet. The gauze is impregnated with sal alembroth and is coloured with aniline blue. The gauze pad is folded once so that the bandage lies outside the gauze. The short end of the bandage is folded in plaits; the long end is also folded in plaits for 18 inches from the pad, and is then loosely rolled for the rest of its length. The rolled portion of the bandage is secured by a stitch to prevent unrolling. The contents of the dressing are compressed so that the outer packet does not exceed $4\frac{1}{4}$ inches in length, $3\frac{1}{8}$ inches in width, and $\frac{7}{8}$ of an inch in thickness.

Directions for the first field dressing are printed upon the outside cover and a printed label of directions is placed upon each of the inside covers. The directions on the outer cover are, 'To open the outer cover, pull the tapes apart. To open the inner waterproof cover, tear apart the uncemented corner. Directions for use: Take the folded ends of the bandage in each hand, and, keeping the bandage taut, apply the gauze pad to the wound and fix with the bandage. One dressing is to be used for each wound. *Do not handle the gauze or wound.*' Similar directions for use are printed on the inner cover.

The orderlies are taught to attend to the following points when applying the first field dressing. 'Expose the wound by cutting open the clothing, never by dragging it over the wound. Never wipe the wound or attempt to clean it while on the field. Take care not to drop the contents whilst opening the packet. Do not handle the gauze that will touch the wound. Apply a dressing in the manner directed on the covers, putting the gauze straight on the wound. Use the second dressing for a second wound.'

A similar packet containing a larger quantity of material has been issued recently to regimental officers and field ambulances under the name of a 'Shell Dressing'. It contains in addition a small phial or *ampoule* of iodine. The iodine is hermetically sealed, has a pad of absorbent wool attached to it, and is enclosed in a stout cardboard tube which is closed at each end with a plug of tow. This plug bears a printed notice upon it 'Iodine Ampoules for External

Use. INSTRUCTIONS.—Push the glass ampoule out of the tube. Hold it vertically and strike the padded end against some hard substance in order to break the glass bulb. The iodine will saturate the pad and should be freely applied to the wound and the surrounding skin before the first-aid dressing is put on.'

The Regimental Aid-post.—When the first field dressing has been applied the man walks or is carried by the regimental stretcher bearers to the regimental aid-post, which is often called the dressing station. The regimental medical officer is in charge of it, and it is situated in a 'dug-out' in the back trenches, or in some building—wrecked or otherwise—at a distance of 500–1000 yards behind the firing line. The transport of the wounded, therefore, must often be left until it can be carried out at night. At the regimental aid-post hæmorrhage is stopped, splints are applied and such operations are performed as are imperatively required, as for instance the amputation of a limb which is so shattered as to be merely hanging to the body.

It should be remembered in applying splints in cases of fractures of the extremity that no bandage should be applied except over the splint, and that in every case the limb must be bandaged from the extremity upwards. The man still has to travel many miles before the splint will be readjusted, and unless these precautions are taken he will suffer much pain, and he runs a risk of gangrene from the swelling of the limb. In like manner a great deal of bleeding takes place into the tissues after a

wound and causes the limb to swell. It is advisable, therefore, to cut through or to remove altogether the surgical bandage within twelve hours of its application, even if it is not considered necessary to remove the dressing itself. In wounds involving a large exposed surface a moist antiseptic dressing is preferable to the application of dry gauze. Peroxide of hydrogen of the strength of five volumes, or a 1:40 solution of carbolic acid, is recommended for the purpose. If iodine is employed the solution should not be stronger than 2 per cent.

The Field Ambulance.—The wounded are evacuated from the regimental aid-post as quickly as possible and are conveyed by the motor ambulances of the bearer division of the field ambulance to the tent division of the field ambulance, which is situated two to four miles behind the trenches. This, however, is not the actual distance that has to be traversed during an action, for the direct road is blocked by every conceivable obstacle, and the motor ambulances have to proceed by such circuitous ways as are open. The journey from regimental aid-post to the field ambulance may therefore occupy many hours and involve many miles. Various emergency operations are done at the field ambulance, but the staff is limited and the wounded are brought in overwhelming numbers and continuously day and night so long as an attack continues.

The Casualty Clearing Station.—It is impossible to undertake more than the very worst cases, and all are evacuated as quickly as possible by motor am-

bulance to the casualty clearing station, which is situated at railhead, that is to say, at the nearest point to which it is considered safe to run the supply trains. This point is generally five to seven miles by the direct road behind the field ambulance and seven to fourteen miles from the front trenches. As in the first part of the journey, the direct road can rarely be followed, and many miles have to be covered before the casualty clearing station is reached.

Ambulance Train.—At railhead the wounded are transferred to the ambulance train, which conveys them to the town where there is a stationary or general hospital. Those who are fortunate may find an ambulance train for their conveyance fitted up with modern surgical appliances. The majority will be carried in the luggage vans—fourgons—of the trains which are returning after bringing up supplies, or perhaps even in horse boxes.

Stationary Hospital.—On the arrival of the train at its destination its occupants are conveyed by Red Cross motor ambulances to the base or stationary hospital or, where possible, to the hospital ship which brings them home.

Ambulance Barge.—Ambulance barges are being utilized to some extent for the conveyance of men with head and chest injuries and with fractures, in place of putting them on the ambulance trains, and as the Franco-Belgian frontier is rich in water-ways the method is humane and seems satisfactory.

General Hospital.—The routine seems complicated

and the course long, but everything works so smoothly that men have been received into the General Hospitals in London in less than thirty hours after they have been wounded.

Immediate Treatment.—Experience teaches that when the first dressing has been applied the less the wound is touched the better it is for the patient. When it is possible to do so the bearers and orderlies should wash their hands before applying the first field dressing. Soaking in methylated spirit is more useful than the perfunctory wash which is alone possible even under very favourable conditions. When iodine is used as the disinfectant it should be applied directly to the skin. The mercurial salts, such as the biniodide or perchloride, cannot be employed, because they are useless when the pyogenic organisms are present in albuminous or oily substances. The mercury forms combinations with albumins which possess very slight antiseptic powers, and as the salts of mercury are not soluble in oil, micro-organisms lying in oily material are not reached by the antiseptic. Carbolic acid, like iodine, can be employed at this early stage, but the solution must be strong and may consist of a 1:20 solution. At the regimental aid-post, and again at the field ambulance, *the temptation to probe wounds must be steadily resisted unless there is some very good reason for doing so*, as it is unnecessary to make a detailed diagnosis at this stage of the patient's journey. It should be the rule, therefore, that the less a wound is interfered with until the journey is completed the better it is for the patient.

No form of aseptic dressing should be employed, but solutions of carbolic acid or of iodine may be applied indifferently.

As little dressing as possible should be undertaken on the ambulance train. The more serious cases are naturally those which must be re-dressed. They are stretcher or 'lying' cases, and they have to be carried in the 'fourgons' or luggage vans on the converted ambulance trains which are chiefly used in France. When such cases have to be re-dressed in transit they must be carried to the coach which is being used as a dispensary. This often entails a journey through several other coaches and over a corresponding number of open corridors connecting the coaches. The dressing necessarily gets soiled during the transfer from and to the original berth. Tunnels, too, are numerous, and the air in them is charged with smuts as a result of the constant traffic. More harm than good, therefore, is likely to be done by re-dressing wounds on trains unless there is an urgent necessity. When it is absolutely required every preparation should be made beforehand, plenty of antiseptic lotion should be used, and the dressing should be changed as rapidly as possible. The pain suffered during transit is often great, and morphia should be given liberally when this is the case. It is often difficult to sterilize the syringe when there is a full load, and a quarter to half a grain of the tartrate placed beneath the tongue is found to be more satisfactory in such cases than a hypodermic injection.

CHAPTER III

IMMEDIATE TREATMENT OF WOUNDS

(continued)

It must be clearly understood that laceration of the tissues and microbic infection are common to the majority of wounds received in action, whilst in many cases foreign bodies are present. Wounds, therefore, in soldiers cannot be treated quite like wounds in civil practice. It takes some time for sepsis to become established, and if the wound can be treated effectively within forty-eight hours of its infliction it may be possible to limit or even arrest the process.

Disinfection of Wounds.—As soon as possible, that is to say, as soon as the patient has arrived at some place where he can be properly nursed, he should be placed under an anæsthetic. A tourniquet having been applied, the skin should be thoroughly cleansed and disinfected. It should be scrubbed with a 1 : 20 solution of carbolic acid and ether soap. It should then be shaved and again washed thoroughly with the carbolic lotion, leaving a cloth saturated with the lotion over the whole area so as to protect the skin and continue the disinfecting process whilst attention is devoted to the interior of the wound.

The wound itself is disinfected, and if it is necessary to gain access to the deeper parts, as is usually necessary, the wound must be enlarged by

suitable incisions. The blood must be removed as completely as possible, for it will be found to have clotted and incorporated itself with the tissues, the wound must be rendered dry, and the skin, fat, and other structures which are visibly soiled with earth or dirt must be cut away. The wound being then held widely open by retractors, a piece of sponge dipped in liquefied carbolic acid is applied methodically to every part of the wound even to its inmost recesses. This strong acid, which turns the raw surfaces grey, should not be allowed to touch the skin because it acts as a caustic. The wound is dried again with a gauze pad, and the carbolic acid may be applied a second and even a third time if it has been much soiled. Five or ten minutes later it is washed out, first with 1:20 solution of carbolic lotion, afterwards with a $\frac{3}{4}$ per cent (3i ad 3i) salt solution, to reduce the chance of carbolic acid poisoning. The tourniquet is then relaxed, any bleeding vessels are tied, and a large drainage-tube is inserted into the bottom of the wound, a counter-opening being made wherever it is possible to do so. Any incisions made by the surgeon are then sutured, but no attempt is made to close the original wound unless flaps of skin have been formed, in which case they may be lightly brought together by a few stitches. The skin should be again washed with 1:20 carbolic lotion as it will probably have become soiled during the manipulation of the wound.

In the case of a wound on the trunk or neck where no tourniquet can be applied and where the bleeding, therefore, cannot be thoroughly checked, the disin-

fection is much more difficult and uncertain, because blood is constantly washing away and diluting the antiseptic. Under these circumstances the wound must be laid open freely and the bleeding arrested by clamping any bleeding-points, which, however, must not be tied at this stage as the ligatures will be rubbed off in the process of cleansing. The wound should then be firmly packed with dry gauze to arrest any oozing.

The skin is cleansed and disinfected in the manner already described, and attention is directed to the wound itself. The plug of gauze is removed and replaced by a smaller one so as to leave the skin and subcutaneous tissues exposed to view. The surfaces so exposed are then dealt with in the manner already described, badly soiled skin and fat being cut away and the surface thoroughly soaked with the antiseptic. Further portions of the gauze plug are then removed until the whole surface of the wound has been thoroughly disinfected. It is irrigated with a 1:20 carbolic lotion and afterwards with salt solution. Finally the vessels are tied and, in doing so, it is well to take off the forceps one by one, touch the tissues which have been clamped in the forceps with pure carbolic acid to disinfect them, clamp them again with a clean pair of forceps and then ligature.

When the disinfection is complete an antiseptic dressing should be applied, an ordinary piece of cyanide gauze with a covering of salicylic wool being highly recommended. More recently it has been

suggested that salicylic acid and boric acid in equal parts, as a powder called 'borsal', may be usefully employed to dust over wounds which have been thoroughly cleansed and dried.

It is perhaps necessary to add that during these manipulations the surgeon must himself be clean, for he should have washed and disinfected his hands; he should wear a pair of sterilized rubber gloves and be clothed in a clean 'overall'.

Preliminary Treatment in a General Hospital.—This method, which is recommended by Sir Watson Cheyne, from whose address on 'The Treatment of Wounds in War' (*The Lancet*, 1914, vol. ii, p. 1185, and *Trans. Med. Soc. Lond.*, 1915, vol. xxxviii, p. 34) it is mainly copied, is only suitable when the wound is seen within twenty-four or at the most forty-eight hours after the injury and before suppuration has begun to any great extent. It is unsuitable when the micro-organisms have already attained a firm hold of the tissues, as is frequently the case when the patient comes into a general hospital. In these cases he is put to bed, washed, and the soiled dressings carefully removed.

A thorough examination of the wound is made, its position, extent, and general appearance being noted. The nature and quantity of the discharge, and whether or not it is offensive, are also observed, and in every case some is sent to the bacteriologist for examination and report, as much valuable information can be obtained. The remainder of the discharge is then washed away by

gently syringing or irrigating the wound with peroxide of hydrogen of the strength of five volumes, i.e. one c.c. of the solution evolves five volumes of oxygen when it is decomposed. Peroxide of hydrogen is a weak antiseptic, but it has the advantage of not precipitating albumin, and it thus allows the purulent discharges to be easily washed out of the wound. It has the disadvantage of being rather painful when it is applied to a raw surface. A one in two thousand watery solution of iodine may be used instead of the peroxide of hydrogen.

Pressure should be made on the surrounding tissues as soon as the pus has been washed away to ascertain whether there has been any tracking of the inflammation and if so in what directions. It will usually be found that the sinuses have been formed beneath the superficial fascia and along the various intermuscular planes, both vertically and horizontally. A sterilized probe must be passed along each track to determine its extent and to ascertain whether any foreign body can be felt. The examination should be made carefully in a good light and without hurrying, since it is easy to overlook the minute orifice of a track which may prove to be of very considerable extent or may lead to a large and deeply-seated abscess. These various points having been elucidated, the wound is dressed with a compress soaked in a 1:2000 solution of iodine, or in a 3-5 per cent salt solution. A bandage is applied, and instructions are given for a skiagram to be taken. The dressing is renewed every four hours

when necessary, and the pulse and temperature are noted.

No operation is undertaken at this stage unless it is urgently needed, because, although the patient is a young and healthy adult, he has probably suffered much in the course of his journey and is temporarily exhausted by shock, pain, and fatigue. It is better to allow him time to recover if the preliminary examination shows that nothing urgent needs treating, rather than to take him at once to the operating theatre. This interval is profitably filled by obtaining reports from the bacteriologist where necessary, from the neurologist, and always from the radiographer.

Bacteriological Report.—The pathologist is asked to examine more especially for the presence of staphylococci, of streptococci, of tetanus bacilli, and of the bacillus perfringens. Staphylococci and streptococci are nearly always found, tetanus bacilli very frequently, and the bacillus perfringens (*bacillus aërogenes capsulatus* of Welch) not uncommonly. It is the organism which causes the characteristically offensive, thick, frothy, rusty-brown and sometimes almost fæcal discharge which commonly pours from the wounds in the earlier days after infection. Each of the organisms is dangerous in its own way. The staphylococcus and streptococcus cause cellulitis with much tracking along the tissues, and sometimes erysipelas or septicæmia. The tetanus bacillus, under conditions favourable to its growth, causes lockjaw. Welch's bacillus invades the tissues, generates gas, and produces the obstruc-

tive form of gangrene known as gaseous or emphysematous gangrene.

Neurologist's Report.—The report from the neurologist is of the utmost importance, and should deal with the central as well as the peripheral nervous system in every case where it is suspected that there has been a nerve lesion.

Radiographic Findings.—The findings of the radiographer are often full of surprises and should never be omitted. A harmless-looking graze of the skull may be found to be associated with a depressed fracture of the vault, wholly without symptoms, and yet needing an operation of considerable magnitude to enable the splintered fragments of the inner table to be removed as soon as possible and before they have caused irritation. A fracture diagnosed as uncomplicated may resolve itself into a longitudinal splitting of the bone involving the neighbouring joint. A joint thought to be slightly injured may be seen to be hopelessly shattered. Bullets, pieces of shell, and extraneous metal carried into the tissues accidentally are also well seen.

Too much, however, must not be demanded of the radiographer in the case of foreign bodies. The skiagram shows, indeed, the presence of a metallic foreign body, and its position and depth from the surface may be localized with a fair degree of accuracy. Its exact localization, especially if a foreign body is small and deeply lodged in muscle, is still difficult, and in most cases the appearances shown by the skiagram can only be taken as approximately its true

position in the tissues. The radiographic findings, therefore, must in every case be checked by careful clinical examination, lest, for example, a bullet which is thought to lie in contact with the back of the humerus is found to be situated in the subcutaneous tissue at the back of the arm.

CHAPTER IV

TREATMENT OF WOUNDS (*continued*)

A FEW days' rest in bed with the application of compresses or the assiduous fomentation of the wound and, where possible, with the use of an arm or leg bath (p. 47) for an hour twice daily, makes a wonderful change in the appearance of the injured part. Sloughs come away, the discharge ceases to be offensive, is thicker and is diminished in quantity. The exposed and injured tissues are covered with healthy granulations and the edges of the wound show a tendency to heal, for they shelve towards the base of the wound and have a bluish white edge of growing epithelium.

Progress of the Wound.—The surgeon must not trust too much to appearances and leave the patient to be dressed by others, acting on their report. He ought to examine the wound himself once a day to make quite sure that the suppurating tracks are not extending beneath the apparently healthy surface and that no pockets of pus are accumulating deeply in the tissues at a distance from the wound. The gentle use of a probe and firm pressure exercised round the wound and directed towards it will usually produce a discharge of pus if such an abscess or sinus exists. It is imperative to lay open all collections of pus at once.

This can only be carried out satisfactorily under a general anæsthetic after the patient has been prepared in the ordinary way for an operation. It is better done at leisure in the operating theatre than in the general ward with the patient in his bed, because it is impossible to tell beforehand how much or how little will have to be done.

Method of Operating.—The patient is anæsthetized, the field of operation is cleansed with a $2\frac{1}{2}$ per cent solution of iodine in rectified spirit, and is surrounded with sterilized towels; the surgeon, dressed in a clean overall, having already disinfected his own hands by thoroughly washing them with soap and water under a tap, plunging them into a 1:500 solution of biniodide of mercury in spirit and afterwards putting on sterilized rubber gloves. When all is ready the skin and the wound itself is again swabbed with the solution of iodine, or, better still, the iodine solution is sprayed over the part by an ordinary coarse atomizer provided with a vulcanite nozzle.

A probe-pointed director is passed along each track, which is then laid open in its whole length by means of a straight bistoury or a scalpel made to run along the groove in the director. A bistoury is preferable to a scalpel because it has a longer and narrower blade. Due regard must be had to the anatomy of the parts when making the incisions, and care must be taken to avoid injuring important nerves and blood-vessels. When a sinus tracks directly downwards in a limb or passes deeply between the muscles and ends blindly it is better to enlarge it as far as possible and make

a counter-opening so that a large drainage - tube can be passed through its whole length.

The operation must be carried out thoroughly, for the tracking will continue and the incisions will have to be repeated unless the entire length of the sinus is laid open and it can be thoroughly drained to prevent pus reaccumulating. In the earlier part of his career the surgeon errs on the side of doing too little rather than too much. Before the dressing is applied the wound should be examined systematically for any foreign bodies, like pieces of clothing, which would not be shown in the radiograph. The bleeding is never serious and is controlled by a few layers of gauze, a good thick pad of absorbent cotton wool, and a firm roller bandage.

The wound is re-dressed on the day after the operation, the gauze being readily removed if it is adherent by gently syringing with a solution of peroxide of hydrogen. Drainage should be effected by rubber tubes, never by plugging. The secret of success in the treatment of these suppurating wounds lies in free incision and thorough drainage coupled with local baths and compresses or fomentations which are frequently changed. It consists in other words in the constant removal from the wound of the products of decomposition, leaving the tissues to exercise their normal power of repair.

Reasons for the Method Adopted.— Experience gained in recent wars has shown that the principles of aseptic surgery are not suitable to the treatment of wounds received on active service, and that

the application of antiseptics does not give the best results unless the wounded surfaces are exposed in their whole extent.

Recent investigations and the advance of the science of bacteriology are beginning to explain what is meant by the expression 'normal power of repair exercised by the tissues', and why the crude methods of the old army surgeons met with such success that, in a modified form, they must still be employed.

When a suppurating wound has been cleansed as carefully as possible a certain quantity of pus is still left in it, partly in the sinuses and pockets formed in the tissues, partly from the infected granulations. This pus furnishes a constant source of micro-organisms which continue to multiply but less rapidly in a well-drained wound than would have been the case if they had been sheltered either by leaving the wound untouched, by a swelling of the orifices of the wound, or by packing it with gauze plugs as is still done too often.

Healthy lymph exuding from an inflamed surface contains active phagocytes, and has in itself the power of preventing the growth of many forms of microbic life. Lymph fouled by any appreciable mixture of pus loses its bactericidal properties and even becomes a favourable culture medium.

The essence of treatment consists in promoting a free flow of healthy lymph into the infected areas, constant removal of the products of decomposition, and free access of air to the depths

as well as to the surface of the wound. This was brought about in former times by the freer admission of air, since waterproofing was unknown and very simple dressings were used by the best army surgeons. Poultices were largely employed. They promoted the flow of lymph, but they were themselves carriers of infection and are now replaced by fomentations and compresses, which should not only be sterile themselves but should be applied to a sterile skin by sterile hands. Care too is now taken to prevent the germs growing in one patient being conveyed to another, thereby producing worse results in consequence of intensive cultivation. The teaching of Lister, therefore, has proved especially fruitful in military surgery. It has enabled surgeons dealing with septic wounds to-day to return to the well-tried methods of the older surgeons, and, having discovered some of the pitfalls, to avoid them.

CHAPTER V

SUPPURATION AND ITS TREATMENT

The Causes of Suppuration.—Inflammation going on to suppuration is due to infection of a wound with micro-organisms which either have the power of killing leucocytes by the toxins which they form, or which set up such acute destructive processes in the tissues themselves as to lead to their death. In the one case pus is produced, and the pus burrowing in the loose connective tissue forms suppurating sinuses; in the other case cellulitis follows, and the connective tissue dies in larger or smaller pieces which are afterwards thrown off by the living tissues in the form of sloughs.

The two processes often occur simultaneously. In the majority of cases in healthy persons the inflammatory process is limited and, by appropriate surgical treatment, can be kept limited to the original seat of the wound. Extreme bodily fatigue, mental depression, the virulence of the organisms, and in some instances an apparent lack of defensive power in the tissues prevents such localization, and a general toxæmia follows which ends in the death of the patient unless very active measures are taken to arrest its spread.

The micro-organisms causing suppuration—the pyogenic organisms, as they are called—are most frequently staphylococci, which cluster in groups; streptococci

or chain-like rods; the bacillus coli, a small rod-shaped motile organism which is found normally in the human intestine; and the pneumococcus. The different groups of pyogenic organisms unfortunately are not incompatible with each other. One group usually predominates, but members of one or more of the other groups are nearly always present, and when they are thus mixed the virulence of the infection seems to be increased.

Signs and Symptoms of Suppuration.—The pulse and the temperature afford the best indications for the progress of suppuration. Pain, too, when it is present is a guide, for an aseptic wound is a painless wound. All three indications may prove fallacious, and they must be used in connexion with the local signs, which alone are of primary importance. Of the three the pulse gives the earliest warning of suppuration, the temperature the most certain, and the pain the most insistent, for the patient calls attention to the fact that all is not going well.

A rapid rise of temperature to 103° – 104° F. with a rigor or an equally rapid fall until the temperature becomes subnormal indicates an absorption of toxic products into the general system or infection with some more virulent organism than usual. A thorough examination of the patient both generally and locally should be undertaken at once, for any delay may seriously prejudice the chance of recovery. It is useless to order aspirin, phenacetin, or quinine, and await the result. Examine first, and then order such drugs as may seem desirable.

Examination of a Suppurating Wound.—A thorough examination of the wound should be made in all cases of suppuration. The points to be especially noted are its size, situation, depth, and connexion with other injuries. As regards the external appearances, the size of the wound, its nature, whether lacerated or perforating, and the character of the edges and surface, whether granulating or sloughing, are the most important. The discharge must always be submitted to bacteriological examination, for it is only by ascertaining the infecting agent that really scientific treatment can be applied.

A consideration of the situation and direction of the wound will give a clue to the possibility of future complications in connexion with arteries, nerves, or joints in the case of the limb or in connexion with the large cavities of the body in the trunk.

The depth and ramifications of the wound must be carefully explored with a probe once and for all, because it is bad practice to probe a wound daily unless there is some urgent reason for doing so. Much can be learnt afterwards whilst the wound is being dressed by gently pressing on the surrounding parts and noticing where the pus wells up in the wound. The presence of such foreign bodies—as pieces of clothing and accoutrements—which are not shown by the X-rays can often be discovered by the careful use of a probe.

Nerve lesions, whether complete or partial, should now be determined by the neurologist as accurately as possible and a record kept of the condition for future reference. The existence of injuries to bone and

the presence of foreign bodies impermeable to X-rays should also be ascertained by means of the fluorescent screen, or better still by skiagrams. Less disturbance of the tissues and less pain to the patient are secured by following this plan than the older one of manipulation and exploration.

Treatment of Suppuration. Suppuration depends upon the continued life of successive generations of pyogenic micro-organisms. Healthy and uninjured animal tissues are able to protect themselves from the organisms unless they are unusually virulent or are present in enormous numbers. The protective power appears to be inherent in the tissues partly as the result of tolerance which offers a passive resistance, partly to active bactericidal properties possessed by the leucocytes and the fluid medium in which they live outside the tissues—the lymph.

Principles of Treatment.—The broad principles of the treatment of suppuration, therefore, are the following: prevention of the multiplication of pyogenic micro-organisms; constant removal of the micro-organisms as they are formed, so that they are never present in overwhelming numbers; the maintenance of the affected tissues as nearly as possible in their healthy state; the acclimatization of the body to the presence of the toxins produced by the pyogenic microbes.

Some of these principles can be secured easily, others with difficulty, and others again only occasionally or not at all. Prevention of the multiplication of septicmicro-organisms is brought about by a knowledge

of their mode of growth. They are able to grow in the absence of oxygen, but the presence of oxygen does not inhibit their power of multiplication. They differ in this respect from such disease-producing germs—pathogenic organisms—as tetanus (p. 91) and the bacillus perfringens (p. 96), which will only grow when oxygen is absent. The ordinary pyogenic organisms are called facultative anaërobes, whilst the pathogenic microbes are compulsory anaërobes.

Pyogenic organisms flourish where the vitality of the tissues is reduced, either by injury or by interference with the lymph flow owing to pathological or physiological changes in the vascular and nervous supply of a part or the whole of the body. The multiplication of pyogenic micro-organisms may be hindered by the action of chemical substances in such dilute solutions that they exercise no appreciably bad effects upon the tissues; in other words the pyogenic micro-organisms are more easily destroyed than the living tissues in which they flourish.

Antiseptics.—The modern treatment of suppurating wounds depends very largely upon an application of these principles. The chemical substances used in solution to hinder the multiplication of pyogenic microbes are known generally as antiseptics. Surgeons of equal experience differ greatly as to which antiseptic gives the best results. Some believe absolutely in carbolic acid and its compounds, others in the soluble salts of mercury, others again in dilute solutions of iodine, whilst others employ nascent oxygen obtained from a solution of hydrogen peroxide or from a stream

of oxygen allowed to play upon the wound. One remedy does not seem to give better results than another, none is infallible, and benefit is often obtained by changing the application from time to time. Broadly the antiseptic which a surgeon is most accustomed to use gives in his hands the best results.

Drainage of Wounds.—The constant removal of the micro-organisms and their products is an essential feature in the treatment of wounds as has already been stated. This is effected by free drainage of the wound. The drainage may be active by the use of free incisions and drainage-tubes, or it may be passive by abandoning plugging of the wound, which prevents the free escape of discharges.

The use of plugging for wounds is still much too general even by those who are well aware of the necessity for a free escape of discharges as soon as they are formed. It seems to be one of the last relics of the ancient surgery which kept wounds open by the use of tents. When a drainage-tube is used properly it is of sufficient size not to be blocked by blood-clots and sloughs, and it is so introduced that it is not compressed in the depths of the wound until nothing is able to pass through it. When a wound is plugged the strip of gauze is pushed in tightly, often in the desire to stop bleeding, and it is left unchanged for twenty-four hours. By this time it is soaked with the discharges from the wound and is an efficient nidus for the rapid multiplication of the pyogenic organisms. It is better not to use plugging at all

in wounds, but when it is unavoidable, the plugging should only be put in lightly and it should be removed at the earliest possible opportunity when it has served its purpose. What has been said of gauze plugging applies equally to gauze wicks in the case of suppurating wounds.

The drainage of wounds is best effected by the use of free incisions, which must be made under a general anæsthetic to enable them to be sufficiently thorough. The amount of scarring is of little importance in comparison with the danger attending an imperfectly drained septic wound occurring as a result of gunshot injuries. Many perforating wounds of the limbs will be found to have septic tracks which are bounded by the deep fascia and are therefore practically subcutaneous. It is better practice to lay these open in their whole length than to enlarge the two external wounds and put in drainage-tubes. The suppuration in the deeper wounds will often be found to track along the intermuscular planes, and these can easily be incised without injury to the muscles themselves or to the structures lying between them.

It is essential that every ramification should be followed up and laid open to its blind extremity, or the tracking will continue and the whole operation will have to be undertaken again. Sloughs and granulation tissue should be gently scraped away and the sinuses can be disinfected with iodine, carbolic acid, or biniodide of mercury. If there is much oozing a dry dressing of sterilized gauze can be applied for three or four hours. The gauze should be removed as soon as the

bleeding has stopped and a fomentation or compress should be applied.

It is equally essential in every case that the person who applies the dressing should have clean hands, and if many dressings have to be done it is well that rubber gloves should be worn not only for the safety of the patient but to prevent the surgeon himself from becoming infected.

Fomentations.—A fomentation is made by cutting a piece of boracic lint or ordinary white lint considerably larger than the wound. Pour boiling water over it, or put it into a saucepan of boiling water. The water is then wrung out by putting it into a wringer or twisting it up in a clean towel until it is dry. The lint is then spread out and applied directly to the wound. It is very necessary to wring out the fomentation until it is quite dry, as otherwise the patient will be blistered. If the fomentation is insufficiently wrung out it will be wet and will cling to the surface of the skin, which thus becomes scalded; if it is merely damp a layer of vapour will intervene between the lint and the skin, which will thus escape injury. A piece of macintosh or oiled silk is placed over the fomentation, care being taken that the waterproof material is considerably larger than the underlying lint, and the dressing is kept in place either with a roller or a many-tailed bandage. It should be changed at least once every four hours.

Compresses.—A wet dressing can be employed in place of a fomentation. It is called a compress and is made by saturating lint in some antiseptic solution.

The solutions chiefly employed are iodine (one drachm of iodine lotion to the pint, see page 46); carbolic acid (1:20 or 1:40), salt solution (3-5 per cent); boracic or boric acid (20 grs. to the ounce); boroglyceride, which is a glycerine of boric acid; boric lint.

A wet dressing is applied by soaking gauze, lint, or absorbent wool in the antiseptic solution, applying it to the wound, and covering it with waterproof to prevent evaporation. The dressing should be changed every two to four hours if there is much discharge, less frequently as the discharge diminishes in quantity. A fomentation as well as a compress should be large enough to cover a considerable area round the wound; the tendency of nurses and orderlies is always to make them too small.

The iodine compress seems to give the best results in well-drained wounds which are suppurating freely. It can be replaced from time to time by a lotion of carbolic acid. Salt solution is of less value as a deodorant, and, although it often clears up sloughy surfaces and converts them into granulating wounds which bleed rather readily, it is not so satisfactory a dressing as iodine or carbolic acid for any length of time. Boric acid and boroglyceride are more often used as fomentations than as compresses. They are not very serviceable in the earlier periods of acute and severe suppuration, but later when the wound is granulating they are used with great benefit. Peroxide of hydrogen is a useful temporary application for foul wounds. It maybe employed in a solution of 5 volumes

strength or it may be used as sanitas (an ounce to the pint). Peroxide of hydrogen is very useful in loosening dressings which have become dry and are adherent to wounds. It can either be syringed under the dressing or allowed to moisten it by pouring some over it.

Baths.—Baths are an essential part of the treatment of suppurating wounds. They may be either complete or partial. When a patient with a large suppurating wound of the trunk or thigh can bear it he should be transferred daily to a bedside bath, where he should lie for an hour or two.

A bedside bath requires 18–20 gallons of water, to which twelve ounces of a 1:40 iodine lotion are added if an iodine bath is ordered. The iodine lotion is made by dissolving two ounces of iodine and two ounces of potassium iodide in two ounces of water. A 1:40 solution is made by making up to 80 ounces with water.

The bath is prepared at a temperature of 100° F., care being taken that the hot and cold water are well mixed together and that the temperature is ascertained by means of a bath thermometer and not by the rough process of dipping a hand or elbow into it. Sufficient assistance is secured to move the patient from his bed into the bath without effort on his part. He is told to put on a pair of bathing-drawers, and when he has been lowered into the bath a blanket is put over his shoulders and another over the top of the bath. A screen is put round and in a ward the bath is given in front of the fire. The temperature of 100° F. is

maintained by adding fresh water at a temperature of 200° F. as often as may be necessary, a corresponding quantity of water being taken out of the bath each time. A bath thermometer is kept in the bath during the whole time of the patient's immersion, and when fresh hot water is added it must be poured into the bath in such a manner as not to scald the patient. A nurse or orderly must be in attendance during the whole time the bath is being given lest the patient faint or find the fatigue is too great to be borne. At the end of the time ordered, sufficient assistance to move the patient is again obtained. He is lifted out of the bath, dried thoroughly, and the wound is dressed as soon as he has been put back to bed.

Arm baths and leg baths are usually medicated by the addition of some antiseptic; iodine, carbolic acid, biniodide or perchloride of mercury, sanitas, and boric acid being those chiefly employed. The bath is filled with sixteen pints of water at a temperature of 100° F., the amount being measured. When an iodine bath is ordered two ounces of iodine solution are added, i.e. one drachm to the pint.

The carbolic acid bath is made of the strength of 1:20, or if this is found to be too strong 1:40; the biniodide of mercury or mercuric potassium iodide bath is made by dissolving one large soloid (8.75 grams) in each pint of water. This makes a solution of the strength of 1:1000. It is necessary to see that the soloid is completely dissolved, for if solid particles of it lodge in the wound they cause pain and irritation. Half an ounce to an ounce of

sanitas is added to each pint of water to make a sanitas bath and the boric bath is made with lotio acidi borici. A local bath should be given for at least an hour morning and afternoon as long as the wounds are sloughy and discharging.

All baths whether bedside or local should be emptied, carbolized, and dried as soon as they are done with, and iodine baths should be decolourized by the addition of a sufficient quantity of 1 : 20 carbolic lotion.

Amputation.—It happens from time to time that the general health of the patient suffers so severely that it is necessary to amputate an injured limb in order to save his life. The general attitude of the surgeon towards amputation in military surgery as a secondary operation—that is to say as it is most likely to be met with in a base hospital—should be conservative. He should hold his hand until he is sure that so radical an operation is absolutely necessary and, when he is convinced in his own mind, he should get his opinion confirmed by consultation with a colleague.

The problem to be solved in military surgery differs materially from that occurring in similar cases in civil life. In military hospitals the patient is young, healthy, of good physique, and comparatively unconcerned about his future prospects. Greater risks can therefore be allowed to him than to the clerk or office boy in the wards of a civil hospital. There comes a time, however, when the patient begins to fail visibly and often rapidly in spite of all that can be done. He suffers from general absorption of septic

products from his wound. Worn out by pain he is unable to sleep ; his appetite fails, he is lethargic or restless, he looks pinched : his complexion is sallow or even jaundiced, his tongue coated ; the pulse rapid, increasing in rapidity from day to day ; the temperature oscillating from 99° to 103° F. with a still more rapid rise to a higher point associated with a rigor ; occasionally a profuse sweat ; the wound itself making no progress, perhaps not much discharge and what there is of an unhealthy character and swarming with pyogenic organisms.

CHAPTER VI

THE VACCINE THERAPY OF WOUNDS ¹

THE subject of immunity is one of great importance, more particularly in its application to the prevention and cure of infections resulting from wounds received in war. We study therefore not only the processes of resistance on the part of the body to the invasion by micro-organisms or their products, but also attempt to apply the knowledge thus gained in assisting the body to remove the micro-organisms or their products.

The Bacterial Flora of Wounds.—The first step therefore is to obtain some information as regards the nature of the bacterial flora of wounds, since the future course of treatment by vaccine therapy is based solely upon this. The bacterial flora of a wound varies considerably during the progress of a case, tending usually in the direction of simplification.

Most of the wounds sustained in this war present at first a complex infection in which six or more distinct species are present, including anaërobic organisms, so called from their inability to grow and multiply in the air, or atmospheres containing

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oxygen. These various types are overcome one by one until the wound is nearly healed, when only one species perhaps remains. Occasionally new forms obtain entrance into the wound, for example, the *Bacillus pyocyaneus*, which imparts a blue-green colour to the discharge.

This disappearance of micro-organisms appears to conform to a definite order in every case, presumably in the capacity of these micro-organisms to withstand the defensive mechanisms of the body. Accordingly, from a bacteriological point of view, the most instructive cases are those coming under observation soon after the infliction of the wound, and before any attempt has been made at healing. Subsequent investigations then indicate which organisms are of little importance and easily overcome, and those which persist and have an obvious clinical bearing. Further, such a mode of procedure would render apparent the special type of infection which was retarding healing, and the influence of vaccine therapy in accelerating the removal of the given infection.

The Nature of Wound Infections.

Methods of Pathological Examination.—In order to ascertain the bacterial flora of a wound two methods are available, and whenever possible these should always be carried out in conjunction. These two methods consist in making (*a*) microscopic films and (*b*) cultures, and it is very important to study both, more especially the former, as much additional information can thus be obtained.

The necessary materials consist of glass slides, a platinum wire, spirit lamp, gummed labels, and culture tubes of agar, serum, and peptone broth. Both films and cultures can then be made during the dressing of the wound with the expenditure of very little time and energy.

Preparation of Films.—The glass slide is carefully cleaned, and passed once or twice through the spirit flame to dry it and render it free from small particles and also bacteria. The platinum wire is held in the flame until it assumes a white heat.

The wound is now carefully examined, and an area selected which is likely to yield a representative flora, and from this a good loopful of discharge is collected on the sterile platinum wire. This is then carefully spread out on the clean glass slide to make a thin film suitable for subsequent microscopical examination. The glass slide is now dried by waving in the air, and then gently passed through the flame a few times in order to fix the film upon it. The name of the patient, rank, and ward is inscribed upon a gummed label and attached to the slide. The film is now ready for transmission to the pathologist, who will examine it by Gram's method of staining and report upon the general characters as observed microscopically, and the relative abundance of the micro-organisms found.

Preparation of Cultures.—Having made a film from the wound, it is advisable also to make a culture on agar, more particularly if vaccine treatment is considered possible and desirable. For this purpose the

platinum loop is again sterilized in the flame, and a small loopful of the discharge gently spread on the surface of an agar slope, or sown in a tube containing serum. Care must be taken in removing the cotton-wool plugging of the tube and also in holding the culture tube in a slanting position to avoid contamination as far as possible. The tubes after being labelled and dated are then ready for transmission to the pathologist, and this should be done with as little delay as possible to ensure their immediate repose in the incubator. The pathologist is thus provided with the necessary materials for reporting upon the general nature of the infection, and the means of isolating the pathogenic forms. The cultures form the starting-point in the preparation of an autogenous vaccine, the time involved varying from one to four days.

Results of Examination of Film.—A microscopical film prepared in the way described above, and examined after staining by Gram's method, would appear to be of importance in the early stages of wound infection. The presence of Gram-positive bacilli, i.e. the organisms which retain the gentian-violet stain, especially the thin rod-shaped forms, denotes the occurrence of anaërobes, and suggests that the wound is contaminated with earth organisms. These should always be regarded as danger signals, since we may expect and even anticipate that such wounds also contain the tetanus bacillus, or a gas-forming organism such as the bacillus aërogenes capsulatus (see p. 96) (= *Bacillus Welchii*).

Whenever films have yielded evidence of such organisms a prophylactic injection of tetanus anti-toxin should always be given, even if the patient has already received a previous injection at the field or clearing hospital. This has been the practice of the writer, and in cases where the tetanus bacillus has been demonstrated in the wound this procedure appears to have been fully justified. Further, before such wounds are thoroughly opened up and suitable drainage carried out it is advisable to administer anti-tetanic serum previously. Unless immediately causing tetanus or gangrene, it is found by film preparations that these Gram-positive bacilli or anaërobes are soon exterminated under treatment.

A group of organisms of the diphtheroid type also frequently appears in wounds, and since they are rod-shaped and retain Gram's stain, they may be mistaken for members of the anaërobic group. These, however, are easily differentiated in culture, especially when grown on serum and appropriately stained. In contrast to these bacilli which possess the particular property of retaining the gentian-violet stain, we frequently meet with rod-shaped bacilli which do not possess such powers. Of these the commonest met with in wound infections is the bacillus coli communis, but from repeated observations this organism does not appear to be of any great clinical import.

In the later stages it is found that the most persistent infections are due to the Gram-positive cocci of the types staphylococcus and streptococcus, and of these, the latter is the most potent in seriously

retarding the healing of wounds. Here again film examination and also cultures indicate the existence of a particular organism, and render possible a close study of the relation between the rate of healing and the bacterial flora of a wound. Further, as soon as it is apparent that any given infection is retarding healing, the effect of an appropriate vaccine can be ascertained, and experience has shown that the influence of such vaccines is peculiarly great. This form of treatment applies more especially to the various streptococcal vaccines, in view of the frequent occurrence of this form of infection in wounds received during the present war.

The General Principles of Vaccine Therapy.

Immunity.—The type of immunity which we attempt to produce by this form of treatment is spoken of as acquired immunity, which in its turn is divided into two kinds—natural and artificial. In the former case we have examples in such diseases as small-pox, scarlet fever, and typhoid, where immunity has been acquired as the result of the introduction of micro-organisms and their products into the body during the course of the disease. Artificial immunity, on the other hand, is produced by the injection of suitable doses of the appropriate organism into the body, generally with little or no ill effects.

The practical outcome of the advances in our knowledge of this problem enables us to apply these methods both for the prevention and treat-

ment of disease. For the purposes of prevention or prophylaxis we may use the vaccine preparations of the pathogenic micro-organism or serum containing the specific antibodies, the former method being known as active immunity in contrast to the passive immunity induced by the latter. As examples of active immunity we may refer to the use of cultures killed by heat in the protective inoculation against cholera and typhoid.

The chief advantage of active immunity is that it lasts for some months or in some cases even for years. It is, however, sometimes attended with general disturbance, and a temporary lowering of resistance (negative phase) for some days before immunity is actually acquired.

The most typical example of passive immunity is that of tetanus antitoxin, which is now being used very extensively for the prophylactic treatment of infected wounds in war. The injection of anti-tetanic serum is not attended with the same discomfort as the injection of anti-typhoid vaccine, but there is the disadvantage that the immunity is only passive and rarely lasts more than a week to a fortnight.

Treatment of Septic Wounds by Anti-tetanic Serum.

Technique.—Every septic wound which is liable to be contaminated with the tetanus bacillus should be treated by a prophylactic injection of tetanus antitoxin, the usual dose for subcutaneous injection being from 1,000 to 1,500 units. [See also p. 94.] The skin over the chest-wall or abdomen should be carefully cleansed

with ether, acetone, or iodine ; and a sterile glass syringe, of 10 to 20 c.c. capacity, provided with a sterile needle, employed for the injection. When not in use the syringe may be kept in a stoppered glass bottle filled with absolute alcohol, and if properly cleaned and sterilized before immersion, is always ready for use. It is important gently to warm the phial before introducing the serum under the skin, and to massage the skin area lightly after injection to allow of more rapid absorption.

This form of treatment is absolutely necessary in every case of wounds arriving from the trenches, and should be given without delay. The serum is obtained in most cases from horses which have been immunized against tetanus toxin, but it is possible that in view of the great demand other animals have been used for this purpose.

Anaphylaxis. — Frequently we find that certain persons exhibit a condition of hypersensitiveness or so-called anaphylaxis, and react to such a marked degree as to suggest that the immunity has been reversed. The so-called 'serum sickness' would appear to be of a similar nature, and a definite chain of clinical symptoms may follow an injection eight to thirteen days later.

The chief symptoms are fever, skin eruptions, (often urticarial in nature), pruritus, joint pains and swellings, and adenitis. As this condition often follows the administration of normal horse serum, it cannot be attributed to the antitoxic constituent of anti-tetanic serum.

In order to overcome these ill effects of 'serum sickness' the administration of calcium salts is recommended, preferably before the injection and for one or two days afterwards. The most useful form of calcium for this purpose is calcium lactate in doses of 10 to 20 grains given twice daily one hour before food. The pruritus may be relieved by the local application of sodium bicarbonate applied at short intervals.

The true form of anaphylaxis or hypersensitivity to horse serum has been frequently noted, particularly when the injection of serum is repeated ten to twelve days after the first injection. In such cases very well marked anaphylaxis may be induced, and may last for a very long time, consequently it is of great importance to record carefully the actual date of the first injections and to realize the possible danger when a second injection of anti-tetanic serum, or even of normal horse serum, is contemplated.

This sensitiveness may, however, be overcome, provided the second injection is given within a week of the first, the patient acquiring an increased immunity to the toxic effects of the serum by this procedure. Should this be rendered impossible, anaphylaxis may still be prevented by the subcutaneous injection of a minute dose of serum four hours before the full curative dose of serum is introduced. This interval of time may, however, be still further shortened if small intravenous injections be given one hour before.

The Preparation of Vaccines and their Application to the Treatment of Septic Wounds received in War.

The wounds sustained in action and calling for special treatment in clearing hospitals and base hospitals both abroad and in this country fall almost entirely under the category of acute bacterial infections. For the specific treatment of such acute infections two chief methods are at present available, namely, (*a*) the administration of an immune serum which contains antibodies to the particular organism contaminating the wound, or (*b*) a vaccine of the organism is given in an attempt to stimulate the patient's system to the production of antibodies.

Serum Treatment.—The first method would appear at first sight to be the most desirable, since it is possible to introduce the antibodies at once into the patient, but unfortunately the results have not been very convincing.

The chief disadvantage is the liability to anaphylaxis or serum sickness, and the remarks made above again apply in this case.

Dosage.—The serum is usually introduced subcutaneously in doses ranging from 25 to 50 c.c.; but if the symptoms suggest the need for rapid effects it is generally best to give an intravenous injection of serum mixed with normal saline solution. The saline is made with freshly distilled water and about 100 c.c of the anti-bacterial sera added to it, the whole being warmed to the temperature of the body before injection.

The serum in general use for the treatment of an infected wound is the anti-streptococcus polyvalent serum, and is best given in large doses as soon as possible after receiving the wound.

Vaccine.—The second method has received a very extensive trial in this country of recent years, with some striking results in chronic infections. With the acute bacterial infections, on the other hand, the results have not been convincing, partly on account of the lowered resistance (negative phase) to which they give rise, and also upon the time involved in a full course of treatment.

The principle of the injection of vaccines is to increase the immunity of the patient, but before this is attained the patient undergoes a period of lowered resistance. It is during this latter stage that serious consequences may ensue, and necessitate the adoption of much care and caution in their administration. This negative phase may, however, be considerably modified, provided that the initial doses of vaccines are small and slowly increased and a definite time allowed to elapse between each successive dose.

Preparation.—The vaccine is made from the appropriate organism or groups of organisms infecting a wound, and hence the necessity of obtaining representative cultures, according to the method described above. The cultures can be made at the time of dressing the wound, and the pathologist can utilize these, when necessary, for the preparation of the appropriate vaccine. It is usual to make a suspension of a forty-eight hours' culture in normal saline,

to count the organisms present, and make up from this suspension the requisite doses, the organisms being killed either by heat, or by the use of 0.5 per cent phenol in the saline used for dilution. The latter effectually kills all the organisms present in a very short time, and further has no harmful effects after injection.

Dosage.—With regard to the dosage required, this depends very largely upon the type of vaccine with which we are dealing; for example, a streptococcal vaccine is given in very small doses and gradually increased, whereas large doses of a staphylococcal vaccine may be given with little or no ill effects. As a general rule, however, it is far better always to begin with small doses, and increase them at definite intervals, carefully observing their effect upon the patient.

Since it is found that the chief infections of wounds, especially those where vaccine treatment is likely to be beneficial, are streptococcal or staphylococcal, we may confine ourselves to the lines upon which these may be applied. At the outset it is obvious that every case presents points of difference, and it is only by close co-operation between the surgeon and the pathologist that any good results can be expected from this form of treatment.

Uses.—It must be clearly understood that vaccine treatment does not attempt to cure and that it is far more successful for protective purposes than for actual treatment. The pathologist is often requested to make up vaccines for the treatment of wounds, where surgical interference is far more

desirable and much more efficacious. It is obvious that vaccine treatment is going to do no good in a case where there are multiple sinuses tracking in all directions, or where foreign bodies or pieces of dead bone are setting up inflammation in the surrounding tissues.

Method of Employment.—When a wound has been thoroughly opened up, and adequately drained, then vaccine treatment will be found to be a useful adjuvant in assisting healing. If cultures from such a wound show a streptococcus as the predominant organism, vaccine treatment with an autogenous vaccine or a stock streptococcal vaccine may be commenced.

The first dose of vaccine given should be from 5 to 10 million, and four to five days' interval must be allowed before the injection of say 20 million, but in some instances even a week may be permitted to intervene before the second dose is given. [See Figs. 1 and 2, pp. 66 and 67.] Successive doses are given of 20 million, 50 million, 75 million, 100 million, 200 million, and 250 million by subcutaneous injection, the usual precautions outlined above being adopted in every case. Should the infection be staphylococcal in nature, much larger doses may be employed, say 50 million, 100 million, 200 million, 500 million, and 1,000 million, with the same interval between each injection.

Treatment of Wound-infections by Sensitized Streptococcal Vaccines.

Sensitized Vaccines.—The principle of this method is to combine both anti-serum and vaccine treatment

together, and represents a considerable advance in our knowledge of the processes of immunization. It has been found that by simply bringing the organisms into contact with their specific immune serum, the antibodies present in the latter are fixed to the bacterial cells and can be separated out with them.

Preparation.—The streptococcal vaccine is first counted and then brought into contact with a good sample of anti-streptococcal serum, preferably Pasteur Institut A. S. serum, in a graduated centrifuge tube, and after allowing for the absorption of antibody from the serum the suspension is centrifuged out and the supernatant fluid replaced by normal saline. The suspension is again subjected to centrifugalization, the traces of serum attached to the organisms being thus removed. The vaccine is now killed by the addition of the required volume of phenol (1 per cent) saline, and is then ready for separation into the requisite doses.

Mode of Use.—In order to facilitate injection of such a vaccine, and to economize space as much as possible, a quantity of say 100 million sensitized streptococci per cubic centimetre of saline is placed in a sterile bottle provided with a thick rubber cap and sealed with molten paraffin wax. Another bottle containing 1,000 million per cubic centimetre is also made up.

To give such a vaccine all that is necessary is to warm gently the rubber cap in a spirit flame to melt the wax, and insert the sterile needle into the fluid, gently tilting the bottle to ensure complete

immersion of the point of the needle. The requisite dose may then be drawn up into the sterile syringe, and injected subcutaneously. For example, if we require a dose of 50 million sensitized streptococci we inject exactly 0.5 c.c. of the suspension from the 100 million bottle, and similarly graduated quantities for the larger doses from the 1,000 million stock bottle.

It is important always to shake the bottle before removing any of the contents, as the organisms tend to agglutinate and sink to the bottom, and also to seal off the perforation in the rubber stopper by gently heating in the flame after the needle has been removed.

Advantages.—The chief advantages to be gained by the use of this special form of vaccine treatment are three in number: (1) immunity is greatly accelerated; (2) there is no resulting lowered resistance such as is met with in ordinary vaccine treatment; (3) the local and general reactions are totally eliminated. In view of these points it is possible to give much larger doses of vaccine, and with a much shortened interval between each injection, and further there is no danger of any serum sickness or anaphylaxis such as results from ordinary serum treatment.

By supplying the specific antibodies attached to the organisms themselves the work of the phagocytes is lightened, and they are then able to devote the whole of their energies to dealing with the toxins in the bacteria present in the wound. In the acute wound infections where streptococci are present, and are in all probability the cause of delayed healing,

such vaccine treatment has been adopted with most striking results.

Dosage.—It is usual in a severe case to give injections of 100 million, 250 million, 500 million, and 1,000 million on successive days, and almost invariably the clinical condition, both locally and generally, has been much improved. The more chronic conditions do not require such intensive treatment, doses of 50 million, 100 million, and so on being given every second or third day.

The effect of such injections upon the general and local conditions has been carefully observed in a number of patients suffering from severe wounds received in the present war. From the temperature charts alone one may infer that the vaccine has been of benefit, but in several cases the patient himself has volunteered information as regards the effects upon his general comfort, appetite, and sleep. Cases can be cited where the results have been almost miraculous; but there are others where the vaccine has proved to have had very little if any effect; but the latter are in a small minority.

The injection of a vaccine which does not give rise to any ill effects, and can be given daily, has also a marked psychical effect upon the patient, and he himself feels that everything possible is being done by bringing up large reinforcements for the war that is being waged against the invading bacteria. The combination of serum and vaccine therapy, as illustrated by the use of a sensitized streptococcal vaccine, would appear to have much to commend it, not only

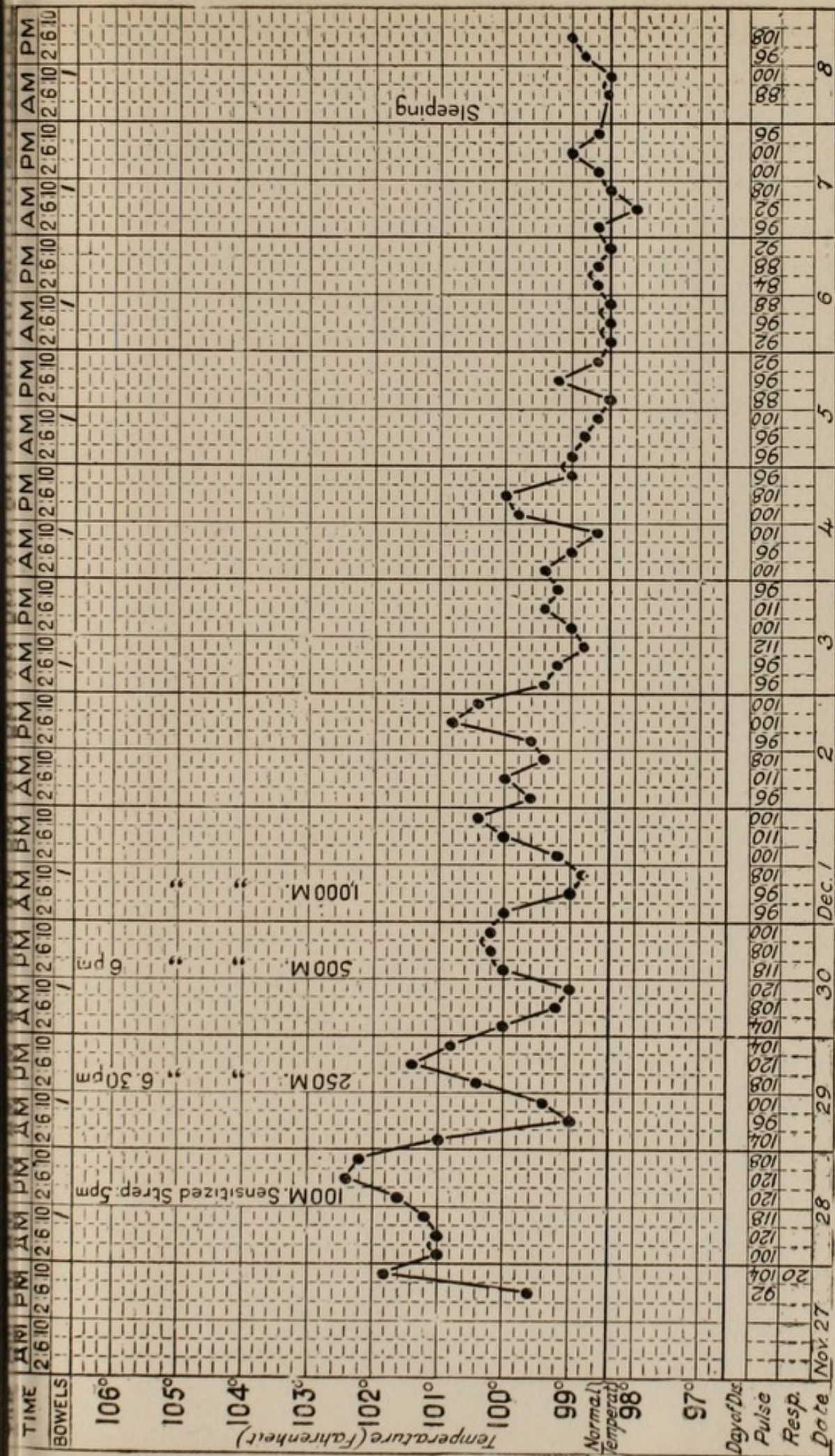


FIG. 2. Lt.-Col. C. This patient received eleven shrapnel and rifle-bullet wounds in different parts of the body. In eight of the wounds pure cultures of streptococci were obtained. The influence of sensitized streptococcal vaccines is well shown in the temperature chart. There was also marked improvement in the condition of the septic wounds under this treatment.

in the treatment of wounds, but also as a prophylactic measure. The rapidity of its action, and the absence of any local or general reaction, appear to be a sufficient justification for giving a prophylactic injection, of say 100 million dose, in every septic wound case arriving in hospital.

CHAPTER VII

RESULTS OF WOUNDS

THE results of wounds may be classified into immediate and remote. The immediate results are shock, hæmorrhage, and pathogenic infection; the remote results are the permanent disability caused by injury to the bones, joints, nerves, and arteries, as well as to the effects of the cicatrization of scar tissue of a peculiarly dense character.

Shock.—Of the immediate sequelæ shock is the most alarming but in reality the least serious. As it is seen in the general hospitals it comes on when the patient—often a boy of the better class—has arrived at home and is safely in bed. He has not inherited a very sound nervous system. He has been obliged to take an undue share of responsibility. He has been wounded and has lost much blood and has undergone the fatigue of a long journey in pain amidst very depressing surroundings. Ensconced at last in bed it is not surprising that his nervous system gives way and he passes into a state of the deepest shock. He looks death-like, his pupils are dilated, he is unconscious or may be delirious, his pulse is rapid but hardly perceptible, his breathing is shallow, his skin hot and dry, his temperature rapidly rising until it may reach $103-104^{\circ}$ F.

The treatment must not be too active, for the condition is due to exhaustion of mind and body. The surgeon should assure himself that there is no organic cause for the shock, and should then place the patient in a quiet, darkened, and cool room. Small quantities of soup alternating with black coffee will prove restorative, the pulse will become slower, the respirations deeper, and the pupils smaller. The comatose condition is replaced by restlessness. If the patient shows no inclination to sleep paraldehyde may be ordered or half a grain of morphia may be given hypodermically. A sound sleep will restore the nervous system and when the patient awakens the shock will have passed off to a very large extent. Rest and quiet with good food will soon bring him back to complete convalescence.

Hæmorrhage.—Bleeding as it is seen in a base hospital is secondary hæmorrhage, that is to say, it is bleeding from a large artery or vein due to ulceration of its coats. It occurs, therefore, in connexion with septic wounds, and is seen most frequently in lacerated wounds of the face and limbs, and in amputation stumps. Its occurrence may be foreseen in some cases by observing the direction in which a sinus is tracking, and a rise in the pulse rate for a short time before the actual hæmorrhage may give warning of its approach. The onset most frequently is sudden. There is no warning until the patient feels his dressings are soaked or an attendant notices his faintness.

The condition is always one of extreme urgency and taxes to the utmost the skill and coolness of the

surgeon. It is useless as well as dangerous to attempt palliative measures in cases of secondary hæmorrhage due to ulceration of the vessel in a sloughing wound. Patients with suppurating wounds bear loss of blood badly, bleeding stopped temporarily is sure to recur and the patient's strength may then be so reduced that he fails to rally from a comparatively simple operation. Immediate and effective measures must be taken. A tourniquet is applied when it is possible, the bleeding is arrested by plugging and a firm bandage, by sponge pressure or by digital compression where it is impossible. The patient is then carried to the operating theatre and anæsthetized. The operation may be prolonged, it needs a good light, it is certain to be bloody, and a considerable amount of anatomical knowledge may be required. A competent assistant is required as well as a skilled anæsthetist.

The object of the operation is to expose the artery and ligature it where the coats are healthy. It is useless, therefore, to try and isolate it in the wound. It must be tied in its continuity and upon the proximal side. The sloughing wound or the previous amputation often obliterates many of the guides to the artery, which has therefore to be found by careful dissection in the line of its course. Perhaps the mistake most often made is to try to find the artery through too small an incision, for the longer the incision, within reason, the easier does the operation become.

An artery is generally exposed by cutting parallel with it. The external maxillary (facial), the subclavian, and the external iliac arteries are exceptions

to the rule because the incisions to find them are made transversely. Arteries which require ligature lie in vascular bundles, always with the vein or veins, and often with one or more large nerves in intimate relationship. The bundles are enclosed in layers of connective tissue and they lie between the muscles and—except in the case of the peroneal—not within them. Muscles, therefore, must be separated not divided to find them. The surest way to fail in finding an artery is to cut into the overlying muscles in the hope that the artery will be found below them. Methodical dissection in the anatomical line of the artery is the only way to expose it, and when there is difficulty in finding it, the tissues which have been drawn aside should be replaced that the surgeon may assure himself that he has not deviated from the true line. A single ligature of No. 3 silk should be employed and the incision should be closed with silkworm gut sutures without employing any drainage.

The arteries most likely to bleed as a result of ulcerative processes are the temporal, facial or external maxillary, carotid branches, axillary, brachial, radial, ulnar, gluteal, femoral, popliteal, tibials, and peroneal.

Temporal Artery.—The temporal artery passes over the zygomatic arch just in front of the pinna of the ear. The incision to expose it is made immediately in front of the antitragus crossing the zygomatic arch at right angles. The artery lies in dense cellular tissue with the vein posterior. It is one of the places where an arterio-venous aneurysm may be produced by a wound.

The Facial or External Maxillary Artery crosses the jaw immediately in front of the anterior border of the masseter muscle. It is easily exposed by cutting along the lower edge of the mandible, separating the fibres of the platysma and dividing the layer of fascia which attaches the artery to the bone. The mistakes made in finding it are to carry the incision too far backwards so that the masseter is encountered and failure to remember that the platysma is often of considerable thickness. The facial or external maxillary vein lies on the masseter muscle, that is to say to the lateral or outer side of the artery and at some distance away. The anastomosis on the face is very free, and it is necessary to secure the artery distally as well as proximally, by the application of two separate ligatures above and below the bleeding-point.

Carotid Branches.—Secondary hæmorrhage from the carotid region is nearly always from one of the branches of the external carotid since hæmorrhage from the main trunks is fatal before any operative measures can be adopted. If it threatens, however, the common carotid should be tied as a measure of precaution. In an emergency it is quicker and easier to tie the common carotid than to expose the external carotid.

The incision is made along the anterior border of the sterno-mastoid muscle without opening its sheath. The centre of the incision is opposite the cricoid cartilage. The skin and platysma are divided and the incision is continued until the upper edge of the omo-hyoid is seen, its fibres forming an angle with

the sterno-mastoid muscle. The carotid artery lies immediately beneath it. In this part of its course the carotid artery lies in a sheath with the vein to the outer side and the vagus nerve beneath it. The sheath must be opened well on the inner side to avoid the vein, and the aneurysm needle carrying the thread is passed from the outer to the inner side. When once the main artery has been found, an incision carried upwards will quickly expose the bleeding-point, should it be from the superior thyroid, lingual or facial branches near their points of origin from the external carotid.

Subclavian Artery.—Wounds at the root of the neck may lead to secondary hæmorrhage from the subclavian itself or more frequently from the vertebral or from the branches of the inferior thyroid artery, viz. the inferior thyroid, the transversus cervicis, or the transverse scapular. The difficulty in finding the bleeding-point in these cases is considerable, because the vessels lie deeply in loose connective tissue and they are partly hidden by the clavicle unless the shoulder is depressed as far as possible. The subclavian artery is exposed in the third part of its course, that is to say external to the scalenus anterior by an incision carried along the upper border of the clavicle for at least three inches commencing at the outer margin of the sterno-mastoid muscle. The clavicular portion of the sterno-mastoid muscle will usually have to be separated from the clavicle for some distance in muscular men, and the deep layer of fascia is then cut through until the posterior belly

of the omo-hyoid muscle is seen running obliquely across the upper part of the wound. This muscle should be recognized, as it forms an important landmark. The artery lies below it and deeper. The dissection, therefore, is continued until the external border of the scalenus anterior (anticus) is found. The transversus cervicis and the transverse scapular arteries cross this muscle, the subclavian lies beneath it and upon the first rib. The aneurysm needle, if the artery is to be tied in its continuity, is passed from above downwards round the artery to avoid any chance of including the medial or lowest cord of the brachial plexus in the ligature.

The Axillary Artery may have to be tied in the first or third part of its course. In the first part it lies deeply below the clavicle, being covered by the platysma, pectoralis major and costo-coracoid membrane with the brachial plexus above and the axillary vein below. The superior border of the pectoralis minor marks the lower limit of the first part of the artery as the second part lies beneath this muscle. The superior thoracic and the acromio-thoracic arteries are given off by the axillary artery in the first part of its course, and secondary hæmorrhage may occur from either of these vessels as a result of wounds of the chest just below the clavicle.

The first part of the axillary artery is exposed by raising the arm to put the pectoralis major on the stretch. The surgeon stands between the arm and the thorax facing the patient. An incision is carried along the lower border of the clavicle for at least

three inches, terminating as soon as the cephalic vein is seen. This vein runs in a groove between the pectoralis major and the inner border of the deltoid muscle. Divide the platysma and the pectoralis major muscles close to the lower border of the clavicle. Retract the pectoralis major where it is cut and the costo-coracoid membrane will be seen. Divide this membrane. Pull downwards the upper edge of the pectoralis minor, the axillary vein will be found lying to the thoracic side of the axillary artery whilst the cords of the brachial plexus are on the outer side of the artery.

It may be necessary to expose the axillary artery in *the third part* of its course. The operation is performed by raising the arm and rotating it outwards so as to expose the axilla. An incision is then made along the medial (inner) border of the coraco-brachialis muscle, the fascia is divided and the artery is readily exposed having the axillary vein on the inner side with the inner head of the median, the ulnar, the medial cutaneous nerve of the forearm and the medial cutaneous nerve of the arm on the inner side, and the lateral (outer) head of the median and the musculo-cutaneous nerves on the lateral (outer) side. The hæmorrhage may come from the transverse scapular or circumflex branches of the main artery.

The Brachial Artery is easily exposed in the arm by an incision carried along the medial (inner) border of the biceps muscle if care be taken not to open the sheath of the biceps. In the middle of the arm the median nerve crosses in front of the artery from

the lateral (outer) to the medial (inner) side, and must be retracted carefully before the vessel is tied ; the ulnar nerve lies on the inner side of the artery. Two small venæ comites accompany the artery.

The Radial Artery often needs ligature either in the arm or at the wrist. It is not difficult to find the vessel if its relation to the brachio-radialis (supinator longus) is remembered and the lateral (outermost) intermuscular space in the front of the forearm is opened. In the upper third of the forearm the outermost interspace is between the brachio-radialis (supinator longus) and the pronator teres ; in the lower third the tendons to be separated are those of the brachio-radialis (supinator longus) and the flexor carpi radialis. Both these tendons are broad and neither of them should be mistaken for the narrow tendon of the palmaris longus. The radial nerve lies on the lateral (outer) side of the artery in the middle third of its course.

The Ulnar Artery is a little more difficult to find than the radial if the right interspace is not taken in the forearm. The line of the artery is from the front of the medial (inner) epicondyle of the humerus to the radial side of the pisiform bone at the wrist. The ulnar nerve lies to the ulnar side of the artery in two-thirds of its course. The incision to expose the ulnar artery is made in the line of the vessel and along the medial (inner) border of the arm. In the middle of its course the artery lies beneath the flexor digitorum sublimis on the radial side and the flexor carpi ulnaris on the ulnar side. This interspace is

a little difficult to find, because the edge of the flexor carpi ulnaris is very thin and slightly overlaps the flexor digitorum sublimis. The operator knows that he is in the right interspace, however, if he finds that he is separating a shining aponeurotic surface—the flexor carpi ulnaris, from a muscular surface—the flexor digitorum sublimis. The wrong interspace is being explored if there is muscular tissue on each side. The ulnar nerve is generally seen first, as the artery lies nearer the median line.

The ulnar artery is exposed in its distal or lower third by cutting along the radial side of the tendon of the flexor carpi ulnaris, immediately beneath which the artery lies with the nerve on its ulnar side. The aneurysm needle is passed from the ulnar towards the radial side to avoid the nerve.

The Superior Gluteal Artery.—The superior gluteal artery issues from the pelvis at a point about an inch external to the junction of the upper with the middle third of a line drawn from the posterior superior spine of the ilium to the middle of the outer lip of the tuberosity of the ischium; the inferior gluteal and pudic arteries emerge a couple of inches lower down. To ligature the artery, turn the patient on his face and make an incision in the buttock midway between the posterior superior spine of the ilium and the great trochanter. The incision should be at least five inches long. Separate but do not cut across the fibres of the glutæus maximus until the glutæus medius is reached. Divide the glutæus medius and the artery is exposed. The superficial branch of the artery

running beneath the glutæus maximus may be used as a guide to the main trunk if it is seen.

The Inferior Gluteal (*Sciatic*) and **Pudendal** (*Pudic*) **Arteries** leave the pelvis at the lower part of the great sacro-sciatic notch below the pyriformis muscle. The line of the arteries runs from the posterior superior spine of the ilium to the middle of the outer lip of the tuberosity of the ischium. The junction of the lower with the middle third of this line marks the point of emergence where the two arteries leave the pelvis, the spine of the ischium forming a good 'rallying point' as the pudendal artery crosses it.

The External Iliac Artery.—The external iliac artery is usually tied about two inches above the inguinal or Poupart's ligament by an incision running transversely to its course. The skin is divided half an inch above the inguinal or Poupart's ligament beginning just external to its centre and carried towards the anterior superior spine of the ilium. The aponeurosis of the external oblique and the muscular fibres of the internal oblique and transversalis muscles are divided, taking care not to cut too boldly lest the peritoneum be wounded. Pick up the fascia transversalis at the inner angle of the wound and divide it, again taking care not to injure the peritoneum. The division of the fascia transversalis is commenced at the inner angle of the wound because there is generally more cellular tissue separating it from the peritoneum at this point than elsewhere. The subperitoneal fat is separated, the peritoneum is gently drawn upwards, and the artery

is found lying upon the inner border of the psoas muscle with the internal iliac vein upon its inner side. The ligature is passed, therefore, from the inner towards the outer side of the vessel. The inferior epigastric artery rises from the external iliac about half an inch above the inguinal or Poupart's ligament and enters the sheath of the rectus abdominis muscle after passing through the fascia transversalis. It can be ligatured, therefore, in the first part of its course through the same incision as that for tying the external iliac itself.

The Femoral Artery often needs ligature for secondary hæmorrhage. Exposure of the vessel at the bleeding-point may show that the bleeding comes from some deeper vessel—usually one of the perforating branches. In such cases it is better not to continue a difficult dissection into the deep muscles of a well-developed thigh. The wound should be closed temporarily with a plug of sterile gauze, and the artery should be tied in the femoral or Scarpa's triangle at a point above the origin of the profunda femoris. The collateral circulation is not very free in a healthy thigh, the tissues, therefore, should be damaged as little as possible in exposing the artery. Clean incisions and gentle retraction of the tissues must be the rule if subsequent gangrene is to be avoided.

In Scarpa's triangle.—The line of the femoral artery is from a point midway between the anterior superior spine of the ilium and the symphysis pubis to the adductor tubercle at the back of the medial or inner condyle of the femur. It is important to

follow the exact line, for if the upper point is taken as midway between the anterior superior spine of the ilium and the spine of the pubes the artery will not be found so easily. The femoral or Scarpa's triangle is bounded externally by the sartorius and internally by the adductor longus muscles. The femoral artery runs through the centre of the triangle with the femoral vein on its inner side in the upper part of the triangle and almost behind it at the apex of the space. It is well to tie the artery high up in the femoral triangle if the operation is performed in this part of its course. An incision is made in the line of the artery, the thigh being abducted and the knee bent. The tissues are divided until the medial (inner) border of the sartorius is seen, its fibres running downwards and medially. The sartorius is drawn to the lateral (outer) side and the sheath of the femoral vessels is seen at once. The sheath is opened over the artery and the needle is passed from the medial to the lateral side to avoid the vein, which there is considerable risk of injuring unless the aneurysm needle is used very gently.

In Hunter's Canal.—The femoral artery has also to be ligatured in the adductor canal. The canal lies in the middle of the thigh, and is formed by the meeting of the vastus medialis (internus) on the lateral (outer) side with the adductor longus and magnus on the inner side. The union is completed by an aponeurosis, and the canal thus formed contains the femoral artery with the femoral vein behind it and slightly external, the long saphenous nerve being superficial and crossing from the outer

to the inner side. The sartorius muscle lies superficially. It is not difficult to tie the artery in the adductor canal if care be taken to cut in the line of the vessel, not to carry the incision too low in the thigh, and to recognize the sartorius muscle. The lower limit of the incision in the line of the artery should be a full handbreadth above the medial (inner) condyle of the femur. Division of the superficial and deep fasciæ brings the sartorius into view. The muscle is known by the direction of its fibres, which run downwards and medially. The vastus medialis (internus) is often mistaken for it, but the fibres of the vastus medialis run downwards and laterally (outwards). The lateral (outer) border of the sartorius is clearly defined, and this muscle is then drawn to the medial (inner) side of the incision. The roof of the adductor canal is thus exposed, the position of the underlying vessels being often marked by a small vein which passes through the fascia. The aponeurotic covering is incised, and the artery is ligatured by passing the aneurysm needle from within outwards. The *anastomotica magna* or *arteria genu suprema* can be exposed at the point where it leaves the popliteal by prolonging the incision downwards for about an inch.

The Popliteal Artery can be tied in the upper part of its course through an incision carried upwards from the adductor tubercle along the hamstring tendons. When these tendons are exposed they should be retracted towards the popliteal space together with the tendon of the sartorius. The artery lies in loose fatty

tissue between the hamstrings and the adductor magnus which is left untouched. The popliteal vein lies to the outer side of the artery in this part of its course, and the aneurysm needle, therefore, is passed from the lateral side of the artery to avoid including the vein in the ligature. This incision has the further advantage that the *anastomotica magna* or *arteria genu suprema* artery can be tied through it if it is found to be bleeding.

In the Popliteal Space.—The popliteal artery may also have to be tied in the popliteal space itself. The patient must then be turned as nearly as possible on his face. The artery lies deeply in the popliteal space, its direction being from within outwards; the popliteal nerve and the popliteal vein, both structures of first-rate importance, lying superficial to it as they are seen during the operation.

The incision to expose the popliteal artery in the ham is carried obliquely from within outwards, but before it is made the surgeon should verify the position of the medial (inner) condyle of the femur, as the patient is now lying upon his face. The skin is divided for at least four inches, and care is taken to avoid or else to clamp in two places and divide the external saphenous vein which joins the popliteal vein in the middle of the space. The internal popliteal nerve is seen as soon as the deep fascia is divided. It should be drawn to the lateral (outer) side. The vein and artery are next seen, and the vein overlies and is so intimately attached to the wall of the artery that considerable difficulty and great care are required to separate them. The vein

runs across the artery from the outer side above to the inner side below. There is consequently a greater interval between the artery and the vein in the proximal and distal part of the popliteal space than in the middle. It is better, therefore, to begin the dissection either above or below and not at the point where the artery is to be tied. The ligature is passed from without inwards.

When a large artery like the subclavian or popliteal is associated with extensive laceration of the tissues and has to be tied for a secondary hæmorrhage, it is probably the better practice to amputate at once.

The Anterior Tibial Artery usually needs ligaturing in the middle and distal thirds of the leg. The line of the artery runs from the mid-point between the heads of the tibia and fibula to mid-way between the medial and lateral malleoli. It is in close relation throughout its course to the lateral (outer) border of the tibia and is under cover of the tibialis anterior. It is easily exposed in the middle and distal thirds by an incision carried along the lateral (outer) border of the tibia. The deep fascia is then divided at the interspace between the tibialis anterior on the tibial side and the extensor proprius hallucis on the fibular side. Care must be taken not to go between the extensor proprius hallucis and the extensor digitorum longus. The artery lies on the interosseous membrane close to the tibia with the deep peroneal (anterior) tibial nerve on its lateral side or lying superficial to it. There are two venæ comites accompanying the artery. The ligature is passed from the nerve towards the bone.

The Posterior Tibial Artery.—The posterior tibial artery lies deeply in the middle of the leg under cover of the gastrocnemius and soleus muscles, but separated from the interosseous membrane by the tibialis posterior, the flexor digitorum longus and the flexor hallucis longus. It is a difficult vessel to find unless great care is taken in dividing the different structures. When the artery has to be tied in the middle of the leg an incision at least five inches in length is made about half an inch behind the medial (inner) border of the tibia. The great (internal) saphenous vein is retracted to the tibial side, the medial (inner) edge of the gastrocnemius is drawn to the lateral (outer) side in the whole extent of the wound. The tibial attachment of the soleus then comes into view. This is divided by cutting directly down upon the bone, and the cut edge of the muscle is retracted towards the lateral (outer) side. The deep fascia of the leg lies immediately beneath it. The fascia is divided and the posterior tibial artery is found lying upon the deep muscles nearly in the centre of the calf. The posterior tibial nerve lies upon the far side and the needle is passed from the fibular towards the tibial side of the artery. If the soleus muscle is not cleanly divided close to its tibial attachment the surgeon may find himself dissecting between its fibres and may miss the deep fascia beneath which the artery lies. On the other hand the deep fascia may be overlooked and the deep muscles of the calf exposed.

The Peroneal Artery.—The peroneal artery lies at first on the tibialis posterior and afterwards in the

fibres of the flexor hallucis longus. It is tied through an incision carried along the posterior surface of the back of the fibula in the middle of the calf. The fibular attachment of the soleus is divided and the deep fascia comes into view. Cut through the fascia and the vessel is found as it runs along the posterior border of the fibula. The peroneal artery is sometimes as large as the posterior tibial, and the hæmorrhage from it may be serious. The successful ligature of this artery at Brussels after the Battle of Waterloo is still remembered as a proof of the skill of Guthrie—the British Larrey.

Traumatic Aneurysm.—An aneurysm or an arterio-venous aneurysm often follows injury to an artery. In both cases the signs of the actual injury leading to the condition may be very slight. In the case of a true traumatic aneurysm the arterial wall may not have been completely perforated, so that there is no necessary history of severe arterial bleeding; more often there is evidence of arterial hæmorrhage which has been arrested without ligature.

Pathology.—The pathology is identical in each case. The wounded arterial wall is repaired by new fibrous tissue which yields under the pressure of the circulation and allows of the formation of an aneurysm, the arterial walls above and below the seat of the injury being healthy.

Symptoms.—The aneurysm presents itself as a pulsating tumour in the course of an artery. The pulsation ceases and the swelling diminishes when the artery is compressed on the proximal side of the tumour. The pulsation is distensile, that is to

say it separates the fingers or the hands placed upon either side of it, and a *bruit* is heard when a stethoscope is applied over the injured artery.

The artery may have been wounded by the passage of a foreign body through the tissues, so that the scar of entry may not be situated near the vessel; sometimes the surrounding tissues may be so inflamed that the pulsation is overlooked because no special examination is made to detect it. Both conditions have led to disastrous mistakes even at the hands of experienced surgeons. In the one case the aneurysm has passed unrecognized until it has ruptured spontaneously, in the other case it has been laid open in the belief that it was an abscess.

Treatment.—The treatment for a traumatic aneurysm is to ligature the artery above and below the tumour and remove it. The operation should be done whilst the aneurysm is still small and before it has contracted adhesions to the surrounding veins and nerves. It should not be done whilst the patient has any open wound, because it is of the utmost importance that the artery should heal by first intention to lessen the risk of secondary hæmorrhage and of gangrene from failure of the collateral circulation.

Arterio-venous Aneurysm.—Arterio-venous aneurysms follow injuries to the larger arteries when the corresponding vein lies in close relation to it. They are found most frequently in the neck between the carotid and the internal jugular; in the thigh between the femoral artery and the femoral vein either in the femoral triangle or in the adductor canal; more rarely

at the bend of the elbow and in the popliteal space; still more rarely at the root of the neck between the subclavian and its vein or the axillary and the axillary vein in the first part of its course.

Course.—The seat of injury, as in the case of an aneurysm, may be over the vessel or the scar may be at some distance away, and the initial hæmorrhage need not necessarily have been an alarming feature. Some days or weeks after the injury changes take place in the artery and the vein. The changes end in the formation of an aneurysmal varix when the blood passes from the artery into the vein, or in a varicose aneurysm, in which case a sac is interposed between the communication from the artery to the vein. The exact conditions which determine whether an aneurysmal varix or a varicose aneurysm is formed after an injury involving an adjacent artery and vein are not yet understood.

Symptoms.—The patient complains of pain and throbbing at the seat of injury, and in the case of the neck of headache and dizziness. He may also be conscious of a purring thrill—especially well marked in varicose aneurysms—which is sometimes so marked as to be audible to persons at a distance of several feet. In the case of an aneurysmal varix where the blood is driven from the artery into the vein, the vein becomes dilated and thickened near the seat of injury, distended and tortuous at some distance away. The affected vein pulsates.

Treatment of Aneurysmal Varix.—Aneurysmal varix may continue without material harm to the patient

for long periods of time. It is not usually necessary, therefore, to undertake any operation for its relief, and the condition may be treated in the case of the limbs by the application of a crêpe Velpeau bandage. When the varix shows a tendency to increase the injured artery and vein must be exposed. The two vessels should be separately clamped if possible above and below. The point of union should be carefully separated and the rents in each vessel should be sutured with a fine glover's needle and vaselined silk. The operation is difficult for one who is unskilled in arterial surgery, and if it is not practicable it may be necessary to ligature the artery above and below the point where it communicates with the vein. Care must be taken not to injure the vein lest gangrene should ensue.

Varicose Aneurysm.—A varicose aneurysm may develop as a result of an injury to an artery leading to the formation of an aneurysm which afterwards opens into an adjacent vein. In other cases it seems to result directly from a simultaneous injury to the artery and vein.

Cause.—It is a much more active condition than that of aneurysmal varix, for it follows in many respects the ordinary course of a traumatic aneurysm. In many instances it increases in size from the commencement, although in others it often remains stationary for considerable periods of time, and may then begin to grow. When it occurs in a limb it gives rise to a sense of weakness, and it becomes more or less adherent to the surrounding tissues.

Treatment.—The treatment is operative and should be undertaken as soon as the varicose aneurysm is diagnosed, as waiting only makes the operation more difficult, and it is almost certain that it will have to be undertaken sooner or later. The swelling should be exposed, the artery ligatured above and below and excised with the aneurysmal sac. The communication on the venous side should be closed without occluding the lumen of the vein.

Hæmatomata.—Hæmatomata of great size may follow injuries to the smaller vessels, rupture of traumatic aneurysms, and passive hæmorrhages into loose connective tissue which has been badly bruised. Such hæmatomata are often absorbed without causing trouble, but they need careful watching for they readily suppurate.

Treatment.—They must be laid open at once when there is evidence that they are increasing in size and are due to a ruptured vessel. In other cases the skin should be cleansed with soap and water, and a light gauze dressing soaked in lead lotion may be applied. When a hæmatoma has been opened the clots should be washed away with a 1:2000 watery solution of iodine at a temperature of 115° F.

CHAPTER VIII

TETANUS AND GASEOUS GANGRENE

THE two bugbears of military surgery are the tetanus bacillus and the bacillus perfringens, which is also known as the bacillus aërogenes capsulatus of Welch. The one causes tetanus, the other gaseous oedema and gangrene. Both organisms are anaërobic, and flourish, therefore, in suppurating wounds, the oxygen in these wounds having been used up during the growth of the pyogenic microbes.

Pathology.—The **tetanus bacillus** occurs frequently in cultivated earth which has been manured and is found normally in the intestines of herbivorous animals. It exists in several forms, being sometimes flagellate and sometimes in the shape of a drumstick, the enlarged end containing a spore. These spores are extremely resistant both to heat and such strong antiseptic solutions as a 5 per cent solution of carbolic acid. The bacilli are large and stain readily with watery solutions of aniline dyes. They were therefore amongst the earliest micro-organisms to be recognized.

The tetanus bacilli manufacture several poisonous substances when they multiply. The most important of these are **tetanospasmin**, causing the convulsions characteristic of the disease, and **tetanolysin**, which leads to destruction of the red corpuscles of the blood. It appears that the toxins are produced

locally at the place where the micro-organisms are growing—that is to say, in the suppurating wound—and are absorbed by the axis cylinders of the nerves. The grey matter of the spinal cord thus becomes poisoned and the signs of the disease are developed.

Symptoms.—Physiologically tetanus is marked by extreme reflex excitability of the spinal cord, leading to tonic contraction of the muscles, interrupted from time to time by irregular efferent discharges along the motor nerves, causing clonic spasms. The symptoms rarely appear before the second day after the injury, because the bacillus is a typical obligatory anaërobe. It will not grow where the smallest amount of free oxygen is present, and time is needed for the pyogenic organisms to complete their work. The incubation period is sometimes greatly prolonged, since it may be as much as three weeks or a month, and in such cases the wound has frequently healed. In many cases an examination of the abdominal muscles will show that they are in a state of tonic contraction some hours or days before the patient complains of symptoms. It is important, therefore, in cases of suspected infection; to make a practice of ascertaining their state of tension daily.

After a period of initial malaise, perhaps associated with a slight rise of temperature, the patient complains of a painful stiffness in the muscles of the neck and jaw—whence the name ‘lock-jaw’. The risus sardonicus due to tonic contraction of the platysma is often a marked feature. The tonic contraction is interrupted by painful spasms which vary in intensity from cramp

of individual muscles to terrible convulsions affecting large groups and drawing the patient into the most contorted attitudes. Death in the acute cases is due to cardiac or respiratory inhibition, the patient usually remaining conscious until the end.

Prognosis.—The prognosis is governed by the time of onset after the injury. The quicker the onset the more acute is the attack. Behring, working experimentally with mice, found that an amount of toxin corresponding to 13 lethal doses produced symptoms in 36 hours, 110 lethal doses caused symptoms in 24 hours, 1,300 lethal doses in 14 hours, and 3,600 lethal doses in 12 hours. Acute tetanus in man kills in one to four days, chronic tetanus lasts from six to ten weeks. Death occurred in 19 patients in whom the symptoms appeared during the first week; 3 out of 22 recovered when the symptoms appeared from 8–11 days after the injury, whilst 9 out of 12 recovered when the symptoms were delayed from 12–29 days.

Treatment.—Treatment consists in early recognition of the tetanus bacillus at the seat of injury, and this can only be done by a routine examination of the discharge from every wound received on the battle-field as soon as it is possible to obtain expert bacteriological advice. A bacteriological examination should also be made of suppurating wounds which are about to be subjected to further operation, lest a few tetanus bacilli lying latent should be led to grow under the new conditions.

Tetanus Antitoxin.—In doubtful cases where there

has been much contamination of the tissues a prophylactic injection of antitoxin should always be given. The tetanus toxins are rapidly fixed in the tissues, and by becoming incorporated with the central nervous system, which is more or less out of reach of the general blood stream, antitoxin is prevented from exercising its full effect unless it is given as early as possible. Antitoxin injections, therefore, have not been found as useful in tetanus as in diphtheria. It seems to be essential that the tetanus antitoxin should be injected before the symptoms have developed, if the best effects are to be obtained from subcutaneous injection. When the spasms have already begun it should be delivered by lumbar puncture into the cerebro-spinal fluid.

The antitoxin treatment consists in injecting at once 1,500 antitetanus units. This quantity is contained in ampullæ of about 9 c.c. each. The skin at the seat of injection is first cleansed with a $2\frac{1}{2}$ per cent solution of iodine in rectified spirit, and the injection is made subcutaneously as near as possible to the wound.

The wound must be looked upon as the local factory for the toxins, as it harbours the tetanus bacilli, and must be treated accordingly. Complete excision should be performed when it is possible, but if the site does not allow of this, the sloughing and suppurating surfaces must be thoroughly scraped and the remaining tissues cleansed with peroxide of hydrogen, a stream of oxygen, a solution of iodine, or a 5 per cent solution of carbolic acid. It is essential that the antiseptic employed should not coagulate the

tissue albumins. Free drainage must be provided, and any packing placed in the wound to arrest bleeding must be as light as possible. The dose of antitoxin must be repeated on the following day, and again on the third day. If the symptoms are held in check a further dose may be given on the tenth day.

When the symptoms have already developed, the contents of two ampullæ may be given (1,500–3,000 units) every six to twelve hours. It is said that chloretone is more effective than chloral in allaying the spasms. It may be administered in one drachm doses as an enema, dissolved in olive oil.

The Lister Institute of Preventive Medicine issues the following directions for the use of fluid tetanus antitoxin :

1. The syringe is manufactured entirely of glass and is of 10 c.c. capacity. It must be boiled for five minutes immediately before the inoculation is made, and it must be rinsed in cold water and then boiled for a minute after use.

2. The injection is usually made under the skin of the abdomen or flank. The swelling which results disappears in a few hours and a slight tenderness often remains for twenty-four hours. The skin must be well washed with soap and warm water and afterwards swabbed with a 1:20 solution of carbolic acid before the injection is made.

3. **Dosage.**—100 c.c. should be given subcutaneously at once; the quantity may be subdivided and injected into four different parts of the body. Another

100 c.c. should be repeated on the two following days, and a final injection should be given, even in favourable cases, ten to fourteen days after the first injection.

4. In certain wounds, such as compound fractures and shell wounds—especially where the wounds are soiled with earth and in certain districts where tetanus is known to occur—a prophylactic injection of tetanus antitoxin is strongly indicated. The prophylactic dose is 20 c.c. of fluid antitoxin injected subcutaneously.

5. Erythematous and other rashes and joint pains may sometimes appear from four days to five or six weeks after the injection. They are of no importance and need cause no apprehension. They appear to be much more common after the injection of some brands of antitoxin than after others. It seems, therefore, that they are dependent upon the serum used rather than any idiosyncrasy of the patient.

The serum should be kept in a dark and cool place, preferably in an ice-safe. It will then remain active for at least a year.

Gaseous Gangrene.

The bacillus *aërogenes capsulatus*, known also as Welch's bacillus and as bacillus *perfringens*, is the cause of many tragedies in surgery. The essence of a surgical tragedy being that the unforeseen happens suddenly, and infection with the bacillus *perfringens* often converts a trivial into a deadly wound.

Pathology.—It is a large rod-shaped and blunt-ended

organism occurring in pairs and irregular groups, motile but without flagella, and enclosed in a capsule which does not stain. It is anaërobic, and is found in undrained suppurating wounds.

Symptoms.—The symptoms following infection are quite uniform, consisting of redness and swelling of the wound with a quick pulse and rapid rise of temperature to 103° – 104° F. The wound generally becomes more or less emphysematous and discharges a thin, brownish offensive fluid, which contains bubbles of gas and is sometimes frothy.

The patient dies rapidly of heart failure unless immediate and very active operative measures are taken. The infective process continues after death unless the body is preserved in a cold chamber, and the swelling may rapidly become so great as to make the corpse unrecognizable. The subcutaneous tissue in these cases crepitates when it is touched, and the blood-vessels are full of an inflammable gas. Bacteriological examination of the discharge from the wound shows that the bacillus perfringens is associated with staphylococcus and bacillus coli in the majority of cases.

The incubation period is always short, from two to four days as a rule.

Treatment.—The infection spreads so rapidly that amputation high up affords the best chance of recovery when a limb is affected. A simple circular amputation without subsequent suturing of the tissues is advised. The raw stump thus exposed and lightly dressed with gauze allows the maximum access of air and affords an unsuitable nidus for anaërobic organisms. When the

stump has granulated another operation may be performed to make it more useful and sightly, but for the time being everything must be sacrificed to arrest the growth of the organism. If the wound is in a part where complete removal at a distance cannot be undertaken, very large and deep incisions should be made and the freest drainage must be provided by means of drainage tubes which are so large as to admit air to the tissues through which they run.

CHAPTER IX

AMPUTATIONS

THE broad principles governing the seat of amputation differ in the upper and in the lower extremities. The arm is used chiefly for delicate movements, and it is important, therefore, that as many of the muscles as possible should be preserved—that is to say that the stump should be as long as possible. The lower extremity is employed for the coarser movements of support and progression. A short stump with well-developed flexor and extensor muscles is preferable to a long one. A secondary amputation both in the arm and leg must be made at a sufficient distance from the wound to allow of the formation of uninfected flaps. This will often appear to involve much waste of tissue, for the amputation must be performed high up in the limb. The waste, however, cannot be helped, because the life of the patient depends upon securing union by first intention, as he will not stand the strain of further suppuration.

Seat of Amputation, Upper Extremity.—In the arm, when the hand and wrist are involved, it is better to amputate in the upper third, saving, if possible, the insertion of the pronator radii teres ; when the forearm is involved, amputation should be performed through the upper arm well below the insertion of the deltoid.

Lower Extremity.—Amputation through the leg is performed about three inches below the head of the tibia for suppurating wounds of the ankle-joint, through the lower third of the thigh for extensive injuries of the knee-joint, occasionally at the hip-joint itself.

Method of Amputation.—It is better to do all the preparatory cleansing of the skin on the operating table, when the patient has been anæsthetized, as he is thereby saved much pain and additional shock. The wounded area is carefully isolated by the application of a fresh dressing and it is wrapped in an aseptic towel. The skin at the seat of amputation is then dry shaved, washed with acetone, and rendered aseptic with a solution of iodine ($2\frac{1}{2}$ per cent in rectified spirit) which can be applied either by means of a dry swab or by a coarse spray. The limb is supported by an assistant and a rubber tourniquet is applied as near the trunk as possible. In the case of the arm the limb is drawn away from the side: in the case of the leg the patient's body is brought to the end of the operating table so that the leg hangs flexed at the knee. Aseptic towels are put in position, and the limb is once more treated with iodine.

The surgeon stands in such a position that he controls the proximal portion of the limb with his left hand, whilst his right holds the amputating knife. This means that a right-handed surgeon stands on the outer side of the limb to be amputated when it is the right arm or leg; inside the limb, i. e. between the limb and the body when it is the left side. The in-

struction seems needless, but failure to observe it has led to very disastrous mistakes, for the flaps have been formed from the stump instead of from the part to be removed.

If the flap method is employed the width of each flap should be half the circumference of the limb at the point where the bone is to be divided. It is best to make a long flap and a short flap, so that the scar may not be exactly over the cut end of the bone. The long flap is equal to half the circumference of the limb in length; the short flap is a quarter the length of the long flap—that is to say, one-eighth of the circumference of the limb. These flaps may be cut laterally in the forearm and in the leg; in the thigh and in the upper arm they are made on the extensor and flexor aspects. In every case they should consist of skin and muscle, and they should be so cut as to be of equal thickness, that the end of the bone may lie in the centre of the stump and be well covered by the soft tissues. In the lower third of the thigh it is not always necessary to use the whole of the flexor muscles, and the bone is exposed at the point of section by a circular sweep of the knife. Such a method has the advantage of ensuring that the femoral artery is divided transversely and is not split, as frequently happens when the whole of the muscles are raised in the flap. The flaps are well retracted and the bone is sawn at their base. The saw is used lightly, quickly, and in the whole length of the blade, the assistant who is holding the limb being warned to depress the part gently but to be careful not to break the bone when it is nearly

sawn through. When there are two bones, as in the forearm and leg, care must be taken to divide the intervening membrane with the amputation knife and to saw them both at the same time.

As soon as the limb has been amputated, the assistant who has been holding it goes behind the operator and raises the stump to give a good view of its raw surfaces. The main artery is recognized, freed from the vein and nerves which surround it, and clamped with a pair of pressure-forceps. The vein, if it is a large one, is also clamped, and both artery and vein are tied securely with a No. 2 or No. 3 silk ligature. Any other arteries whose position is known or whose cut ends become visible are ligatured. The main nerves are pulled gently out of their sheaths and are cut short with a scalpel to enable them to retract into the tissues and diminish the likelihood of a painful stump afterwards.

The tourniquet is then loosened, the assistant standing by to tighten it again if necessary. The rest of the bleeding-points are secured and the flaps are sutured with silkworm-gut sutures after the surgeon has assured himself that the bleeding is only an oozing and does not come from any considerable vessel.

It is unnecessary to put in a drainage tube if the amputation has been performed, as it ought to have been, through healthy tissues and the bleeding has been satisfactorily arrested. If there is any doubt on either of these points a drainage tube must be placed at either angle of the wound.

A dressing of gauze and absorbent wool is applied, and the stump is raised and allowed to rest on a pillow when the patient gets back to bed. Unless a considerable quantity of absorbent wool has been put on it is very likely that it will be necessary to 'pack' the dressing within a few hours, but there is no need to change it in the majority of cases, as the bleeding is more often an oozing than a true reactionary hæmorrhage. The dressing is renewed on the day after the operation and the drainage tube is removed. If the pulse and temperature continue satisfactory it need not be touched again until the stitches are taken out on the eighth day. It will be seen from this account that a secondary amputation differs in many respects from the primary amputation required shortly after the wound has been inflicted, or for the treatment of such acute infections as emphysematous gangrene. The good effects of a secondary amputation performed in a well-selected case are often little short of marvellous. The pain disappears, the temperature falls, sleep and appetite return, and a patient who seemed moribund quickly becomes convalescent.

In many cases it is impossible to fashion the flaps according to rule, and they have to be shaped from such healthy tissues as have been left by the wound and subsequent sinuses. When the tissues are infected, as is often the case, care must be taken not to suture the flaps too securely; it is enough if they are held together by a few silkworm-gut sutures, or they may be merely brought into apposition by strapping or a gauze dressing.

Circular amputation.—Circular amputations are useful in the thigh and upper arm. They are also performed as methods of urgency in other parts when the limb has become infected with anaërobic organisms. As a routine operation the cut end of the bone forms the apex of a cone and is therefore well buried in the surrounding tissues. The amputation is made by three circular sweeps round the limb with the amputating knife. The first sweep divides the skin and fasciae until the muscles are exposed. These are well retracted and a second sweep is made through the muscles down to the bone. The muscles in their turn are retracted and the third sweep divides any remaining tissues and the periosteum. The bone is sawn across at a point at least three inches above the line of the first incision. Care must be taken therefore not to cut through the skin too high in the limb.

The emergency circular operation is designed to expose the whole of the cross-section of the limb to the air. The tissues are not retracted and the bone is cut flush with the surface. The stump usually heals well, but it may be necessary to reamputate when the danger of infection is over.

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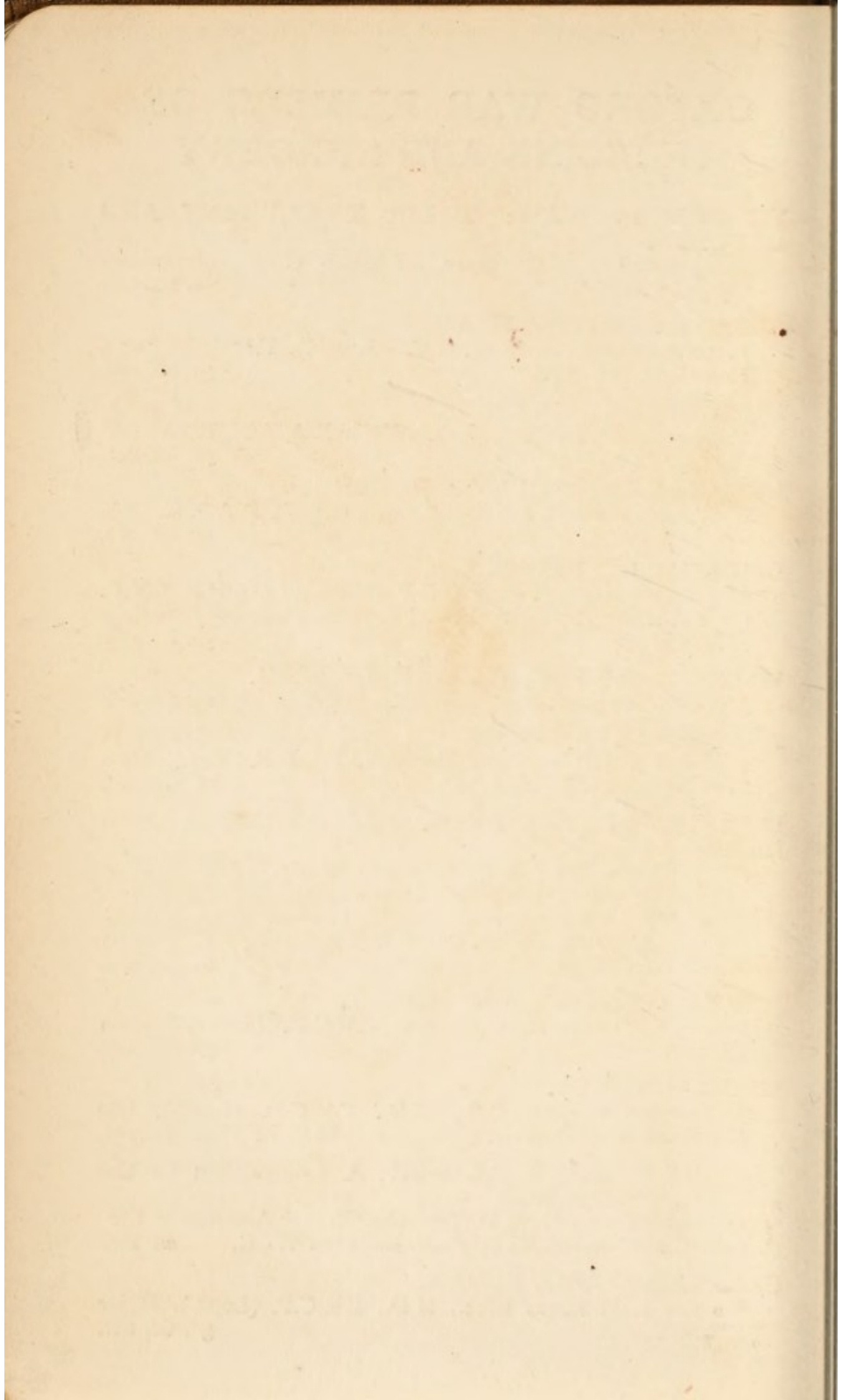
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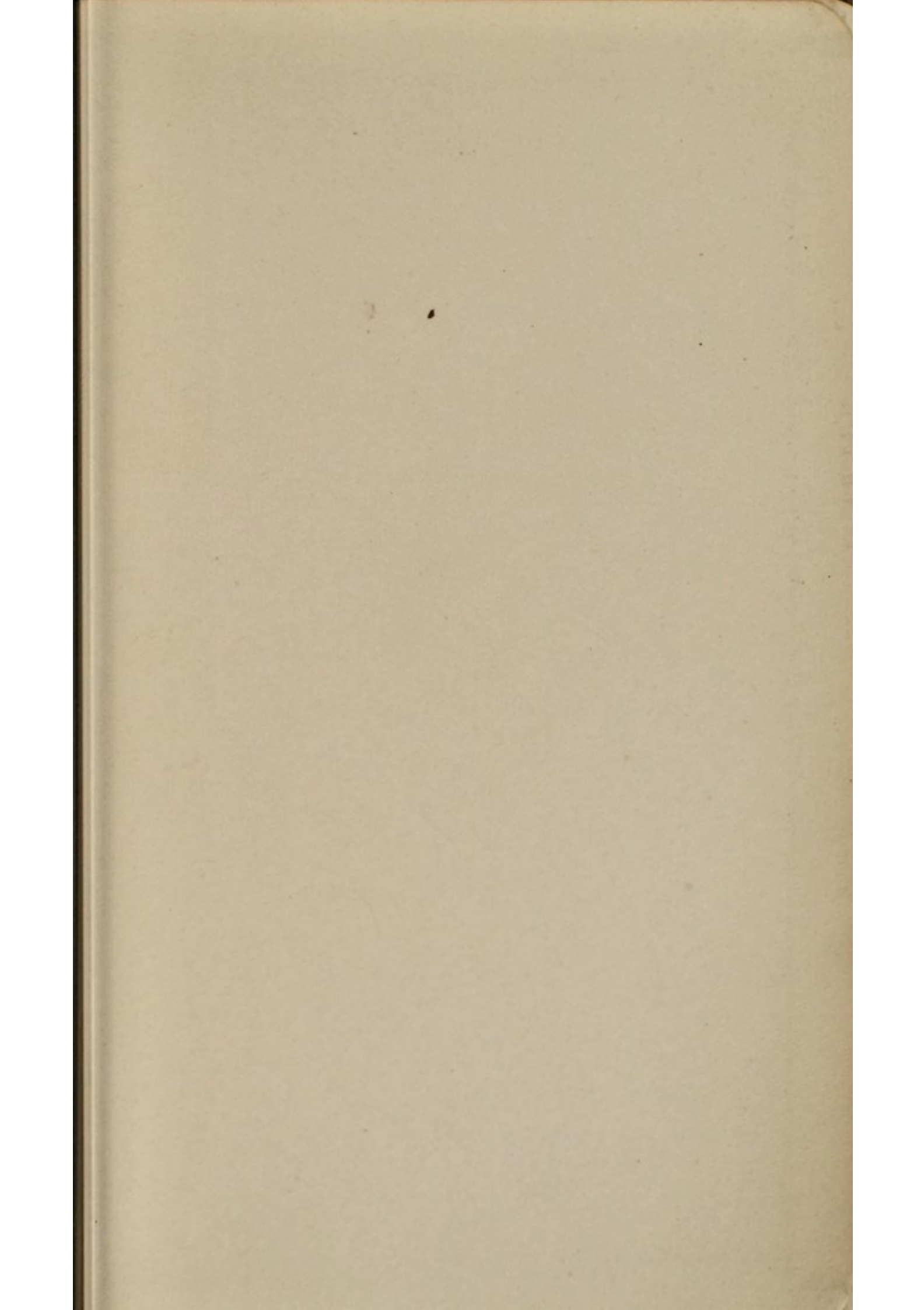
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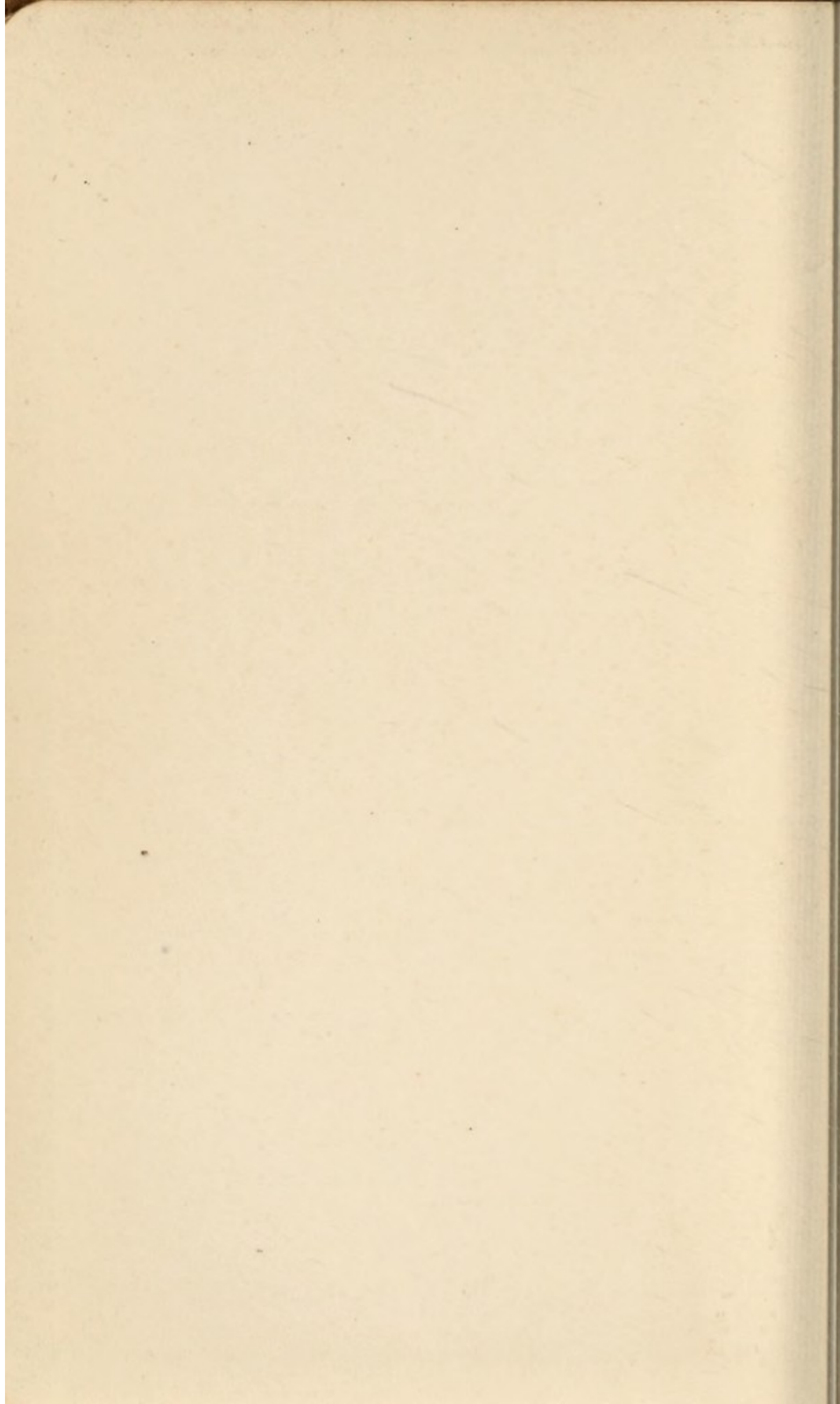
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