disarticulations at certain joints it presents advantages which are worthy of consideration (see Fig. 129).

Flap Method.—As already indicated, this consists in the formation of one or more flaps, comprising integument and muscular tissue, or integument alone, and designed in a manner completely to cover the divided extremity of the bone or its exposed articular surface. According to the anatomical components of the flaps, they can therefore be called tegumentary and musculo-tegumentary.

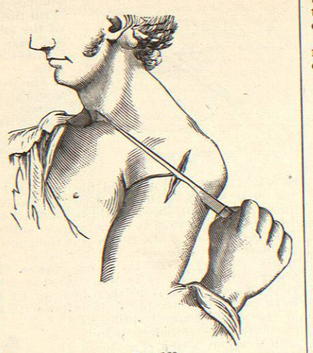

FIG. 129.

Tegumentary Flaps.—This operation is generally practised by making two semilunar incisions, the ends of which meet on opposite sides of the part, down to the deep fascia, and dissecting up the skin and subcutaneous cellular layer to an extent sufficient to cover the stump (Fig. 130). When it is practicable, the flap should be taken from the anterior and posterior aspects of the limb in the forearm, thigh, and leg, and they should not be of equal lengths, the anterior flap usually being made longer, to fall like a curtain over the divided end of the bone, where it comes in contact with the posterior (shorter) flap. In recent years the tegumentary method, with only one cutaneous flap, made from the anterior surface of the limb, has been most highly advocated (Carden, Bruns). When, from choice or necessity, a single tegumentary flap is to be made, the incision should be commenced on a level with the point where the division of the bone is contemplated, and carried for a varying distance down one aspect of the limb, parallel to its axis, and then by a wide curve on the opposite side to a point on a level with its commencement (see Fig. 130). In this manner the base of the cutaneous flap extends over half the circumference of the limb, while its length should be greater than its antero-posterior diameter at the level of the amputation. After separation of this flap from the deep fascia (it may be made to include this) it is reflected and the ends of the incision are united by a posterior incision carried perpendicularly to the axis of the limb as in the circular operation (Fig. 131).

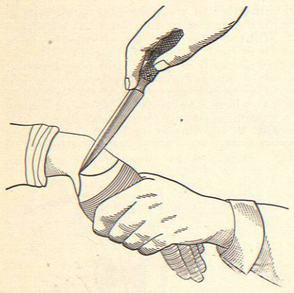

FIG. 130.

Whether one or more cutaneous flaps be made, the division of the remaining soft parts is practised by a single sweep of the knife, carried perpendicularly around the limb at the base of the flap, as in the circular operation. Owing to this division of the muscles, amputations by the tegumentary flap method are not infrequently called "modified circular operations."

Musculo-tegumentary Flaps.—Here, as in the tegumentary method, one or more flaps may be made, to cover the stump. They may be formed by transfixion

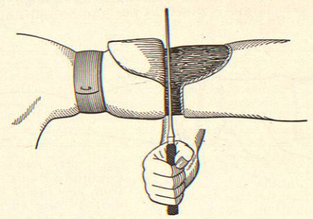

FIG. 131.

of the limb and cutting from within outward, or by cutting from without inward, or by making one flap by the former and the other by the latter mentioned method. Where there is but a single bone (thigh, arm), it is customary to make at least one flap by transfixion. The integument being well retracted, and the soft parts raised from the bone with the left hand, a sharp-pointed and large amputating knife is passed through the limb from side to side, the knife being made to graze the surface of the bone (Fig. 132). By a sawing movement the instrument is gradually carried downward and forward, and then obliquely outward, thus forming a wide

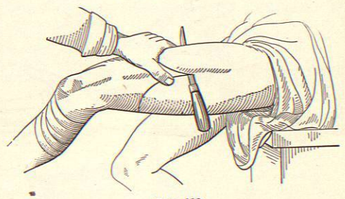

FIG. 132.

flap with convex margin. The danger of making a flap too narrow is best avoided by not cutting outward too soon. The knife is then entered at the angle of the wound on one side, passed around the bone on the side where the soft parts are still adherent, and out at the opposite end of the wound. The second flap is then made by cutting outward as before. The flaps being now retracted, the knife is rapidly carried around the bone, as high as possible, to divide the muscular tissue still adhering to it. The application of the saw then follows. In order to make sufficient allowance for shrinkage, the flaps should have a length at least equal to three-fourths the diameter of the limb. Redundance of the flap is always preferable to insufficiency, since the excess of muscular tissue can easily be removed with a few strokes of the knife. In flap operations, owing to unequal retraction of the soft parts, tendons and nerves are particularly apt to protrude above the surface of the wound, thus giving it an irregular appearance, and interfering with its ready union. After ligation of the

blood-vessels, these protruding masses are to be carefully removed with the scissors. The protrusion of the muscular tissue of the flap and the irregularity of the latter can be totally avoided by cutting from without inward. This plan, generally known as that of Langenbeck (Fig. 133), insures perfect symmetry of the flaps, and permits the ligation of the vessels as they are exposed or divided. It is also practicable to cut through the skin and subcutaneous tissue from without inward, and complete the operation by transfixion. Although already practised by Dupuytren, this plan has been recently advocated by Agnew ("System of Surgery," vol. ii., p. 305).

Rectangular Flap.—In 1855 Mr. Teale, of Leeds, practised the

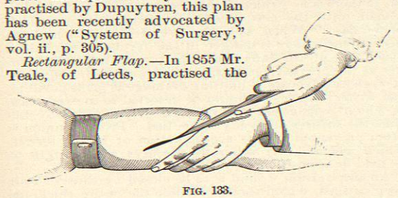

FIG. 133.

formation of one long and one short rectangular flap, each of which comprised one-half the circumference of the limb and all the tissues down to the bone. The operation is made as follows: A rectangular anterior flap (posterior in the forearm), equal in length and breadth to half the circumference of the limb at the base of the flap, is marked out by one transverse and two parallel longitudinal incisions, the latter involving only the skin and superficial fascia, and the former being carried down to the bone. The longitudinal incisions should be so placed that the posterior obtains one-fourth the length of the anterior flap. The two flaps are then turned up from the bone from below upward, and the saw is applied. To insure equal width of the flaps at their bases and their extremities it is best to map out the flaps by actual measurement before the incisions are made. In closing the wound, the long flap is doubled upon itself so that the square ends of the two flaps are brought into apposition, where they are retained by a number of sutures (Fig. 134).

COMPARISON OF METHODS.—The surgeon who would obtain the best results after amputations should be familiar with all the different methods without becoming too partial to any, since the condition of the part to be amputated, the thickness and vitality of the subcutaneous cellular tissue, the position of the wound, and many other circumstances should guide him in the selection of a method rather than individual preference. To save as much of a limb as possible must be the first aim of the operator, and this can be accomplished only by resorting to various methods according to the exigencies of individual cases. If one method of operating deserves a preference, it is that by tegumentary flaps with circular division of the remaining soft parts. By this method the position of the angles of the wound for favorable drainage and that of the cicatrix can be readily determined, and when two oval cutaneous flaps are made no anxiety for their vitality need ordinarily be entertained. When the subcutaneous cellular layer is very thin, there is a manifest advantage in dissecting up with the integument some of the superficial muscular fibres. The marked advantage of the tegumentary flap over the circular method lies in the fact that by it, when the disease extends higher on one side of the limb than on the other, it often enables us to amputate several inches lower than we could by the circular method. While during the early part of this century the musculo-cutaneous method, by transfixion, was very extensively practised, on account of the rapidity with which it could be executed and the muscularity of the stump which it left, it is gradually being discarded for two reasons chiefly. In the first place, the general use of anæsthetics has removed the necessity for unusual haste, and in the second place, the muscular tissue left in the stump generally undergoes atrophic changes from disuse during the first year. A most decided disadvantage of the musculo-tegumentary flaps exists in the oblique division of the blood-vessels, on account of which they are often difficult to find and to ligate. It is for this reason that secondary hemorrhages are more prone to follow amputations made by this method, although by proper care in the act of ligation and with sufficient compression of the stump with the dressing this can usually be avoided. The circular operation commends itself, owing to the facility with which it can be executed, even by a novice in the operative art, and by its special applicability for amputations in certain parts, as in the forearm and lower part of the leg. Where the operator can choose his method, amputations may be made with good results as follows: In the arm and forearm, by circular method or rectangular flaps; in the upper part of the leg, by tegumentary and rectangular flaps (lateral or antero-posterior); in the lower part of the thigh, by antero-posterior muscular flaps; in the middle of the thigh, by one tegumentary flap raised from the anterior surface of the limb. The oval method will be found particularly applicable to amputations at certain articulations, while the method of Teale, which has not been extensively practised in this country, will give good results in amputations of the leg and forearm where the injury or disease has invaded a limb more extensively on one side than on the other.

LIGATION OF VESSELS.—When the amputation proper is completed, the entire attention of the operator must at once be directed toward permanently controlling the hemorrhage. For this purpose it is best to grasp the divided blood-vessels, one after another, as they are seen, with hæmostatic forceps, which are allowed to remain in the wound until all the vessels are thus held. This accomplished, the vessels are separately tied with (animal ligature or carbolized) catgut or silk. The ligatures are then cut short. Veins should be tied to avert the development of a general infection out of a possible local infection. As a rule, not more than from four to six arteries will require ligation in all amputations, except those of the hip and shoulder, although long-standing disease (large neoplasms or pre-existing occlusion of the main artery) may have multiplied the number of vessels requiring ligation. Here, as in ordinary wounds, at least the larger arteries should be carefully exposed before the ligature is applied. In the smaller vessels, where their exposure would entail an unnecessary loss of time, portions of the tissues in which they are embedded may safely be included in the ligature by passing this with a needle behind the bleeding vessel. The question has for a long time been discussed as to whether the veins should be ligated. There can be no question but that the ligature of the divided veins removes a common source of secondary hemorrhage, and materially reduces that immediately following the removal of the Esmarch bandage. The opposition to the ligation of veins in amputations has been mainly based upon the fear of exciting an ascending phlebitis and of giving rise to embolic processes. That these fears are utterly groundless has been conclusively demonstrated. "Of forty cases of ligation of the internal jugular vein, death was fairly ascribable

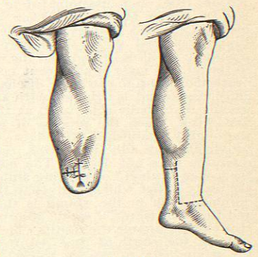

FIG. 134.

to the ligature in only four, all due to secondary hemorrhage coming on about the time of the separation of the thread. In not a single instance was diffused phlebitis excited. In twenty cases of ligation of the external jugular vein, and fifteen of the axillary, additional evidence of the safety of ligation of veins is recorded." The most troublesome hemorrhage is the parenchymatous oozing which supervenes when the Esmarch bandage is removed. How to contend against this has already been discussed (see above). It is proper to add, however, that in every case the application of an abundance of hot water is of unquestionable value. When the oozing from the divided end of the bone is not checked by this, the medullary canal may be temporarily plugged with clean white wax, or with sterile gauze. The accurate closure of the wound and pressure upon it by a well-applied bandage are among the best means of checking the capillary hemorrhage. When it is necessary to resort to this means, a large gauze pad is firmly pressed against the wound and retained until the sutures are passed. As the sutures are tightened the pad is gradually withdrawn while an assistant tightly presses the wound surfaces against each other. In large amputation wounds, the size can be greatly reduced by buried continuous catgut sutures which bring the divided muscles close together. Sutures thus applied in purse-string fashion or in tiers help to cover the bone and to prevent the formation of dead intermuscular spaces.

After-Treatment.—It is beyond the scope of this article to enter into an extended discussion of the various methods of treatment of wounds, although in hardly any other class of wounds are the good or evil results so clearly attributable to the manner of treatment adopted. The question at once presents itself whether the surgeon will pursue a course which will reasonably assure a total, or at least partial primary agglutination of the wound, or whether he will avoid the dangers of retention and decomposition of the secretion of the wound by treating this openly, thus expecting its closure by the slower process of granulation. The latter plan, which is now known as the "open method," was first enunciated by Vezin, Bartscher, and Burow, in Germany (*Deutsche Klinik*, 1856), and disseminated in this country by the late Dr. James R. Wood. When this method of treatment is adopted, sutures, adhesive straps, etc., are entirely dispensed with, the stump being comfortably placed on a pillow or pad, and the wound freely exposed to the air. A mass of absorbent cotton is placed underneath the stump to catch the discharges from it. Twice daily the wound is irrigated with an antiseptic solution, usually of carbolic acid, until at the termination of the first week, when the process of granulation has been thoroughly established, the edges of the wound are approximated by adhesive strips, care being taken that retention does not occur. The manifest advantage of the "open method" of treating amputation wounds is in the ready outlet which is given to the secretions. Their decomposition in the wound is thoroughly prevented, and the chief factor of septic absorption is thus avoided. However admirable the results which have been obtained from it, the length of time required for the closure of the wound (six to twelve weeks) militates against its general adoption. While incomparably better than the older methods of tightly closing the wound regardless of proper drainage, the open treatment of wounds has subserved its purpose, and has yielded to the superior advantages of the aseptic method, which strives to obtain the ideal of the surgeon in the treatment of wounds, viz., primary union. The open treatment of amputation wounds has been therefore properly relegated to those cases in which the surgeon is convinced that, from the condition of the parts in which the operation has been made, or from the general condition of the patient, primary union cannot take place.

When a doubt exists as to the certainty of primary union, sutures should be passed both deeply and superficially and left untied. The wound itself is packed lightly with sterile gauze. If, at the end of forty-eight or seventy-two hours, there is no evidence of septic infection, the gauze may be removed and the sutures closed with prospect of securing union without suppuration. When, on the other hand, primary union is aimed for, all drainage is to be dispensed with unless there is considerable oozing. The rubber drainage tube formerly extensively used is gradually being replaced by a narrow wick of sterile gauze drain passed through the angle of the wound from the immediate vicinity of the divided bone. This can be removed on the third or fourth day, or, if there is no evidence of infection, may be allowed to remain until the first dressing is changed, after a week or ten days. When, as in the case of amputation of the heel (Syme), there is danger of the formation of a dead space, one of the flaps can be perforated in such a manner as to prevent pocketing of wound secretion. Although an advocate of limiting drainage as far as possible, the writer believes it should be resorted to in every case in which oozing has not been entirely stopped by the time the sutures are ready to be tied. Primary union is often prevented by the accumulation of bloody serum, which mechanically separates surfaces which ought to be held in apposition.

An amputation wound is to be closed by three or four deep sutures, which should include the entire thickness of the muscles on each side of the divided bone. They should be of silver wire or silkworm gut. The superficial sutures should be placed at distances of about one-third of an inch from one another. In recent years the writer has formed the habit of bringing the divided muscles together by tiers of buried catgut sutures, and the wound margins by subcuticular silkworm-gut sutures.

The dressing of the wound follows. The amount of material used should be ample and it should be so applied that pressure will tend to keep the wound surfaces in apposition. Unless a moist dressing is deemed advisable because a doubt as to the asepsis exists, a dry dressing should always be used with scrupulous attention to surgical cleanliness. Even large amputation wounds, as those of the thigh, hip, or shoulder, will generally heal under one or two dressings. As in other operations, the dressing should be allowed to remain for at least a week or ten days. Should there be a slight oozing, a change of dressing is imperative. The stump should always be maintained in an easy position on a pillow or on a well-padded posterior splint. It is usually advisable to elevate this to a degree sufficient to facilitate the return of blood through the veins. Post-operative oozing can thereby be best prevented.

After amputations in which the asepsis has been successfully carried out, even the largest wounds will heal entirely by first intention. The dissimilarity of tissues which are often brought in contact with one another in an amputation wound, and which were formerly supposed to preclude the possibility of immediate union, is no obstacle to the achievement of this result. Of greater importance are the novel relations of the blood-vessels to one another. The circulation of the veins of the stump has lost the *vis a tergo* so essential to the proper performance of their function, while the smaller arteries are distended with blood in consequence of the interrupted circulation in the main vessel. It is for this reason that a marked œdema and congestion will often manifest themselves in the stump. Unless infection has occurred, these manifestations will disappear in three or four days.

In whatever manner the wound heals, certain marked changes will occur in the stump. The muscular tissue undergoes atrophic changes, its fibrous elements becoming firmly adherent to the end of the bone. This itself gradually decreases in size, the end becoming rounded off and often covered by a rounded osteophyte formed from the periosteum or from the granulations springing from the medullary canal. Where two bones are present, an irregular osseous bridge not infrequently unites them (see Gueterbock, *P. Arch. f. klin. Chir.*, Bd. xv. and xvii.). As a rule, the end of the bone is intimately united to the soft parts covering it, although at times a

bursa is developed between them. The ligated vessels are converted into firm fibrous cords for a varying distance, and are reduced in size, not only in the stump but also in the entire limb. Thus, in amputations of the leg, the artery and vein are reduced over one-half in size, as high as the inferior vena cava and the bifurcation of the aorta. The divided nerves lose their nervous elements by atrophy, while their connective-tissue components increase in number until their extremities are often expanded and bulbous, thus forming false neuromata.

Complications.—Pain and muscular spasm may be said to be present to a greater or less degree after every major amputation. They usually supervene soon after the patient regains consciousness, and may develop to a distressing severity, particularly in persons of a nervous and irritable disposition. For the relief of these symptoms hypodermatic injections of morphine act most promptly. The jactitations of the stump are most successfully overcome by lightly fastening the stump with a few turns of a bandage to a well-padded posterior splint.

A very slight reaction may be said to be necessary to the process of repair. When infection has taken place, the evidences are speedily seen in the wound. It may lead to more or less extensive suppuration, to a limited sloughing, or to gangrene of the stump. When such severe inflammation attacks the wound, the stump becomes exquisitely sensitive and hot, and assumes a dusky red and glistening appearance. The discharges from the wound are scant and offensive, while the elevated temperature and hard and rapid pulse sufficiently indicate the constitutional disturbance. When the inflammatory process extends along the intermuscular spaces the limb becomes sensitive to the touch, and swollen for a considerable distance above the seat of operation. When suppuration ensues all may yet be well. On the other hand, the exudation into the tissues may develop in proportions incompatible with the vitality of the parts, when extensive sloughing, and even gangrene of the entire stump, may result.

The treatment of these conditions must be conducted upon established antiphlogistic principles; iron, quinine, salicylates, and alcoholic stimulants are almost always indicated. For the local condition nothing answers so excellent a purpose as measures which relieve the tension. Stitches, when too tight, must be removed, and as soon as a suspicion of purulent accumulation is aroused, free incisions are to be made. When such extensive suppuration has supervened it is advisable to remove all constricting dressing, and to treat the wound by the open method, removing sloughs as fast as they are formed. Frequent irrigations with sublimate solutions and hydrogen dioxide are now indicated. As a dressing the balsam of Peru (ten per cent.) in castor oil applied on strips of gauze will do away with the necessity of drainage. As an especially dangerous seat of inflammation the medullary canal of the bone must be referred to. Periostitis and osteomyelitis are particularly prone to follow amputations made for gunshot injuries. It usually manifests itself during the first week after the operation by a brownish or greenish appearance of the medulla, the bone appearing dull and devitalized, while the periosteum is detached from its surface. The pain is usually very severe, and associated with it are the well-known symptoms of systemic infection, *i.e.*, rigors, elevated and irregular temperatures, diminished secretion of the kidneys, and a dry and thickly coated tongue. Not only does this condition lead to extensive necrosis when recovery ensues, but frequently death results from the absorption of the pus which is retained in the medullary canal. The only measures that offer any hope for this condition are to scoop out the bone cavity with a sharp spoon, and if this prove unavailing, to resort to a second amputation at the nearest joint. However desperate this procedure may be, a very large number of cases have been reported in which lives have been saved which, without it, would have been inevitably lost.

As a sequel of moderate inflammation of bone, necrosis of its extremity is not infrequently encountered. This may result from devitalizing of the bone from excessive heat generated by the improper use of the saw. If the necrosis be limited to the divided end, this condition does not interfere with the primary union of the greater part of the wound. The existence of such a superficial sequestrum can be deemed probable when, after the permanent closure of the wound, a fistulous tract continues to discharge more or less pus. Its actual presence can always be recognized by the cautious use of a probe. When the sequestrum is of larger proportions, numerous fistulous openings will usually be found in the soft parts, which are then more or less adherent everywhere to the bone. The treatment of this condition must be palliative until nature has completely separated the sequestrum, when it can ordinarily be removed with little difficulty by laying the fistulæ freely open. When the sequestrum is large, it occasionally becomes necessary to resort to a formal sequestrotomy for its removal. In a very small proportion of cases the irritation consequent upon the long-standing discharges from the necrosis of the bone gives rise to epithelioma of the latter, for the relief of which a second amputation is usually necessary.

One of the most dreaded complications of an amputation is hemorrhage. It may supervene within a few hours after the completion of the dressing, or as late as the third or fourth week. The sources of early and late hemorrhages after amputations differ materially. The former arise from small arteries or veins that have escaped ligation, from arteries divided above the ligature, or from the divided capillaries of the muscles. This condition is readily recognized by the staining of the dressing, the distended appearance of the stump, and the flowing of blood from a number of places where the edges of the wound have been separated. The rapid distention of the stump and the bright hue of the blood which is discharged, at once indicate the arterial source of the hemorrhage. The darker appearance of the blood and its appearance in a sluggish stream sufficiently indicate its venous origin. When the hemorrhage is slight, and particularly if it can be recognized as venous, elevation of the limb and the application of ice may suffice for its control. When it becomes evident that such simple measures are futile, the wound must be reopened, the coagula removed, and the bleeding vessel found and ligated. When it is found that the hemorrhage has come from the medullary canal, this must be treated in the manner already described. The hemorrhages which supervene during the second week, or even later, usually result from the softening of the plug that occluded a ligated vessel, or from erosion of the latter from primary disease of the vessel wall, or from its being bathed in pus. By cutting short both ends of the ligature the necessity for the "cutting through" of the latter is done away with, and at least one important factor in the causation of late hemorrhages is thus removed. For the relief of late hemorrhages, compression of the artery by a compress and firm bandage should first be tried. When this proves unsuccessful, pressure should be made at different points of the main artery to determine the point nearest the stump where the hemorrhage can be controlled. Here the artery is to be exposed and ligated, or, what seems to be preferred by most recent writers, it may be included in the pressure of an acupressure needle. In extreme cases it may become necessary to resort to re-amputation.

A peculiar and very rare condition of the stump is the development in it of a dilatation of the blood-vessels, commonly in the form of an aneurismal varix. Cases of this nature have been recorded by Cadge, of Norwich, England, by Gross, and by Agnew. Whereas, in some cases of this kind, operative treatment would not be called for, in others it may become directly indicated. Thus, in the case of Gross ("System of Surgery," vol. i., p. 530), ligation of the femoral was deemed necessary. The operation resulted fatally, from secondary hemorrhage, on the sixth day.

The form of the stump very frequently gives rise to

considerable annoyance and suffering. A healthy stump should present a nicely rounded outline, with the bones hidden beneath and away from the cicatrix. From a variety of causes this normal appearance of the stump may give place to prominence of the bone, retraction and ulceration of the soft parts covering it, and uselessness of the part for locomotion. Such an abnormal condition is commonly known as the "conical" or "sugar-loaf" stump. It may result from an insufficiency of flap, from inordinate retraction of the soft parts, or from gangrene of the integument alone. It is a condition which is more likely to follow the circular and tegumentary flap amputations, although with ordinary precautions it would seem that amputations in healthy tissues should not result in a badly formed stump. When this condition does result, nevertheless, its treatment must vary according to the extent of the deformity. When from an insufficiency of flap or excessive retraction of the soft parts, the end of the bone assumes a too prominent position, the flaps can be drawn down by appropriate bandaging, from above downward; or, by the aid of adhesive straps and weights, extension may be made in such a way as to cover the end of the prominent bone with

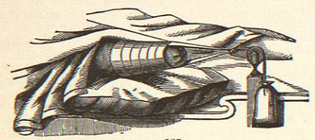

FIG. 135.

integument (Fig. 135). When, notwithstanding these measures, the proper relation between bone and soft parts cannot be brought about, nothing remains but to enlarge the wound, remove the periosteum from the bone, and divide this several inches above the level of the first section. It is unnecessary to defer this until the first wound has cicatrized. In extreme cases of conical stump reamputation will be indicated. It can be more highly recommended since reamputation is not often followed by bad results. Mr. Bryant refers to a very interesting condition of amputation stumps in children, in whom the development of conical stumps may be in a measure expected, since, in the process of growth, the bone appears to develop more rapidly. In the case of a boy whose leg was amputated, he found it necessary on two occasions, at intervals of three years, to remove two pieces of bone at least an inch long.

Neuroses of the stump are among the most intractable of its diseases. They may appear in the form of severe neuralgias, or in the form of spasmodic muscular contractions. The former condition usually depends upon an adherence of the divided nerves to the bone or the cicatrix, while in exceptional cases it results from the bulbous enlargement of the extremities of the nerve. For the relief of the former condition, subcutaneous division of the adherent cicatrix must be practised. Where neuromata can be felt, these are to be removed; when, from the number of these enlargements or from their deep positions, this procedure is impracticable, nothing short of a reamputation will give relief. Continuous jactitations, or "chorea" of the stump, as it might be termed (Gross), is very rarely encountered. It is more prone to develop in the thigh than elsewhere. The stump, when thus affected, is the seat of a constant tremor, often sufficiently active to be noticed when the limb is covered. In a case of this character which I saw two years ago, and which involved the thigh in an otherwise healthy subject, the spasms continued, notwithstanding all efforts to allay them. The most efficient measure was the deep injection of ether, which would relieve the spasm for about two weeks at a time, when the injection had to be repeated.

PROGNOSIS AND MORTALITY.—In estimating the inherent dangers of the operation, we must take into consideration only those cases in which the individuals operated on were—aside from the lesion which necessitated the operation—in the enjoyment of comparatively good health. As it is incorrect to attribute the immense mortality of tracheotomy for diphtheritic croup to an operation which, if performed for the removal of foreign bodies, is almost always successful, so it is manifestly improper to attribute most deaths after amputation to the operation itself. A compilation of the amputations of "expediency," made in Guy's Hospital, indicates a mortality of 26.8 per cent. If we remember, however, that these statistics of Bryant and Golding Bird include amputations made for neoplasms, and that the most valuable methods of after-treatment were at that time not employed in the hospital in question, this percentage must be misleading as to the inherent dangers of amputations. That the mortality of the operation under favorable circumstances can be greatly reduced from the percentage above given can be easily demonstrated. Thus, of 716 late and pathological amputations collected by Sir James Y. Simpson from smaller hospitals and private practitioners of Scotland and England, only 74, or 9 per cent., died. Of 100 amputations (including 39 of the thigh) made by Bruns, only 12 terminated fatally. According to the latest statistics of Bruns, of 204 major amputations 2 per cent. only died. Finally, of 187 amputations made by Volkmann for disease, only 7 succumbed (3 per cent.). This number includes 74 amputations of the thigh with only 2 deaths.

Unhappily these statistics are largely at variance with those gathered either from large hospitals or from the battlefield. Thus, of 560 larger amputations for all causes collected by Malgaigne in the hospitals of Paris, 299 ended fatally, the mortality being 53 per cent. The fatality attending amputations by English surgeons in the Crimean campaign is represented by 426 operations, with 169 deaths (39.6 per cent.), while the figures of the French surgeons during that war are 4,390 amputations, with 3,218 deaths, giving the appalling mortality of 73 per cent. Compared with such results those obtained during the War of the Rebellion show a most decided improvement. Of 29,980 amputations, the result was determined in 28,261; of these, 20,802 recovered. There were 7,459 deaths, thus yielding a mortality of 26.3 per cent. This is about the fatality that attends amputations in civil practice in the larger hospitals of this country and of England, although occasionally better results are recorded. Thus, of 100 amputations made in the Pennsylvania Hospital (1874–78) only 17 died, while of 539 amputations made for all causes in St. Bartholomew's Hospital (1873–82) only 88 died, giving a mortality of 16.3 per cent.

John F. Erdman,* in 1895, tabulated the statistics of amputation performed in the leading hospitals in New York, done during the decade preceding. Of 709 major amputations 109, or 15 per cent., died. Page† in 1895 collected 712 major amputations from the infirmary, Newcastle-upon-Tyne, of which 61 died, giving a mortality of 8.5 per cent. In 30 of the fatal cases death resulted from shock and loss of blood. Forty years before, Fenwick had tabulated 225 amputations done in the same infirmary with a mortality of 54, or 24 per cent. Of 163 amputations done in the Cincinnati Hospital during the decade preceding January 1, 1900, 19 terminated fatally. The gross mortality of the series was 12.7 per cent. From the clinic of Bruns‡ comes the remarkable record of 81 amputations of the leg without a death. An examination of all statistics will show that the mortality of major amputations is gradually being reduced. If the cases are subtracted in which death resulted from shock and the loss of blood, the mortality of all major amputations will

* Annals of Surgery, vol. xxii., p. 358.
† Page: London Lancet, 1895, 1., p. 923.
‡ Bruns: Beitrage z. klin. Chir., vol. xxii., p. 2.

be reduced to about 4 per cent., as has been the case with the statistics published by Estes.

It is not the least important achievement of Malgaigne to have directed the attention of surgeons to the chief causes which modify the prognosis in individual cases of amputation, and how, therefore, statistics must vary according to certain now well-known conditions under which they are collated. In a somewhat similar direction were the investigations of Simpson. The conditions which influence the prognosis of amputations will now be considered in the order of their importance.

Age.—The mortality of amputations is determined more by age than by any other one factor, since they are better borne in childhood and adolescence than later in life. Malgaigne was the first to point this out by the tabulation of 560 cases in which the mortality steadily increased with the age of the patients. Amputations between the ages of five and fifteen years yielded a mortality of 33 per cent., those between fifty and sixty-five one of 71.4 per cent. Similar investigations have been made by Callender, Holmes, Bryant, and Golding Bird in England, and by Morton and Ashhurst in this country. The last-mentioned author has combined the statistics from various sources, and, after the manner of Mr. Holmes, he has divided life into three periods of twenty years each. The total number of cases thus tabulated is summarized as follows:

TABLE SHOWING PERCENTAGE OF MORTALITY AT DIFFERENT AGES.

Whole number of cases.	Mortality below 20 years.	Mortality between 20 and 40.	Mortality over 40 years.	General death rate.
2,649	16.7	30.1	43.4	29.4

TABLE SHOWING PERCENTAGE OF MORTALITY BEFORE AND AFTER THIRTY YEARS OF AGE.

Whole number of cases.	Mortality below 30 years.	Mortality above 30 years.	General death rate.
1,805	19.2	37.4	26.7

The comparatively excellent results after amputations in children must be attributed to the rapidity with which even large wounds unite in them, to the resistance which their ordinarily unvitiated constitutions offer to septic processes, and to their freedom from visceral complications. The ease with which even large amputations are supported in childhood was particularly impressed on the mind of the writer by the case of a lad of seven, in whom he had amputated below the shoulder for railway injury. Because he was not given the freedom of the ward, the boy escaped from the hospital (Good Samaritan, in Cincinnati) on the eighth day after the operation. The wound had healed *per primam*.

The very unfavorable results which follow amputations in advanced life are readily accounted for by the reduced vitality of the system at large, by the imperfect nutrition of the stump from impaired integrity of the blood-vessels, and by the rapidity with which these patients succumb to septic infection. It is extremely probable that if the latter could be prevented the marked influence of advanced life on the results of amputations would be materially lessened. Thus of sixty-one uncomplicated amputations made by Volkmann, in persons over fifty, only 4.8 per cent. died. Among these was a successful amputation of the thigh for injury in a man eighty-four years of age.

Seat of Operation.—The danger of an amputation always increases with the size of the wound and its proximity to the trunk—amputations of the lower extremity yielding a greater mortality than those of the upper. Since about thirty-two per cent. of the deaths following amputations are directly attributable to the combined shock and hemorrhage consequent upon the injury and the operation, it is easily understood why the mortality varies in the manner indicated. The dangers of septic infection also increase with the size of the wound, and when amputation wounds fail to unite by primary union, death often results from the exhaustion consequent upon protracted suppuration. The situation at which the bone is divided also materially influences the result. The opening of the medullary cavity of a large bone like the femur, or tibia, is more apt to be followed by osteomyelitis and its consequences than is the division of the bone through its articular end. This is well shown by a comparison of the results of amputation through the lower third of the thigh and through the femoral condyles, the former operation yielding a mortality of 39 per cent. against 29 per cent. of the latter.

The ratio of deaths following amputations for injury and disease in different parts of the body is well illustrated in a subjoined table which is based upon large hospital reports, issued from 1864 to 1884. For exceptional operations (hip joint and elbow) reports of cases from private practice were included. This doubtless explains the apparently greater mortality of amputation of the thigh than of the hip, since relatively more successful than unsuccessful cases are thus recorded.

TABLE I. (From Max Schede).

	Amputations for Injury.			Amputations for Disease.		
	Total number of cases.	Number of deaths.	Mortality per cent.	Total number of cases.	Number of deaths.	Mortality per cent.
Amputation—						
at hip joint	55	39	70.9	153	65	42.6
of thigh, upper third	73	57	78.0	42	15	35.7
of thigh, middle third	67	50	74.6	137	55	40.1
of thigh, lower third	149	74	50.0	205	64	31.0
of thigh, through condyles	136	44	32.3	79	20	25.4
of thigh, locality not specified	1,384	664	48.	2,494	817	32.7
at knee	314	103	32.8	123	30	24.4
of leg, up. and middle third	130	54	41.5	178	44	24.7
of leg, lower third	33	3	9.1	128	19	14.0
of leg, locality not specified	1,956	785	40.	1,695	215	12.7
of foot, partial	223	45	20.2	562	70	12.4
at shoulder joint	274	116	42.3	118	33	28.0
of arm	1,167	364	31.2	441	81	18.4
at elbow joint	23	6	26.	8	1	12.5
of forearm	1,316	143	10.8	506	62	12.2
at wrist	199	5	2.5	27		
of fingers and toes	337	6	1.8	329	6	1.8

Nature of Lesions.—Very potent in its influence on the results of amputations are the causes for which they are made. When the operation is resorted to in an individual who, while in perfect health, has received a severe injury from which he has probably lost a considerable amount of blood, the prognosis is much less favorable than when it is made for disease. This applies particularly to amputations after railway injuries and traumata inflicted by heavy machinery. The shock and hemorrhage are very often so severe that death results within a few hours after the operation. The prejudicial effect of a trauma on the results of amputations is still further enhanced if the subject is addicted to intemperate habits. This was well illustrated in our recent riots (Cincinnati, 1884). Those injured were for the most part more or less under the influence of alcohol when wounded, and four-fifths of those on whom amputations were made succumbed.

It will be seen from the table given below that the statistics indicate with remarkable uniformity the greater mortality of amputations when made for injury than when made for disease. The explanation generally offered for this feature of the prognosis of amputations is that patients who have for a long time been subjected to suppurative processes (necrosis, caries, etc.), are so inured to suffering that they bear the shock of an operation comparatively well, and that they are less prone to septic infections which are so often the immediate cause