of plant life. In one sense it is perhaps unfortunate that the article on surgery has to be written at the present time, because, while there are few who now hold that these organisms are inert, there are some who do not grant that they are the cause of disease; and there are many differences of opinion as to the best methods of applying this scientific knowledge to practical use. In other words, although much of the surgical practice of the present day is founded on a scientific basis, the practical details are still matter of dispute.

It is impossible in the present sketch to go with any fulness into the details of the experimental research by which the truth of the germ theory was proved; but some allusion must be made to the salient points which have a bearing on the work of the surgeon. It has long been known that subcutaneous injuries follow, as a rule, a very different course from open wounds; and the past history of surgery gives evidence that surgeons not only were aware of this great difference but endeavoured, by the use of various dressings, empirically to prevent the evils which were matters of common observation during the healing of open wounds. Various means were also adopted to prevent the entrance of air, *e.g.*, in the opening of abscesses by the "valvular method" of Abernethy, and by the subcutaneous division of tendons in the common deformity termed "club-foot." Balsams, turpentine, and various forms of spirit were the basis of many varieties of dressing. These different dressings were frequently cumbersome, difficult of application, and did not attain the object aimed at, while at the same time they retained the discharges, and gave rise to other evils which prevented rapid and painless healing. In the beginning of the 19th century these complicated dressings began to lose favour, and practical surgeons went to the opposite extreme and applied a simple dressing, the main object of which was to allow a free escape of discharge. Others applied no dressing at all, laying the stump of a limb after amputation on a piece of dry lint, avoiding thereby any unnecessary movement of the parts. Others left the wound open for some hours after an operation, preventing in this way any accumulation, and brought its edges and surfaces together after all oozing of blood had ceased and after the effusion, the result of injury to the tissues by the instruments used in the operation, had to a great extent subsided. As a result of these various improvements many wounds healed in a thoroughly satisfactory manner. But in other cases inflammation often occurred, accompanied by pain and suppuration or the formation of pus, and various feverish conditions, due to and in some way connected with the unhealthy state of the wound, were observed. These constitutional sequelæ frequently proved fatal and the general impression of surgeons was either that the constitution of the patient rendered him liable to these conditions, or that some poison had entered into the wound, and, passing from it into the veins or lymphatic vessels that had been cut across, reached the general circulation, contaminating the blood and poisoning the patient. The close clinical association between suppuration (or the formation of pus) in wounds and many of those fatal cases encouraged the belief that the pus cells from the wound entered the circulation (whence the word "pyæmia"). It was also frequently observed that a septic condition of the wound was associated with the constitutional fever, and it was supposed that the septic matter passed into the blood (whence the term "septicæmia"). It was further observed that the crowding together of patients with open wounds increased the liability to these constitutional disasters, and every endeavour was made by surgeons to separate their patients and to improve the ventilation of the larger hospitals. In building hospitals the pavilion and other systems, with windows on both sides and cross ventilation in the wards, were adopted in order to give the patients as much fresh air as was attainable. Hospital buildings were spread over as large an area as possible; the blocks were restricted in height, and if practicable were never higher than two stories. The term "hospitalism" was coined by Sir J. Y. Simpson, who collected statistics comparing hospital and private practice, by which he endeavoured to show that private patients were not so liable to those constitutional sequelæ.

This was very much the condition of affairs when Lister in 1860, from a study of the experimental researches of Pasteur into the causes of putrefaction, stated that the evils observed in open wounds were due to the admission into them of organisms which exist in the air, in water, on instruments, on sponges, and on the hands of the surgeon. These organisms, finding a suitable nidus for their growth and development in the discharges and surrounding tissues, germinate in them and alter their chemical constitution, forming various poisonous compounds, which, if absorbed into the blood, give rise to pyæmia and septicæmia. Having accepted the germ theory of putrefaction, he applied himself to discover the best way of preventing these organisms from reaching the wound from the moment that it was made until it was healed. He had to deal with a plant and he desired to interfere with its growth. This was possible in one of two ways,—either (1) by directly destroying or paralysing the plant itself before it entered the wound or after it had entered, or (2) by an interference with the soil in which it grew, for example, by facilitating the removal of the discharges and preventing their accumulation in the wound cavity, and by doing everything to prevent depression of the wounded tissues, because healthy tissues are the best of all germicides. Several substances were then known possessing properties antagonistic to sepsis or putrefaction, and hence called "antiseptic." Acting on a suggestion of Lemaire's, Lister chose for his experiments carbolic acid, which he used at first in a crude and impure form. He had many practical difficulties to contend with,—the impurity of the substance, its irritating properties, the difficulty of finding the exact strength in which to use it: on the one hand, he feared to use it too strong, lest it should irritate the tissues to which it was applied and thus prevent healing; on the other hand, he feared to use it too weak, lest its true antiseptic qualities should be insufficient for the main object in view. It is unnecessary to dwell on the details of his tentative experiments. As dressings for wounds he used various chemical substances, which, being mixed with carbolic acid in certain proportions, were intended to give off a quantity of carbolic acid in the form of vapour, so that the wound might be constantly surrounded by an antiseptic vapour which would destroy any organisms approaching it and at the same time not interfere with its healing. At first, although he prevented pyæmia in a marked degree, he, to a certain extent, irritated his wounds and prevented rapid healing. He began his experiments in Glasgow and continued them after his removal to the chair of clinical surgery in Edinburgh. After many disappointments, he gradually perfected his method of performing operations and dressing wounds, which will be best understood by an illustration.

A patient is suffering, let us say, from a diseased condition of the foot necessitating amputation at the ankle joint. The part to be operated on is enveloped in a towel which has been soaked with a 5 per cent. solution of carbolic acid. The towel is applied two hours before the operation, with the object of destroying the (putrefactive) organisms present in the skin. The patient is placed on the operating table, and brought under the influence of

chloroform; the limb is elevated to empty it of blood, and a tourniquet is applied round the limb below the knee. The instruments to be used during the operation have been previously purified by lying for half an hour in a flat porcelain dish containing carbolic acid (1 to 20). The sponges are lying in a similar carbolic lotion. Towels soaked in the same solution are laid over the table and blankets near the part operated upon. The hands of the operator, as well as those of his assistants, are thoroughly purified by washing them in the same lotion, free use being made of a nail brush for this purpose. The operation is performed under a cloud of carbolized watery vapour (1 in 30) from a steam-spray producer. The visible bleeding points are first ligatured; the tourniquet is removed; and then any vessels that have escaped notice are ligatured. The wound is stitched, a drainage-tube made of red rubber being introduced at one corner to prevent accumulation of discharge; a strip of protective (oiled silk coated with carbolized dextrin) is washed in carbolic lotion and applied over the wound. A double ply of carbolic gauze[1] is soaked in the lotion and placed over the protective, overlapping it freely. A dressing consisting of eight layers of dry gauze is placed over all, covering the stump and passing up the leg for about 6 inches. Over that a piece of thin Mackintosh cloth is placed, and the whole arrangement is fixed with a gauze bandage. The Mackintosh cloth prevents the carbolic acid from escaping and at the same time causes the discharge from the wound to spread through the gauze. The wound itself is protected by the protective from the vapour given off by the carbolic gauze, whilst the surrounding parts, being constantly exposed to its activity, are protected from the intrusion of septic contamination; and these conditions are maintained until sound healing has taken place. Whenever the discharge reaches the edge of the Mackintosh the case requires to be dressed, and a new supply of gauze applied round the stump. The gauze that is used should be freshly made and kept in a tin box to prevent evaporation of the volatile carbolic acid. This precaution is most needful in warm weather. Whenever the wound is exposed the stump is enveloped in a vapour (1 in 30) of carbolic acid by means of the steam-spray producer. At first a syringe was used to keep the surface constantly wet with lotion, then a hand-spray, such as Richardson's ether-spray producer. More recently a steam-spray producer has been introduced into practice. These dressings are repeated at intervals until the wound is healed, the drainage-tube being gradually shortened and ultimately removed altogether.

In the case of an accidental wound to which the surgeon is called a short time after its occurrence, carbolic lotion (1 to 20) must be injected into the cavity of the wound to destroy any organisms which may have fallen into it. The dressings already described are then applied. In operating on a case in which putrefaction has occurred, every endeavour must be made to destroy the causes of putrefaction which are already present. The substance most frequently used for this purpose is chloride of zinc solution, 40 grains to 1 oz. of water. This powerful antiseptic was extensively used some years ago by Mr De Morgan, Middlesex Hospital, London. When the wound has been thus purified from its septic condition, the after-treatment must follow strictly the plan already recommended for a recent wound to avoid secondary contamination at subsequent dressings.

The object Lister had in view from the beginning of his experiments was to place the open wound in a condition as regards the entrance of organisms as closely analogous as possible to a truly subcutaneous wound, such as a contusion or a simple fracture, in which the unbroken skin acts as a protection to the wounded tissues beneath. The introduction of this practice by Lister effected a complete change in operative surgery. Although the principle on which he founded it was at first denied by many, it is now very generally acknowledged to be correct. In Germany more especially his views were speedily accepted. In France and England their adoption was slower. In Scotland, perhaps in consequence of the fact that many saw him at work and worked under him, acquiring perhaps some little part of his persevering enthusiasm, he soon had many believers. Since about 1875 surgeons have been trying to improve and simplify the method; chemists have been at pains to supply carbolic acid in a pure form and to discover new antiseptics, the great object being to get a non-irritating substance which shall at the same time be a powerful germicide. Iodoform, eucalyptus, salicylic acid, boracic acid, corrosive sublimate, have been and are being used, and the question as to their relative superiority is not yet settled. Carbolic acid has the disadvantage of irritating the tissues. This is partly counterbalanced by its anæsthetic properties. Absorption of the carbolic acid has occasionally taken place, giving rise to symptoms of poisoning. But this danger has been greatly lessened by the introduction of pure acid. Of the antiseptics named carbolic acid, eucalyptus, and iodoform are volatile; the rest are non-volatile. At first Lister for some years irrigated a wound with carbolic lotion during the operation, and at the dressings when it was exposed. The introduction of the spray displaced the irrigation method. At the present time the irrigation method is again gaining favour. All these different procedures, however, as regards both the antiseptic used and the best method of its application in oily and watery solutions and in dressings, are entirely subsidiary to the great principle involved—namely, that putrefaction in a wound is an evil which can be prevented, and that, if it is prevented, local irritation, in so far as it is due to putrefaction, is obviated and septicæmia and pyæmia do not occur. Alongside of this great improvement the immense advantage of free drainage is now universally acknowledged. Surgeons now understand the dangers which lie on every side, and this knowledge causes them to take greater care in the purification and in securing the greater cleanliness of wounds, and some hold that much of the good result follows from these precautions apart from the principle of the system.

Putrefaction has been clearly shown by Pasteur, Tyndall, and others to be due to the activity of certain lowly forms of organized matter. Scientific men have therefore had their attention more particularly directed to these lower forms of plant life. A careful study has been made of their life history, and several diseased conditions are now known to be due to the deposit and growth of organisms of a specific form in the blood and in the tissues. This is not the place to discuss points still *sub judice*; but there can be no doubt, *e.g.*, that the *Bacillus anthracis* is the cause of splenic fever and of its local manifestation, malignant pustule, and that erysipelas is due to the presence of a micrococcus. There are many other diseases spoken of as zymotic or fermentative, upon which observers are now at work, and hardly a month passes without the publication of new observations (compare SCHIZOMYCETES).

[1] The gauze dressing consists of thin gauze which has been soaked in a mixture of carbolic acid (1 part), resin (5 parts), and paraffin (7 parts). The object of the paraffin is to prevent the gauze sticking to the skin. The resin retains the carbolic acid and prevents evaporation at the ordinary temperature; at the temperature of the body, however, a certain quantity of the carbolic acid is constantly being given off, and in this way the part operated on is enveloped in a vapour of carbolic acid. This antiseptic vapour persists as long as there is any carbolic acid in the gauze. A gauze dressing is not reliable for more than a week; by that time the carbolic acid in the gauze is dissipated and the dressing requires to be renewed.

certainly be said that the relation between those organisms and various specific diseases is the question which at present most occupies the attention both of pathologists and of practitioners of medicine and surgery. It is now known that there are many varieties of organisms (in Crookshank's *Bacteriology* sixty are described), some of which are hurtful to the human economy, though others are apparently harmless. Those of the former class give rise to an alteration in the tissue in which they grow; and during their growth they alter its composition and cause it to break up into various compounds, some of which, when absorbed into the blood-stream, poison the individual. Some, on the other hand, are either in themselves innocuous or are killed when they enter the blood, which is a fluid tissue and acts as a germicide; hence the tissues in a healthy condition are spoken of as "germicidal." Some apparently grow only on dead tissue, or in tissue the vitality[1] of which has been lowered.

Fermentations. The alteration in the tissue is strictly analogous to a fermentation—such, for example, as the change which takes place in a solution of grape sugar in which the yeast plant has been planted. The solution breaks up into alcohol and carbonic acid; along with this change there is an increase in the quantity of the yeast. The most common fermentation is the alteration termed "putrefactive" or "septic." The cause of this change is in all probability a special organism named *Bacterium termo*. It lives on any dead matter containing nitrogen when exposed to heat and moisture; dryness and cold are antagonistic to its growth. Its results are so evident and of such common observation that the term "antiseptic" was used long before the primary cause of the condition was understood. Antiseptics originally were substances which interfered with sepsis. The term has now, however, a wider meaning, and includes any substance opposed to fermentation. "Antifermentative" or "antitheric" would be a better term. An antitheric substance is one which interferes with fermentation by destroying or paralysing the organism which is the primary cause of the condition. The word "antiseptic," on the other hand, should be reserved to denote any substance which is opposed to putrefaction or sepsis,—one form of fermentation. Many of the most dangerous fermentations have nothing in common with putrefaction: the products which result are odourless; the appearances which arise bear no similarity to the changes which occur when putrefactive fermentation is present. Plant the *Bacterium lactis* in milk, and souring, or the lactic acid fermentation, takes place; plant the *Bacterium termo* in milk, and putrefactive fermentation occurs. The fermentations of smallpox, vaccinia, syphilis, scarlet fever, typhoid, relapsing fever, typhus, erysipelas, and cholera may be taken as examples of fermentations of the non-putrefactive class. Apparently in them the organism enters the blood-stream, there develops and forms its products, which, acting directly or indirectly on the heat-centre, give rise to a specific fever. This fever continues until the soil is worn out, and the organism, finding no longer a nidus for its development, dies out, and recovery takes place. Death of course results if the individual has not sufficient strength to withstand the attack. There is a general law regarding all living things which holds true of these lowly organisms as of the highest: remove its food and the organism dies, or at any rate ceases to develop. It may, however, lie quiescent, again appearing when a new nidus is provided for it. These considerations explain the reason why, after one attack, the individual is protected for a longer or shorter period. They also explain why many diseases are becoming through course of time less virulent than they once were: the soil is becoming exhausted in relation to the special requirements of the organism, and the organism is therefore incapable of flourishing as it formerly did. Plant the organism in a virgin soil—take, for example, as was unwittingly done, the organism of measles to Fiji—and a disease which in Great Britain is comparatively harmless becomes a most deadly scourge.

[1] John Hunter defines "vitality" as the power which resists putrefaction.

An attempt has been made to divide organisms into two great divisions—the infective and the non-infective. The first class can grow in living tissue; the second cannot. The first form their products in living matter; the second can only grow in dead or lowly vitalized matter. The infective organism can migrate from the original point of entrance by the vascular and lymphatic streams to distant parts of the body, and may there form secondary foci of infection. As regards the non-infective the manufactory of the poison is principally restricted to the near neighbourhood of the original point of entrance, generally a wound. It cannot migrate into the living tissues around if they remain healthy. Both kinds of organism form ptomaines (πτῶμα, a carcase), the products of the fermentation which result from the breaking up of the tissue or discharge in which the organisms grow. They may enter the blood-stream and poison the patient. Their entry into the blood must be differentiated from the entry of the organism itself into the stream. Clinically, the two conditions, although often met with in one individual, are in many cases distinctly separable. This physiological division of organisms into infective and non-infective is at present only tentative, and much work must be done before a strictly physiological classification can be attempted; at present the main line of inquiry must be principally morphological. Even in this direction a difficulty meets the observer, because organisms change their shape according to the media in which they are cultivated.

In the present article only a general view of the present aspects of surgical practice can be given. Special stress will be laid upon the principles which guide the surgeon in his daily work. For full particulars with reference to any special points the reader is referred to Holmes's *System of Surgery*, Erichsen's *Science and Art of Surgery*, and Gross's *System of Surgery*.

Surgical affections may be divided into two great classes—those which are the result (1) of injury and (2) of disease.

I. Injuries.

Before proceeding to the consideration of the different injuries it will be necessary to say a few words about the general condition termed *shock* or *collapse*, which supervenes after a severe injury. Care must be taken not to confound this state with faintness or syncope from loss of blood. Undoubtedly in many cases both conditions are present. Syncope from loss of blood is considered below. Syncope from mental emotion differs from shock in degree only. In shock the patient is pale, and bathed in cold clammy perspiration; his sensibility is blunted; his pulse is small and feeble; he is unable to make any active exertion, but lies in bed indifferent to external circumstances, and can only be roused with difficulty; he frequently complains of a feeling of cold; and he may have a distinct shivering or rigor. These symptoms may continue for some hours; the first evidence of improvement is that he shifts his position in bed and complains of the pain of the injury which has caused the condition. The pulse becomes stronger, and he then passes from the state of shock into the condition of reaction. If the improvement continues recovery will take place, but if it is only transient the patient will sink back again into a drowsy condition, which, if it persists, will end in death. In severe cases there may be no reaction; the patient then gradually becomes weaker and weaker, his pulse feebler and feebler, till death ensues. Shock is due to an impression conveyed to the central nervous system by an afferent nerve of common or special sensation. This impression produces a change in the medulla oblongata, by which the nerve-centres are so affected that a partial paralysis or paresis of the voluntary and involuntary muscular fibres in the body takes place. In consequence of the change in the voluntary muscles the patient is unable to lift his arm or move his leg; the respiratory functions are performed wearily, and the

muscle of the heart contracts feebly; the muscular fibres in the walls of the blood-vessels lose their tonicity and the blood-vessels dilate; the blood collects in the large venous trunks, more especially of the abdomen; the vessels of the skin are emptied of blood, giving rise to the marked pallor. Two of the great causes that keep up the normal circulation of the blood through the body are in partial abeyance: the heart has not sufficient energy to contract, and there is not a sufficient quantity of blood passing into it from the blood-vessels. The heart beats feebly (1) because its nervous energy is lowered, and (2) because it has not a sufficient quantity of blood to act upon. An understanding of these facts gives the general indications for treatment,—(1) external stimulation over the heart by mustard poultices or turpentine stupes; (2) elevation of the limbs, to cause the blood to gravitate towards the heart; (3) manual pressure on the abdominal cavity from below upwards, to encourage the flow of blood from the dilated abdominal veins into the heart. These different measures may be supplemented by the administration of stimulants by the mouth, or, if the patient cannot swallow, by subcutaneous injection of a diffusible stimulant, such as ether or ammonia. In syncope or faintness from mental emotion the weakened heart cannot drive a sufficient quantity of blood to the brain; the patient feels dizzy and faint and falls down insensible. The condition is a transitory one, and the recumbent posture, assisted if need be by elevation of the limbs, causes the blood to gravitate to the heart, which is thereby stimulated to contraction; a sufficient quantity of blood is then driven onwards to the brain, and the insensibility passes off. If the patient is in the sitting posture when he feels faint, the head should be depressed between the knees, which will cause the blood to rush to the brain, and the faintness will pass off.

With few exceptions the soft parts are freely supplied with blood-vessels, and as a preliminary to a consideration of the different forms of injuries it will be well to say a few words about hæmorrhage or bleeding. If a blood-vessel is torn or cut across, the blood within it escapes, either externally on to the clothes or floor, or, in the case of a subcutaneous injury, into the tissues, giving rise to *ecchymosis*. Cessation of the bleeding may take place in consequence of an arrest of the hæmorrhage either by nature's effort or by the adoption of artificial means by the surgeon. The loss of blood may be so great that the heart's propelling power is weakened, and in this way the natural arrest is assisted. But there is always a danger that with the arrest of the hæmorrhage the heart's action may recover its power and the bleeding recommence. In arresting hæmorrhage temporarily the chief thing is to press directly on the bleeding part. The pressure to be effectual need not be severe, but must be accurately applied. If the bleeding point cannot be reached, the pressure should be applied to the main artery between the bleeding point and the heart. In small blood-vessels pressure will be sufficient to arrest hæmorrhage permanently. In large vessels it is usual to pass a ligature round the vessel and tie it with a reef knot. Apply the ligature also, if possible, at the bleeding point, tying both ends of the cut vessel. If this cannot be done, the main artery of the limb must be exposed by dissection at the most accessible point between the wound and the heart, and there ligatured. Hæmorrhage has been classified in three varieties—(1) primary, occurring at the time of the injury; (2) reactionary, or within twelve hours of the accident, during the stage of reaction; (3) secondary, occurring at a later period, and caused by unhealthy processes attacking the wound and giving rise to ulceration of the coats of the blood-vessels. In treating these different varieties the principles already laid down hold good. In cases of severe hæmorrhage the patient suffers from syncope owing to loss of blood. Syncope from loss of blood is to be treated on the same principles as those already laid down for shock. But in addition it may be necessary in cases of severe hæmorrhage, in which much blood has been lost, to introduce into the circulation fluid which will give the heart something to act upon. Blood drawn directly from the arm of a healthy person, and introduced through an opening in the vein of the arm, has frequently been made use of. The tendency of the blood to coagulate when brought in contact with foreign matter has led to the adoption of ingenious instruments to avoid this danger. Some surgeons have used defibrinated blood, and others milk. The opinion is at present gaining ground that a nutrient fluid is unnecessary, and that all that is required is to introduce an aseptic neutral fluid at the temperature of the body which has no tendency to cause coagulation of the blood with which it mixes. A saline solution, composed of ·75 per cent. of common salt in distilled water, fulfils all these requirements; 4 to 6 oz. are generally sufficient. Recent experiments have been made by which blood drawn from the arm of the giver is mixed with a solution of phosphate of soda. This admixture prevents the blood from coagulating, and it can be introduced into the blood-stream with safety.

In a recent contusion careful pressure should be applied, with cotton wadding fixed in position with a bandage. The aim is to prevent ecchymosis and to hasten the absorption of the effused blood after it has escaped into the tissues. Accurate pressure fulfils these ends more perfectly than the commoner application of cold.

The procedure for the treatment of an open wound is—(1) arrest of hæmorrhage; (2) removal of any foreign bodies in the wound; (3) careful apposition of its edges and surfaces,—the edges being best brought in contact by the use of horse-hair stitches, the surfaces by carefully applied pressure; (4) free drainage of the wound to prevent accumulation either of blood or of serous effusion, which may be done—(*a*) by leaving the dependent corner open, or (*b*) by introducing a drainage-tube, a skein of catgut, or a skein of horse-hair; (5) avoidance of putrefaction by the use of antiseptic precautions; (6) perfect rest of the part by appropriate means during the cure. These methods of treatment require to be modified for wounds in special situations and for those in which there is much contusion and laceration. In punctured wounds free drainage is of primary importance. When a special poison has entered the wound at the time of its infliction or at some subsequent date the following dangers have to be combated—(1) an intense inflammation in the wound itself and surrounding parts; (2) inflammation of the lymphatic vessels leading from it; (3) inflammation of the lymphatic glands; (4) blood-poisoning of the general circulation. One of the commonest poisons is that connected with wound putrefaction; of others some are the result of diseased action in the lower animals, *e.g.*, hydrophobia, whilst some are special diseases in man. These diseased conditions are at the present time being carefully studied, and the observations all tend to one conclusion, that they are due to specific organisms which have found entrance into the diseased animal or man, and, finding there a suitable nidus for their growth and development, have set up a specific disease. If the surgeon is accidentally wounded in operating on the living subject, or the pathologist in making a post-mortem examination, the poison may pass into the wound and give rise to one or more of the symptoms already indicated. There can be no doubt that these special poisons,[1] which are spoken of as pathogenic or infective, are in some way associated with low forms of plant life, and that in this they resemble the poison of putrefaction. If the operator is in good health the poison will generally have little effect; if he is in bad health the effect may be very severe. We do not yet know in what cases bad results are to be expected. The great point in every doubtful case is to purify the wound thoroughly with some powerful antiseptic, so as to destroy the poison at the point of inoculation. If the poison escapes the germicidal action of the antiseptic used and enters the system, the patient should be stimulated, as the poison exercises a depressing action. For hydrophobia no cure is at present known. Experiments are, however, now (1887) being made by Pasteur which will throw some light on this dreadful disease.

Burns are dangerous accidents in young children and in old people, when the areas affected are large, and when they are situated over the cavities of the body. The patient may die of shock soon after the accident, of deep-seated inflammations coming on during the stage of reaction, or of hectic, which in all probability is a form of chronic pyæmia associated with profuse discharge from the wounded surface. To prevent death from any of these causes stimulating treatment is necessary. It has long been known that it is important to keep the air from the wounded surface, and antiseptic dressings must be used to prevent the access of organisms to it. When the skin is destroyed to any great extent contraction is apt to take place, followed by deformity. Care must be taken during the process of cure to prevent this, by keeping the limb in an extended position during the treatment of burns on the flexor surface. To hasten cicatrization after a burn in which the skin has been destroyed grafts of epidermic tissue may be planted on the granulating surface according to the method of Reverdin. These grafts, each the size of a pin's head, become fixed and from them cicatrization spreads over the surface. After cicatrization the tendency to contraction is not nearly so great. Epidermis grafting must not be confounded with skin grafting in which the grafts are of the whole thickness of the skin.

A bone may be broken at the part where it is struck, or it may break in consequence of a strain applied to it. In the former case the fracture is generally transverse and in the latter more or less oblique in direction. The fully developed bone is broken fairly across; the soft bones of young people may simply be bent—"*green stick*" or "*willow*" *fracture*. Fractures are either simple or compound. A simple fracture is analogous to the contusion or subcutaneous laceration in the soft parts; a compound fracture is analogous to the open wound in the soft parts. The wound of the soft parts in the compound fracture may be caused either by the same force which has caused the fracture, as in the case of a cart wheel going over a limb, first wounding the soft parts and then fracturing the bone, or by the sharp point of the fractured bone coming through the skin. In either case there is a communication between the external air and the injured bone. As some years elapse before the epiphyseal extremities of the bone become united by osseous deposit to the shaft, external violence may cause a

[1] For their classification, as yet very imperfect, consult Ziegler's *Pathological Anatomy* (trans. by Macalister, London, 1883-84).

separation of the epiphysis from the shaft. This variety of fracture is termed a *diastasis*. When a bone is broken there is generally distortion and preternatural mobility, inability to use the limb, and pain on pressure over the fractured part. In the majority of fractures there is also crepitus,—the feeling elicited when two osseous surfaces are rubbed together. When a bone is bent, or when a diastasis has occurred, there is no crepitus. It is also absent in impacted fractures, in which the broken extremities are driven into one another. In order to get firm osseous union in a case of fracture the great points to attend to are accurate apposition of the fragments and complete rest of the broken bone. Accurate apposition is termed "setting the fracture"; this is best done by the extension of the limb and coaptation of the broken surfaces. Complete rest is attained by the use of appropriate splints. As a rule it is of great importance to command the joint above and below the seat of fracture. In cases of fracture near a joint, in which very commonly a splintering of the bone into the joint has taken place, more especially in those cases in which numerous tendons in their tendinous sheaths have been stretched, if the surgeon forgets that there may be effusion into the joint and the tendinous sheaths, and that this effusion may form fibrous tissue leading to stiffness of the joint and stiffening of the tendons, the result, more especially in old people, will be a permanently stiff joint or permanently stiffened tendons. Care must be taken in such instances by gentle passive movement during the process of cure to keep the joint and tendons free from the fibrous formation. To take a common example,—in fracture of the radius close to the wrist joint, it is necessary to apply appropriate splints to keep the bone at rest, and to arrange them so that the patient can move his fingers and thumb to prevent stiffness, and the splints must be taken off occasionally in order to move the wrist joint gently. If, however, the splints extend to the points of the fingers and are kept on for some weeks without removal, the consequence is a normal radius and a useless hand. Instances occasionally occur in which non-union results, either from want of formative power on the part of the individual or in consequence of improper treatment by the surgeon. For the treatment of this condition the reader is referred to one of the systematic works mentioned above. For fractures of the cranium see below, p. 688.

Treatment of compound fractures.

There is no form of injury in which the truth of the principles first advocated by Lister has been more prominently brought forward than in compound fractures. When such an accident occurs from direct violence the soft parts are generally much crushed and the bone is frequently comminuted. When a bone is broken from indirect violence the fracture is frequently oblique and the sharp point of the bone projects through the skin. In such a case the injury is, as a rule, not so severe. Formerly compound fractures were the dread of the surgeon: septic inflammation occurring in the wound reached the open medullary cavity of the bone, and the open blood-vessels of the bone gave easy access to the causes and products of the inflammation into the general blood-stream, giving rise to pyæmia. It is not asserted, however, that this accident always occurred. In a case of compound fracture the wound should be at once covered with a towel thoroughly soaked in a five per cent. solution of pure carbolic acid. And, if some time elapses before the arrival of a surgeon, more of the solution must be poured upon the towel, which should be kept thoroughly soaked. After the fracture is set it will probably be necessary to inject the solution into the interstices of the wound, over which an efficient antiseptic dressing must be applied. When the injury is so severe that it is impossible to preserve the limb, amputation is the only resource. It is often a difficult thing to say when the surgeon should amputate. The question will frequently be settled by a consideration of the general circumstances and surroundings of the patient, and no definite rules can be laid down. Speaking in general terms, an artificial substitute may take the place of the lower limb, but no artificial substitute can ever efficiently take the place of the upper limb; and therefore surgeons will run some risk in attempting to save an upper limb which they will not do in treating an injury of a lower limb.

There are three principal types of joint injury—(1) sprain or strain, in which the ligamentous and tendinous structures around the joint are stretched and even lacerated; (2) contusion, in which the cartilaginous surfaces of the opposing bones in the joint are driven forcibly together; (3) dislocation, in which the articular surfaces are separated from one another; in this last injury the ligamentous capsule of the joint must be torn to allow the accident to occur. Joint strength may be classified anatomically under three heads—(1) ligamentous, due to the ligaments binding the bones together; (2) osseous, due to the shape of the bones forming the joint; (3) muscular, due to the muscles surrounding the joint. Ligamentous strength predisposes to sprains, osseous to contusions, and muscular to dislocations. A joint is frequently saved from injury in consequence of the relative weakness of a bone near it. The ankle joint is saved by the weakness of the fibula, the wrist joint by the weakness of the radius, the sterno-clavicular joint by the weakness of the clavicle; the fracture of the bone preserves the joint from injury. The tonicity of the muscular structures around a joint often prevents a dislocation, the patient being prepared for the violence to which his joint is subjected. The osseous strength of a joint will depend very much on the position of the limb at the time of the accident.

When a joint is sprained or contused there is effusion into it and into the structures around it. In such cases accurately applied pressure will prevent effusion, and along with gentle passive exercise and rubbing will prevent subsequent stiffness. When a joint is dislocated it is of importance to restore the bones to their normal position as soon as possible after the accident. Within the last few years, in several dislocations, the treatment by extension of the limb and forcible pressure of the bones back into their normal position has been given up, and a method of treatment at one time in use in the French schools has been revived by Dr Bigelow of Boston, Mass., who has pointed out that with less force and therefore less injury a dislocated joint may be reduced by manipulation. The great principle at the root of this treatment is to manipulate the limb so as to cause the dislocated bone to pass back into its normal position by the same path by which it left it. In compound dislocations the same precautions must be attended to as in compound fractures.

II. Process of Repair.

After an injury certain changes take place, which, if kept within bounds, terminate in repair, in other words, in a restoration of the injured part to a condition as nearly as possible normal. When the injury is severe the restoration may fall far short of the normal. The recovery may take place with very little pain or discomfort even in severe injuries. Frequently, however, as the result either of improper treatment on the part of the surgeon or of feebleness on the part of the person injured, local uneasiness and a general feverish condition arise, which interfere with the healing. When these evil results follow, a local death of tissue in a greater or less degree is observed. Three forms of local death have been described —(1) suppuration or the formation of pus; (2) ulceration, or the formation of an ulcer; (3) mortification, or the formation of a slough. These three processes run imperceptibly into one another. They are not distinctly separable from one another, and they very frequently occur together. It is to be noted that the process of repair and the local death which interferes with a painless repair differ only in degree. As a general rule, in the truly subcutaneous wound of tissue, be it the soft parts or bone, the changes that take place ending in its repair are simple and uncomplicated; it is in the open wounds of the soft parts and in compound fractures of bone that complications arise.

Forms of local death.

In order to understand this process, it will be best to take a simple injury, such as a clean cut. As the result of the passage of even the sharpest knife through the tissues a microscopic laceration along the line of the incision must occur. The skin, subcutaneous fat, fascia, and muscle are divided. These parts being vascular, bleeding takes place from the cut vessels. Let us suppose that the bleeding has ceased, and that the surfaces and edges of the wound are not brought into contact. The retractile power of the tissues, when they are divided, necessarily produces a trench-shaped gap. If the sides of this gap are watched a weeping of a straw-coloured fluid will be observed, which, when examined under the microscope, is seen to have corpuscles floating in it. The fluid is the liquor sanguinis of the blood, and the corpuscles are the blood corpuscles. In the blood as it circulates throughout the vessels in the body, the yellow or red blood corpuscles are greatly in excess of the white. In this fluid the white blood corpuscles are very numerous. Careful observation, with the aid of a sufficiently powerful microscope, will show the formation of fine fibrils of a solid substance, which gradually extend over the field; this fibrillation takes its start from the white blood corpuscles. The effusion has coagulated. A soft solid—fibrin—is formed, which gradually contracts, and a clear fluid escapes; this is the blood serum. To return to the wound,—in consequence of the injury the smaller blood-vessels dilate, their walls are thinned, and a stasis or stoppage of the flow of blood within these vessels takes place. The stasis is caused by the injury to the vessel walls, rendering the blood corpuscles more adhesive. The circulation is going on in the vessels beyond the area of stasis. The blood in a state of stasis acts as an obstruction, and consequently there is an increased pressure on the inner surface of the thin walls. As a result the fluid part of the blood or liquor sanguinis and the corpuscular elements of the blood escape into the tissues and on to the surface of the wound. On this surface and in the tissue next the surface a clotting takes place, and fibrin is formed. The surface of the wound becomes glazed, and as the fibrin contracts the blood serum oozes out upon the wound surface and escapes. The glazed surface then becomes vascular; new blood-vessels are formed in it; and through these a circulation is set up continuous with the circulation in the blood-vessels around. If the surfaces of the gap are now brought into gentle contact, the blood-vessels on the two surfaces will unite. At first the uniting tissue is very succulent and vascular, and further changes must occur before the uniting

Repair of an incised wound.

medium is consolidated. This is effected by the formation of fibrous tissue in the deeper parts of the uniting medium and by the formation of epithelial tissue in the more superficial parts where the skin is divided. Along with these changes the uniting medium becomes less vascular, and a linear scar is the result.

This is the case of an incised wound in which the surfaces are not brought at once into contact. If, however, this is done, the same changes take place, and in a small wound no untoward results need follow. But in a wound of some size there is danger in bringing the edges of the wound into contact. In consequence of the difference in the retractile power of the different tissues that are divided, it may be impossible to bring the deeper parts into accurate contact. The patient will complain of local pain, accompanied by a throbbing sensation, showing that an accumulation of serum has taken place. If a stitch is removed, the serum will escape and the local uneasiness disappear. If, however, no relief is given, the retained serum, pressing upon the surrounding tissues and acting as a foreign body, will cause effusion of more serum. The white blood corpuscles will pass from the vessels in large numbers, will die, and practically a cemetery of white blood corpuscles will be formed; if a stitch is then removed a creamy fluid escapes. This fluid is termed "pus." Once the tension is relieved, the local uneasiness disappears; but the wound cannot then heal by primary union. The walls of the cavity must again become glazed; vascularization must take place; and, as the walls of the cavity gradually come together by contraction, fibrous tissue is formed. This is *union by second intention*.

The collection of white blood corpuscles floating in the effusion and eventually forming pus is termed an *abscess*. Pus may also form amongst the tissues after a blow or other injury. As the result of a blow a certain area of tissue becomes congested, and effusion takes place into the tissues outside the vessels; the effusion coagulates and a hard brawny mass is formed. This mass softens towards the centre; and if nothing is done the softened area gradually increases in size, the skin becomes thinned over it, the thinned skin loses its vitality, and a small slough is formed. When the slough gives way, the pus escapes. Such shortly is the history of an acute abscess under the skin, and the explanation generally given is that a local necrosis or death of tissue takes place at that part of the inflammatory swelling farthest from the normal circulation. When the dying process is very acute death of the tissue occurs *en masse*, as in the core of a boil or in the slough in a carbuncle. Sometimes, however, no such evident mass of dead tissue is to be observed, and all that escapes when the skin gives way is the creamy pus. In the latter case the tissue has broken down in a molecular form; in the former case it has broken down *en masse*. After the escape of the core or slough along with a certain amount of pus, a cavity is left, the walls of which become lined with lymph. The lymph becomes vascular, and receives the name of granulation tissue. The cavity heals by second intention. Pus may accumulate in a normal cavity, such as a joint or bursa. It may also be met with in the cranial, thoracic, and abdominal cavities. In all these situations, if the diagnosis is clear, the principle of treatment is free evacuation of the pus, and in joints and in the peritoneal and pleural sacs washing out the cavity at the time of opening, free drainage, and careful antiseptic treatment during the subsidence of the inflammatory process. The tension is relieved by letting out the pus. If the after-drainage of the cavity is thorough the formation of pus ceases, and the serous discharge from the inner side of the abscess wall gradually subsides; and as the cavity contracts the discharge becomes less and less, until at last the drainage-tube can be removed and the external wound allowed to heal. The large collections of pus which form in connexion with disease of the vertebræ in the cervical, dorsal, and lumbar regions are also now treated by free evacuation of the pus, with careful antiseptic measures. In all cases care should be taken to make the opening as dependent as possible in order that the drainage may be thoroughly efficient. If tension occurs after opening by the blocking of the tube, or by its imperfect position, or by its being too short, there will be a renewed formation of pus.

When a considerable portion of tissue dies in consequence of an injury, the death taking place by gradual breaking down or disintegration, the process is termed *ulceration*, and the result is an ulcer. As long as the original cause which formed the ulcer is at work, the gap in the tissues becomes larger and larger. Suppose that the ulcerative process is going on and the ulcer is spreading. The ulcer is then painful and the parts around are inflamed. Remove the cause by appropriate treatment and the necrotic process ceases, the shreds of tissue are cast off, the ulcer gradually cleans, the inflammation subsides, the pain disappears: the ulcer becomes a healing ulcer. The surface of the gap becomes glazed, and those changes take place in it which have already been described as occurring in an open wound. The gap gradually contracts in size. Round the edges cicatrization occurs, leaving a scar or cicatrix. Within the last few years the process of cicatrization has been hastened by planting on the granulation tissue small grafts of dermic tissue in the manner already described (p. 681). There can be little doubt that the growth of an ulcer, as well as the disintegrating process which precedes its formation, is closely associated with the multiplication of low forms of plant life in the decaying tissue. By destroying these organisms with some powerful antiseptic the destructive process may be checked. Since these organisms live on decaying matter, they are termed "saprophytic." The healthy tissues are antagonistic to their growth, and any treatment which renders the tissues around the gap healthy will interfere with their further development. The entrance of these organisms into a wound made by the surgeon, if they find in it a suitable soil for their development, is undoubtedly also a fertile cause of suppuration in wounds. But it must be distinctly remembered that any means which are adopted to keep the injured tissues in a healthy condition interferes with the growth of these saprophytes as directly as if the surgeon used some antiseptic substance which destroyed them. What relation obtains between a local necrotic process, such as the formation of a boil with its central slough, situated necessarily in the first instance under the skin, or the equally necrotic process, the formation of pus in a subcutaneous abscess, and these low forms of plant life? There can be no doubt that by the injection into the tissues of a powerful irritant these necrotic changes can be induced without the intervention of organisms. Professor Ogston and Mr Watson Cheyne have also shown that micrococci are present in the great majority of acute subcutaneous necrotic inflammations, as they are commonly met with in the human body. Here the question at present rests. The opinion of the present writer is that in all probability they are the cause of the necrotic process. It is not asserted that they are the cause of the primary inflammation, which need not go on to necrosis; but the probability is that they find in the inflamed area a nidus for their growth and development. It is not known how they cause it, whether by direct action upon the tissues or by irritating products formed during their growth. The organisms described by Ogston and Cheyne have a life history and require conditions for their existence and development different from those demanded by the saprophytic organisms already described. To reach the subcutaneous area of inflammation they must pass by the blood-stream, and must be able to exist in the living blood. They are probably associated with the infective class of organisms. In some suppurations at the present moment, such as acute suppurative periostitis, the formation of pus under the periosteum connected with bone, a suppuration within the medullary cavity of a bone called osteomyelitis, and in acute ulcerative endocarditis, the organisms met with are undoubtedly infective. We do not know exactly how they enter the blood-stream, but we know that they can live in it, and that the occurrence of these diseased conditions is undoubtedly a local effect closely connected with blood-poisoning.

A portion of the body may die in consequence either of an intense inflammation or of a cutting off of the blood-supply. Besides these two distinct varieties there is a great intermediate group of cases in which both causes may be at work. A comparatively slight injury affecting a portion of the body imperfectly supplied with blood may give rise to an inflammatory condition which in a healthy part would be easily checked, but which in consequence of imperfect nutrition may end in mortification. Whilst the pressure of a tight boot in an old person with atheromatous vessels can give rise to mortification, the same pressure in a healthy person would give rise only to an evanescent redness. Frost-bite is a localized death of a portion of the body which has been exposed to prolonged cold. It may attack the fingers or toes. The death may occur directly without any intermediate reactionary inflammation, or it may follow an excessive reaction. The rule of treatment in all cases of gangrene in which there is a tendency to death is to keep the part warm by layers of wadding, but to avoid all methods which hurry the returning circulation; because any such increase would be followed by excessive reaction, which in its turn in a part already weakened would be followed by secondary death. When the part is dead, envelop it in antiseptic wadding to prevent putrefaction; wait until the line of demarcation between the living tissues and the dead part is evident, and then, if the case permits, amputate at a higher level. In spreading gangrene in which sepsis is present, and in which no line of demarcation forms, the best chance for the patient—at best a poor one—is to amputate high up in sound tissues. In these cases the blood is generally poisoned, and if the patient recovers from the primary shock of the operation a return of the decaying process may attack the stump, and carry him off.

III. Diseases.

1. *Diseases of Blood-vessels.*

An aneurism, in so far as we have to deal with it at present, may be defined as a sac communicating with the lumen of an artery. The sac-wall may be formed of one or more of the arterial coats which have become dilated. The tissues around, being condensed and being more or less adherent to the sac-wall, strengthen and support it. The dilatation of the arterial coats is generally due to a local weakness, the result of disease. The diseased condition is almost always a chronic form of inflammation, to which the name *atheroma*