CHAPTER X

TREATMENT OF THE AMPUTATED

In the first portion of this book, no mention was made of amputations performed at the front since these are strictly surgical in nature. The usual operation is a simple oval or circular amputation, executed as rapidly as possible, with little thought of any result other than saving the patient's life. When these patients with a limb already amputated reach the base hospital, their further treatment should fall into the hands of some one versed not merely in surgical technic but in orthopedic principles and, above all, in the application of artificial limbs. The practice of turning the patient over to the manufacturer of artificial limbs as soon as the amputation wound has healed, is frequently responsible for much unnecessary suffering and many instances of poor function. Only by a rational harmonizing of surgical technic and orthopedic treatment with the brace-maker's art, can satisfactory results be achieved.

Preliminary Treatment of the Stump.—*When the Amputation Wound is Still Unhealed.*—It frequently occurs that by the time the patient has reached the base hospital the loose sutures applied at the time of the primary amputation have torn out, the skin flaps have retracted, and a large granulating area lies exposed. Attempt must be made to prevent further retraction of the skin. This is best done by applying a piece of stockinette to the stump after first painting it with some adhesive mixture, such as a solution of mastic.[1] The free ends of the stockinette projecting below the stump are gathered

[1] The solution of mastic is made as follows:

℞.	Mastic	20;
	Chloroform	50;
	Linseed oil	gtt. xx.

together by a stout cord, which, passing over a pulley, serves for the attachment of a suitable weight, (3 to 10 pounds). To bandage the wound, the cord is loosened and the edges of the stockinette turned backward so as to expose the granulating area. In many cases where the skin has not already become adherent, this method suffices to coapt the skin edges; when much retraction has already taken place and the skin has become adherent to the deeper structures, it merely prevents further retraction.

Postural Treatment.—Care must be taken to prevent the development of contractures. The most frequent mistake is in the case of patients with amputations of the thigh or of the calf. The nurse, in her effort to make the patient comfortable, places a pillow beneath the stump, thus flexing the thigh at the hip or flexing the knee. This error, usually unnoticed at the time, results in flexion contractures whose significance is not appreciated until the first fitting of the artificial limb. Then the brace-maker tells the surgeon that something is wrong, and that he cannot make the artificial limb fit correctly. As a consequence months of treatment are required to lengthen the contracted tissues until the free range of motion has again been acquired.

The same principle emphasized in the treatment of injuries to the muscles should be applied to the amputated; the position of the limb should be such as to prevent the overaction of the strong muscles at the expense of the weaker. Thus, at the hip and at the knee, every effort must be made to prevent the strong flexors from overcoming the action of their weaker antagonists. At the shoulder, the strong adductors must not be allowed to contract at the expense of the abductors. The application of the principle is simple. In the case of a patient with thigh amputation, a small pillow is placed under the buttocks so as to allow the thigh by its own weight to fall into the position of slight hyper-extension. For the amputation of the calf, a pillow is placed not in the popliteal space, as is so frequently done, but near the end of the stump, so as to promote the full degree of extension. For amputations of the arm, a small pillow is placed between the chest and the limb, so as to promote abduction. For amputations of the lower arm, the limb is simply allowed to lie in the fully extended position.

The one exception to this rule is in the case of amputation just below the knee, where the stump is so short that there is no possibility of affixing the artificial limb to the calf. In this event, it is particularly difficult to keep the short segment of the calf extended and as the artificial limb is constructed so as to permit the patient to walk about with the stump flexed, there is no advantage gained in attempting to maintain the extended position.

Re-amputation.—The surgeon should not be too hasty in deciding that re-amputation is necessary. I well recall two instances in which despite the discouraging appearance of the stump, which led me to prepare the patient for operative revision, I was able within several weeks' time to secure excellent results by non-operative procedures. The extension method for exerting traction on the skin has already been described; in addition to this, every effort is made to encourage epithelialization. The presence of scar tissue over the end of the stump does not necessarily mean a poor stump, although it is, of course, preferable to have a normal skin covering.

The indications for re-amputation are: (1) projection of the bone beyond the granulation tissue; (2) persistent ulceration of the stump owing to the thinness of the epithelial covering; (3) a fixed contraction of a short stump in such a position as to render application of the artificial limb impossible; (4) in rare instances for painful neuromata which yield to no other form of treatment. A conical stump is in itself no indication for re-amputation since it may, if properly exercised, develop excellent functional capacity.

A discharging sinus, due to the presence of a sequestrum or foreign body, necessitates operative removal (easily accomplished through a small incision) but this operation is in no way analogous to a re-amputation.

Whenever possible, re-amputation should be avoided, since it invariably necessitates shortening the stump. This means loss of power, since the longer the stump, the more accurate its coaptation to the artificial limb and the more effective its action. Of course, if the stump be a long one, with the site of the amputation just above the ankle or the knee, a few inches can be sacrificed without appreciable diminution of power.

The principle of maintaining the maximum length of the stump disagrees with the practice of many eminent surgeons, and therefore deserves further consideration. Thus, it is maintained by Riedel, who himself suffered amputation below the knee-joint, that the stump of the calf, although amply sufficient for the attachment of the artificial limb, was a useless encumbrance. After one year's trial, he insisted upon a re-amputation at the knee, using the Gritti method, and professed himself far happier with the short stump than with the longer. My experience has led me to the opposite conclusion. Except in those rare instances already referred to, where the stump of the calf is so short as to make it impossible to grip it in the socket of the artificial limb, every patient whom I treated found it of great advantage to be able to control the prosthesis by the action of the intact quadriceps extensor muscle. Whether the stump was suitable for weight-bearing or not, made far less difference than the additional security given by the voluntary control of the knee-joint. The longer the stump of the calf, the longer the leverage arm controlled by the patient, and the easier for the brace-maker to secure an accurate fit. This is made clear if one thinks of the stump as the piston of an air-pump. Just as the security of the piston is most marked when it is pressed downward its full length into the air-pump, so too, the stability of the stump within the artificial limb is greatest when there is the largest area of contact between it and the prosthesis.

The same holds good for amputations of the thigh, where in the case of the short stump, it is exceedingly difficult for the patient to manipulate the apparatus; whereas, with the long stump, almost the normal stride can be attained. With the upper and lower arm, the effectiveness of the stump for practical purposes is in proportion to its length; and in the case of wounds shortly below the elbow, everything should be done to preserve a stump of the forearm, however short that may be.

In applying the rule relative to the maximum length of the stump, the surgeon must beware of ultraconservatism. Thus, for instance, when an amputation at the ankle is indicated, it would be unwise to leave the astragalus attached to the stump, since in the first place, this bone would render the stump too long for the proper application of the prosthesis; in the second place it would not be as well suited to weight-bearing as an osteoplastic stump. George Marks recites an instance of amputation through the mid-calf in the case of a patient whose knee-joint had already been ankylosed. Naturally this ultraconservatism made the normal application of the prosthesis impossible, and the patient had to go about with one thigh apparently 6 inches longer than the other.

The principle of maintaining the maximum length of the limb does not belittle the importance of securing, whenever possible, a weight-bearing stump. If the stump can be rendered capable of supporting the body, the problem of fixing the artificial limb is rendered much simpler. To this end, certain osteoplastic operations are of great value and should be performed wherever feasible. In a class by themselves stand the Pirogoff and Gritti amputations. Both these procedures are excellent examples of the physiological method, and when properly executed invariably give good results. Of course, an important condition for the success of all the osteoplastic operations is an absolutely aseptic field. When this cannot be had, the operations are contraindicated.

In the calf, when the stump is a long one, so that several inches may be sacrificed with comparatively little loss of power, the Bier osteoplastic method usually results in a weight-bearing stump. When this operation is not feasible, it matters little whether the so-called "aperiosteal" technic is followed, or whether the periosteum is left adherent to the stump. Irrespective of the treatment of the periosteum, it will be found that in some cases bony spurs develop, and in others they do not. In all cases of amputation of the calf, the fibula should be divided at least ½ inch above the level of the tibia.

I have found the following technic to give good results in cases where the Bier osteoplastic method is contraindicated. The skin flaps are so planned that the anterior is large enough to cover the inferior surface of the stump. The muscle flap, on the contrary, is taken from the posterior aspect of the calf, since the fleshy gastrocnemius and soleus furnish the best covering for the inferior surface of the tibia. The muscles are attached to the periosteum by strong sutures anterior to the weight-bearing surface; as the skin suture lies posterior, there is no suture line subjected to pressure when the artificial limb is applied.

In amputations of the thigh, where the Gritti is not applicable, the Bier method can be followed provided the stump is sufficiently long.

If the stump be short, as little tissue should be sacrificed as possible. An elliptical incision is made, and a cone of granulation tissue and muscle—with its apex at the bone—is excised, the bone sawed off at this level, and the parts drawn together by strong, coapting sutures.

In patients with a femoral stump, not more than 2 or 3 inches long, the presence of an abduction or flexion contracture renders the application of the artificial limb impossible. The problem in these cases is solved most simply by disarticulation of the femur at the hip. Nothing is lost, since the stump is too short to control the artificial limb, and much is gained in the ease of application.

For amputations of the upper limb, the question of weight-bearing plays no rôle whatever. The stump should invariably be left as long as possible, and re-amputation performed only when there is urgent indication.

Kinetic Stumps.—Vanghetti and later Ceci attempted the utilization of the latent muscular force of the stump by freeing the tendons or muscle bellies in such a way as to enclose them with skin flaps. These flaps could then be moved by the voluntary muscular contraction of the patient's stump. During the last 3 years the method has been modified by Sauerbruch (until recently professor of surgery at the University of Zurich) and the technic so developed that it can be regarded as a perfected surgical procedure. Figs. 127 *et seq.* illustrate the steps of the operation. Instead of the original Vanghetti technic a much simpler method has been adopted. **After freeing a skin flap of appropriate size (Fig. 127) a**

tunnel is bored through the muscle belly (in this instance the biceps) and widened sufficiently to admit the skin flap which has been sutured to form an epithelial lined tube (Fig. 128). A simple skin plastic completes the operation (Figs. 129 and 130). The canal is kept patent by means of a rubber drainage tube or ivory peg, and as soon as possible active exercise of the muscle (see Fig. 130) begun.

FIG. 127.—The Sauerbruch method of producing a kinetic stump. First step of operation. A tunnel has been bored through the biceps muscle. A skin flap has been freed and is being sewed about a piece of rubber tubing with the epithelial surface turned inward.

Excellent though the operative results are, the practical benefit to the patient has thus far been slight, owing to the difficulty in constructing a prosthesis capable of utilizing the muscular force placed at its disposal. If this mechanical problem can be solved, the Sauerbruch procedure will constitute an important advance in our methods of treating the amputated.

Although Sauerbruch has, so far as I know, confined his operations to the upper extremity, its field of usefulness might well be extended to amputations of the thigh. Here voluntary control of the artificial limb by means of the quadriceps extensor, would be of great assistance to the patient, particularly to one whose work called for walking over uneven ground, hill climbing, and ascending or descending steps.

The Education of the Stump.—Even before the wound has healed, the physician must begin treating the stump with a

Fig. 128.—The Sauerbruch method of producing a kinetic stump. Second step of operation. The epithelial-lined tube is being drawn through the channel in the muscle.

view to developing its function. The muscles should be massaged and the patient should be encouraged to move the limb. As soon as the wound has healed, more vigorous measures can be adopted. The stump should then be bathed daily with cold water, and in addition to the massage, graduated

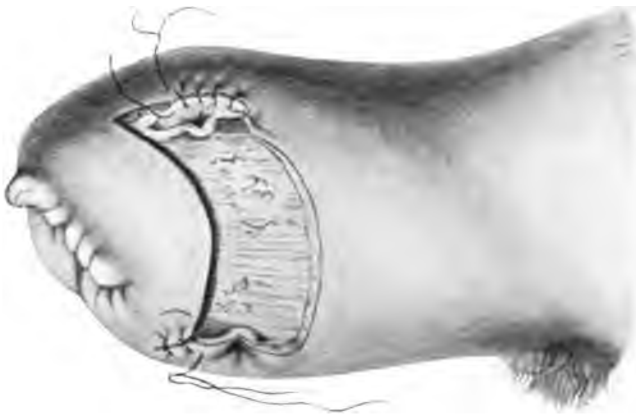


Fig. 129.—The Sauerbruch method of producing a kinetic stump. Third step of the operation. The sutures are being taken to unite the edges of the skin flap to the skin of the arm near the point of emergence from the muscular channel.

Fig. 130.—The Sauerbruch method of producing a kinetic stump. Fourth step of operation. The operation is completed by uniting the skin edges as shown in the illustration. The canal is kept patent by running a piece of rubber tubing or an ivory peg through it.

exercises should be performed. These consist of simple movements—flexion, extension, abduction, adduction and rotation—against the resistance of a weight running over a pulley, or of the hand of a trained masseur. Bandaging the stump firmly helps remove fat and reduce the œdema. To

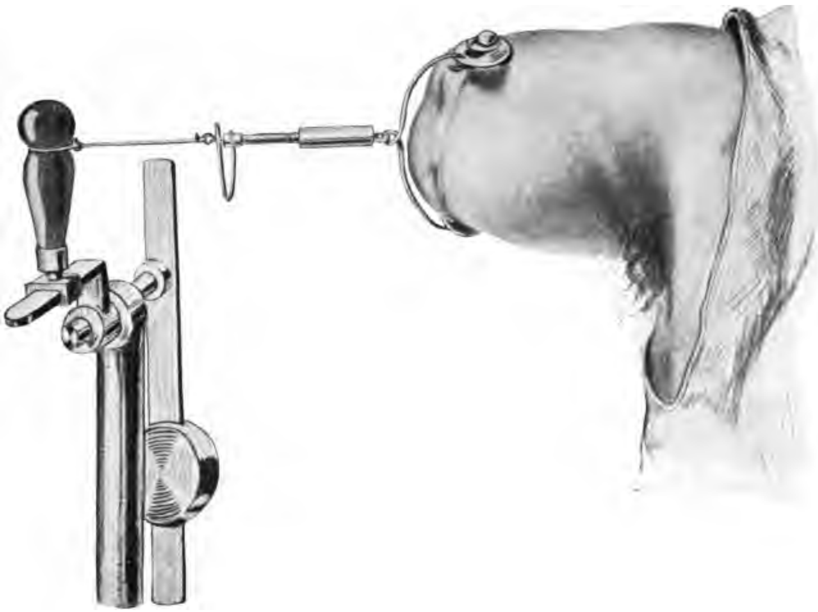


Fig. 131.—The Sauerbruch method of producing a kinetic stump. The after-treatment. To exercise the muscle through which the channel has been bored, the ivory peg running through it is attached to a pendulum apparatus. The patient can by a voluntary contraction of the muscle cause the ivory peg to move upward and thus move the lever of the apparatus. By regulating the length of the pendulum the exercises can be graduated to meet the increasing muscular power of the patient.

assist in the hardening process, leading to weight-bearing function, the patient should learn to rest the end of the stump against a chair or stool of suitable height. At first the chair is thickly padded; gradually the padding is removed, until the patient is able to bear his weight on the bare wood. He then begins to hammer with the end of the stump against the support, since a certain amount of this pounding motion is incidental to walking with the artificial limb. This treatment should, of course, be carefully graduated, otherwise the stump tends to become irritated instead of hardened.

Some authors have laid great emphasis on forming a deep circular furrow in the stump. This furrow serves for the attachment of the socket of the artificial limb, and does in some instances undoubtedly add to the stability of the prosthesis. I have found that with rare exceptions, however, the method is not of particular value. The exception consists of those instances of short stumps of the calf (about 3 inches long) which it is difficult to grasp firmly with the artificial limb. In these cases, a furrow is of distinct assistance. The Esmarch bandage, or better still, a strong piece of rubber tubing about 3/8 inch in diameter, is applied to the stump under as much pressure as the patient can stand, and kept in place for an increasing length of time with each application. After several days the patient is usually able to stand the pressure for several hours. Within two weeks, a distinct furrow can be developed.

The greatest educator of the stump is the artificial limb itself. Therefore, it should be applied as soon as possible. The use of a crutch for the amputated is an indication of inadequate treatment. The early use of an artificial limb presents one great difficulty: the stump is still swollen, a large amount of fatty tissue is still present, and the muscles are usually flabby. With time, the stump changes its shape so markedly that the artificial limb, which fitted accurately when first applied, is no longer suitable. If this has been made of leather or wood, great expense has been involved, and the value of early training of the stump seems to be outbalanced by the economic waste of time and material involved in the construction of an artificial limb whose period of usefulness is so short-lived. Owing to this difficulty, the provisional or temporary prosthesis has been evolved. The evolution of these provisional limbs has been most interesting. At first they were constructed in the crudest way of a broom-stick or a piece of bamboo incorporated in a plaster shell fitting the patient's stump (see Fig. 132). Later, an iron framework was substituted for the broom-stick, terminating in a flat metal plate which could be rivetted into the empty shoe of the patient. A still later development was the use of a hinged joint corresponding to the knee (see Fig. 133), in cases of amputation of the thigh, so that the patient could learn early to utilize the joint of the

FIG. 132.—A simple type of provisional artificial limb, consisting of a broom stick incorporated into the plaster dressing which envelops the stump.

artificial limb instead of striding with a stiff leg. All of these contrivances served their purpose in helping to educate the stump and in teaching the patient how to walk.

To Mommsen belongs the credit of evolving what is, in my experience, the most practical and efficient provisional artificial limb. Assume that the patient has been amputated six inches below the knee. An exact plaster impression is taken of the stump by enveloping it with a plaster-of-Paris bandage. The plaster should not be thicker than $\frac{1}{16}$ inch. While it is hardening, the operator should carefully mould the tuberosity

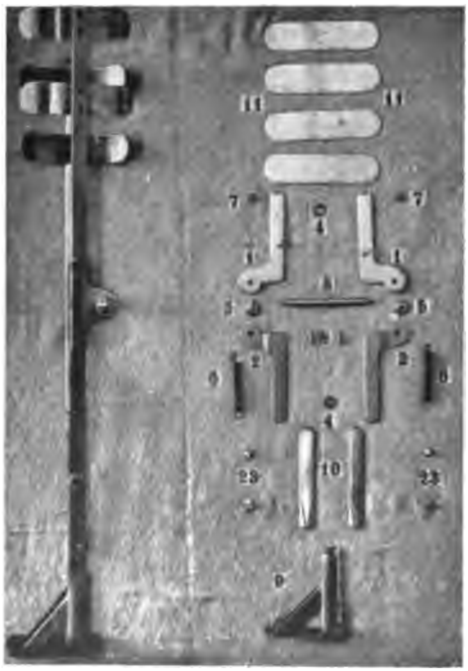


FIG. 133.—A provisional artificial limb (Spitzy) with movable knee joint. The transverse pieces marked 11 are easily bent, so that they conform to the curve of the thigh and are easily attached to the plaster dressing which encircles the stump. The foot piece is rivetted to the patient's boot.

of the tibia (see Fig. 134), since this bony projection forms the chief weight-bearing area. The head of the fibula and the condyles of the tibia are not subjected to pressure, since experience has shown that they are not adapted to weight-bearing. The plaster negative is then turned over to the brace-maker, who makes the corresponding foot, steel supports, knee-joint, and thigh-piece, just as though he were making an artificial limb for a patient whose stump had assumed its final definite form. The one difference between the final

FIG. 134—Making a provisional artificial limb for an amputation of the calf. (*Mommsen.*) The figure illustrates the first step in the process when the exact plaster impression is taken of the patient's stump. Note that the surgeon is bringing pressure to bear on each side of the tuberosity of the tibia. The condyles and the head of the fibula should not be exposed to pressure.

prosthesis and this provisional one, lies in the fact that the plaster shell has been substituted for the usual leather socket (see Fig. 135). The steel uprights are firmly fixed to the plaster by means of two rivets, and a series of bandages soaked in a mixture of plaster-of-Paris and bone glue (see footnote).[1] In other words, the patient is given at once the same type of artificial limb which he is to wear after the stump has attained its constant shape. During the stump's transition period, the

FIG. 135.—The provisional artificial limb for an amputation of the calf. It is exactly like the finished prosthesis, except that the socket into which the stump fits is of plaster-of-Paris instead of leather.

plaster negative can be changed whenever necessary, since the cost is minimal and the labor involved comparatively slight.

[1] This mixture, which though light is extremely hard, is prepared as follows: 400 grams of bone glue, broken into small chips, are dissolved in half a liter of water, heated over a water-bath. When boiling, 400 grams of alabaster plaster-of-Paris in the form of a thin plaster cream are added slowly to the glue. The mixture is constantly stirred during the process, and the preparation kept as near 100°C. as possible. When thoroughly mixed and boiled, the requisite number of starched bandages of appropriate width are immersed in the fluid, and when saturated are wound about the plaster shell, so as to strengthen it and hold the steel upright of the artificial limb firmly in place. Complete by a few turns of a plain gauze bandage. Dry in a warm room one to two days.

For amputations of the thigh, the technic is similar. In these cases, the surgeon must lay stress upon an accurate moulding of the tuberosity of the ischium, since this bone is to bear the weight of the patient's body (see Fig. 136).

When the stump has, after many months, assumed a form which no longer changes, then leather is substituted for the plaster-of-Paris, and the patient is equipped with a finished prosthesis.

FIG. 136.—Making the provisional artificial limb for an amputation of the thigh. (*Mommsen.*) An exact plaster impression is taken of the stump. The surgeon's fist brings pressure to bear just below the tuberosity of the ischium, so as to mold the support for the weight of the body.

Types of Artificial Limbs for the Lower Extremities.— It would far exceed the limits of this book were even mention to be made of the hundreds of different varieties of artificial limbs designed for amputations of the lower extremities which have been devised during preceding centuries, or which are now on the market. Study of about fifty different specimens has impressed me with certain conclusions which are, I think, of greater importance than the details of each particular invention.

1. *For amputations of the thigh,* it is important to distinguish between those stumps which are weight-bearing and those which are not. In the latter case, the success or failure of the artificial limb depends upon an accurate fit at the ischial tuberosity. Most brace-makers fail to realize that the tuberosity does not slant from above downward and forward but in the reverse direction, namely, from below upward and forward. This upward inclination, be it ever so slight, must be taken into account. The usual type of support given by the brace-maker, does not conform to this anatomical fact, but slants from above downward and forward, so that the patient slips downward on the support and almost invariably suffers pain anteriorly, near the pubic bone. The result is that the stump is rotated, and the artificial limb does not fit.

In addition to the tuberosity of the ischium, the adductor muscles are capable of bearing great weight when they have been properly hardened. The pubic bone, however, cannot stand pressure and must be left free. The gluteal muscles and the vasti also help to support the body-weight.

When the stump is short, a pelvic girdle with a strong joint at the level of the trochanter is necessary; whereas in the long stumps, the pelvic band and trochanteric joint are unnecessary. In patients with marked atrophy of the muscles, unable to balance themselves securely upon their stump, the trochanter joint should allow flexion and extension only, since the pelvis would drop toward the opposite side of the body, were abduction permitted.

In applying the steel uprights which support the body, or, in case of a wooden limb, in joining the thigh-piece with the calf, it is advisable to give the calf about 2° of genu valgum position. This adds markedly to the stability of the artificial limb.

The type of knee-joint does not, so far as I can observe, play an important rôle. In general, the simpler the mechanism the more effective. Complicated screws, ratchets, or springs add merely to the likelihood of breakage and to the cost of keeping the limb in order. Besides, for the majority of patients, who live at a distance from the industrial centres where brace-makers are to be found, the entire construction of the limb should be so simple as to permit the wearer himself to make the necessary repairs. In one European hospital there is an admirable custom of giving each amputated patient a 3 weeks' course in the brace-maker's shop, and discharge from the hospital is dependent upon ability to repair his own prosthesis.

An essential in the mechanical construction of the joint is the location of its axis posterior to the centre of gravity of the

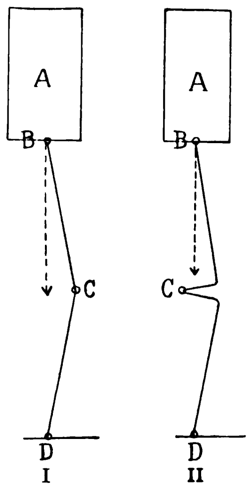


Fig. 137.—Diagrams illustrating the importance of posterior displacement of the knee joint of the artificial limb. A, Body; B, hip; C, knee joint; D, ankle. In Fig. I, the axis of the artificial joint corresponds in position to the anatomical. A slight degree of flexion brings the body weight posterior to the axis and, as is evident from the figure, further flexion must result. For the patient this position of the axis causes insecurity since the least degree of flexion is almost certain to cause him to fall. In Fig. II, the axis of the artificial limb has been displaced posteriorly. The body weight, represented by the dotted line, now falls anterior to C (the axis) and tends to lock the knee instead of producing further flexion.

anatomical joint. If this demand is not complied with, the patient loses all sense of security, because the artificial leg tends to bend at the knee under the patient's weight. If the mechanical joint lies posterior to the normal, then the body-weight tends to lock the joint as is seen by reference to the diagram (Fig. 137).

An artificial quadriceps does not, I find, add to the naturalness of the stride, but almost invariably tends to hold the leg fully extended, so that the patient walks as though the knee were ankylosed. A freely swinging joint with some simple rubber or spring device to prevent jarring in extension or flexion gives the patient the best opportunity to imitate the normal gait.

2. *For amputations of the calf,* the type of limb depends upon the length of the stump. If it is short—less than one-half the length of the calf—there must invariably be a thigh-piece and a knee-joint. If it is long, these may be dispensed with provided the stump is capable of weight-bearing.

As already indicated, when the stump is not capable of weight-bearing, the artificial limb must be so moulded as to grasp the tuberosity of the tibia firmly, not the condyles, as is usually taught. The patella-tendon also is capable of weight-bearing, as can be learned by observing any patient who has worn an artificial limb for many years.

Some difficulty is frequently experienced in bringing the leather socket of the artificial limb over the gastrocnemeii. This can be obviated by slitting the socket posteriorly and inserting eyes so as to lace it up when once it is in proper position.

The ankle-joint, like the knee, should be of the simplest type, allowing merely flexion and extension. In addition to the ankle-joint, there should be one corresponding to the metatarsophalangeal junction.

Types of Artificial Limb for Amputations of the Upper Extremity.—The problem of dealing with amputations of the upper extremity is far more difficult than is the case with amputations of the lower limbs. The legs merely have to carry the body, but the arm has a great variety of functions to perform. Depending upon the nature of these functions, and also to a great extent upon the site of the amputation, the artificial limb must vary from one case to another. Thus, an artificial limb which might be of value to a lawyer or business man would be of little use to the farmer or mechanic; and of two farmers, one with an amputation of the forearm, another with an amputation above the elbow, the one would have to be equipped with a type of limb differing markedly from that supplied to the other. There is no universal artificial limb applicable to all cases.

1. *Types of Artificial Arms Designed for Amputations of the Fore-arm.*—For the farmer and artisan, a simple and effective prosthesis has been designed by August Keller. Amputated

FIG. 138.—The Keller artificial hand. The picture illustrates Keller's method of inserting a small knife, with which he is sharpening his pencil. Note also the piece of cork attached to the pencil. This enables him to grip the pencil between the claws and to write with it. The lower arm socket is held firmly in place by a broad strap which makes a figure-of-eight turn about the elbow.

himself, some nine years ago, he constructed an artificial limb of the simplest materials, so well adapted to the needs of the farmer that the amputated scarcely note the handicap under which they are compelled to work. Keller's device consists of a leather socket reinforced by two longitudinal steel bars, held in place by a figure-of-eight strap which passes just above the elbow (Fig. 138). The hand-piece, made of wood, can be removed from the socket if desired (Fig. 141). Inserted into the wooden hand-piece are three strong steel hooks. These are not adjustable. They aid the patient in two ways: first, small objects, such as pencil or knife, can be inserted between them, second, they furnish the leverage for larger instruments. To hold these latter in place, a leather strap, attached to the

FIG. 139.—The Keller artificial hand. Keller at work with his spade.

anterior portion of the apparatus, is made to take a double turn about the handle of the article used (see Fig. 143) and then passing backward between the hooks, is fixed to the posterior aspect by means of a steel pin. The illustrations indicate how Keller uses his own device. The speed, accuracy and power which he exhibits are scarcely inferior to that of the normal individual.

A large number of other contrivances have been evolved to replace the fingers. These consist of hooks, rings, clamps, and holders designed for special articles, such as knife, fork, spoon, pen or pencil, knitting needle, etc. Some of these are shown in Figs. 144, 145, 146 and 147. Several excellent devices have been invented by Judge Corley, of Dallas, Texas. One of these, a most ingenious arrangement enabling the wearer to button his own collar, is illustrated in Fig. 148.

For the business man, or the professional, a more suitable type is the arm designed by Carnes. In this, the mechanism

Fig. 140—The Keller artificial hand. Keller pruning a small tree.

is far more complicated, and the cost therefore proportionately greater. Despite the delicate mechanism, however, it is capable of standing the usual amount of wear and tear, and a break of any constituent part can readily be replaced. The essential feature of the arm is the voluntary control of motion of the fingers and of the wrist by means of bands which become shortened or lengthened by motion of the elbow-joint. The arm requires considerable practice before the technic of its use can be acquired. To give a patient such an artificial limb and expect him to be able to use it at once, is as illogical as presenting a man with a violin and telling him to play upon it. When, however, its use has been mastered, it gives surprisingly good results.

The mode of attachment of the artificial limb to the stump is of importance. The hinge-joint at the elbow with an upper

FIG. 141.—The Keller artificial hand. The hand attachment can be removed, permitting the insertion of various instruments. In this instance a hammer has been inserted, which Keller is able to use with the same dexterity as a normal individual.

arm cuff, the usual type found in the brace-maker's shop should not be employed, since it gives no opportunity for pro- and supination. A simpler and far more advantageous method of attachment is the figure-of-eight strap, which passes just above the condyles of the humerus and crossing the posterior surface of the humerus descends again over the anterior surface (see Fig. 138).

2. *Types of Arm Designed for Disarticulation of the Elbow or Amputations of the Upper Arm.*—The classical type of limb is a useless encumbrance and is almost always relegated to the

garret by the intelligent patient. To be of any assistance to its wearer, the prosthesis must, even more than in the case of that for the forearm amputation, be particularly designed for the special work to be performed. Fig. 149 shows a fourteen-year-old patient to whom belongs the credit of evolving a prac-

FIG. 142.—The Keller artificial hand. For aesthetic purposes Keller draws a glove over the hooks. This he terms his "Sunday" hand.

tical working arm for disarticulation at the elbow. When this lad was placed in the carpenter shop, I suggested that he construct an artificial limb to help him at his work. I expected to see the usual hinge-joint at the elbow, prolonged downward to serve for the attachment of a hook or a clamp. To my great surprise, after a few days the lad showed me the artificial limb pictured in Fig. 150. It will be noted that instead of a hinge-joint, there is a ball-and-socket joint at the

FIG. 143.—Keller splitting wood. Note the double turn of the leather strap around the handle of the axe. This gave Keller so strong a grip on the handle that the united strength of three men was unable to pull the axe away. Keller's dexterity equalled that of an expert woodsman.

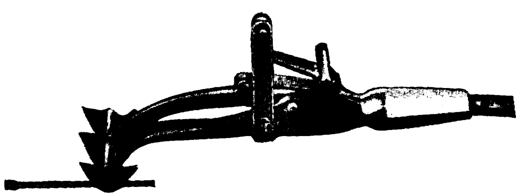


FIG. 144.—The Fischer clamp for the use of the one-armed. The three prongs facilitate holding objects obliquely as well as in the axis of the limb.

elbow, which, according to the patient's statement, he had constructed because he wished not merely to bend at the elbow but also to turn the forearm. In other words, he had solved a problem which makers of artificial limbs had for centuries

FIG. 145.—Clamp and hook serviceable for the amputated workman. The clamp serves to hold a file, brush, small hammer, etc. The hook can be used to carry a pail or to lift heavy objects.

FIG. 146.—A professional pianist, whose right hand had to be amputated because of gunshot injury. Equipped with a special device of Hoeftemann's, he was able to continue his profession. It was possible for him to strike single notes and chords with facility.

failed to answer; namely, the best method of combining flexion and extension with pro- and supination. Between the concave extremities of the upper and lower arm pieces was inserted a wooden sphere, bound to the adjacent concavities by a strong spring. The friction between the opposing surfaces was sufficient to lock the arm at any desired angle. With

FIG. 147.—Hoeftemann's device for the professional pianist shown in Fig. 146.

FIG. 148.—Judge Corley's apparatus for helping the man who has lost both hands to button his own collar.

the aid of this simple device, the patient within two years became an expert carpenter and, entirely unassisted, was able to do the finest kind of cabinet work. Of course it must be remembered that the artificial hand plays the rôle of assistant to the sound arm, and the success of the patient in becoming an expert artisan was due in large part to the fact that the major work done by the carpenter is performed by one hand aided to a comparatively slight degree by the other.

FIG. 149.—A 14-year old carpenter's apprentice amputated at the elbow, showing the artificial limb which he himself designed. By inserting a wooden sphere between the concave extremities of the upper and lower arm pieces he could not only flex and extend but supinate and pronate.

Another valuable type of arm is illustrated in Fig. 152. This device is purely for working purposes, and must be supplemented by another arm which hides the defect. It consists of a broad padded metal ring which fits over the shoulder and is held firmly in place by straps passing around the body. To this ring is attached a second, which, running on ball bearings, has perfect freedom of rotation on the first ring. To the second are attached steel uprights which run parallel with the stump and terminate at the level of the elbow in a circular disc to which various instruments useful to the carpenter can be

Fig. 150.—The carpenter's apprentice shown in Fig. 149 guiding the plane with his artificial arm.

attached. The stump is bound firmly to the steel uprights by means of straps, and owing to the ball-bearing joint at the shoulder the wearer has almost the normal range of motion. A little ingenuity in devising the tools to be inserted into the disc enables the amputated to do even the most delicate kind of carpentry work. One tool suffices to grasp the screw of the screw-and-bit; another grasps the nail so that the uninjured hand is free to hammer; another is designed to hold the chisel, etc.

An interesting modification of the working arm suitable for amputations above the elbow, is the utilization of a spring at

FIG. 151.—The carpenter's apprentice already pictured in the preceding figures, at work with the saw. The artificial limb is used to steady the board.

the elbow-joint, which permits a springy motion of distinct value in hammering, filing, etc., work in which absolute fixation at the elbow takes away from the freedom of the stroke. Fig. 154 illucidates the principle of this arm. By fastening screws *A* and *B*, the arm can be absolutely fixed at any desired

FIG. 152.—The Siemens-Schuckert arm for amputations above the elbow. For descriptive text see page 209 *et seq.*

FIG. 153.—The Biesalski artificial arm for amputations above the elbow. (First model.) This arm was probably the first in which an elbow joint was constructed corresponding to the anatomy of the normal, and the first in which a working arm was combined with an æsthetic means of hiding the defect. The lower arm portion consists of a strong metal tube, into which working implements can be inserted and over which the artificial hand can be placed, when the wearer is through with his day's work.

angle. By releasing screw *A* which controls the springs, the plunger is allowed to move backward and forward, allowing about 10° motion, but not beyond the limit set by the screw *B*. Pronation and supination are not possible in this type of

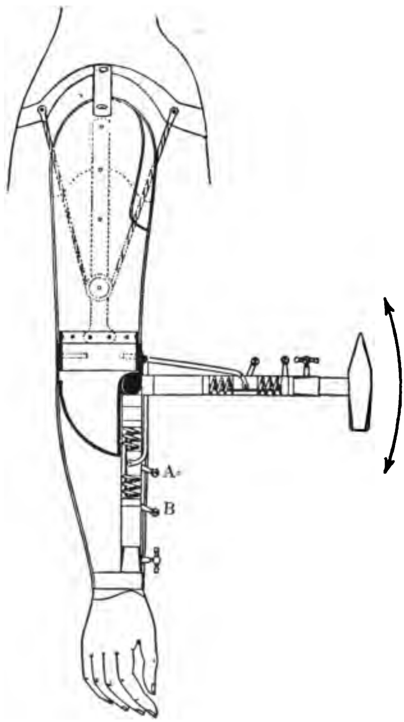


FIG. 154.—Artificial arm in which a limited amount of springy motion can take place at the elbow by adjusting the screws *A* and *B*. (*Model of Biesalski.*)

arm except by rotating the tool which is inserted into the hollow barrel corresponding to the forearm.

Two types of working arm have been constructed after the pattern of the ball-and-socket joint devised by the young carpenter's apprentice already mentioned. To render the fixation at the elbow firmer, a screw is attached to the elbow articulation which locks the upper and lower arm against the spherical surface of the intervening steel ball (see Fig. 155). Although these two arms are capable of withstanding great strain, they are not, so far as I have been able to judge, as advantageous as that pictured in Fig. 152, because the tool is not brought into sufficiently intimate contact with the stump.

Screw locking the elbow at any desired angle

Fig. 155.—A working arm designed for amputations above the elbow (Rota arm). The joint at the elbow is so constructed that not only flexion and extension but pro- and supination are made possible. The portion corresponding to the lower arm consists of a tube into which tools of various kinds can be inserted. It can be fixed in any desired position by a turn of the screw just above the elbow joint.

As a rule, with practically no exceptions, the nearer the stump can be brought to the instrument which it is to control, the more effective is the amputated's use of the implement.

The Carnes arm already described in speaking of amputations of the forearm, is also applicable to amputations of the upper arm. The motor power is then derived by the movements of the shoulders (see Figs. 156, 157 and 158). The difficulty in learning to use the arm is increased when the amputation lies above the elbow, nor is it particularly well suited to the use of the artisan. For æsthetic purposes, however, it is the most ingenious device of which I know.

The shorter the upper arm stump, the more difficult the attachment of the prosthesis, and the more difficult it is to

FIG. 156.—A case of double amputation, on the right side through the elbow, on the left 4 inches below the shoulder. In a case of this kind, unlike that pictured in Fig. 171, an artificial limb is necessary, since the two stumps cannot be approximated. The Carnes artificial arms are seen lying on the table. The patient can put these on without assistance and is then able to eat alone, dress, shave and use many tools. (See also Fig. 157.)

render the stump capable of doing its fair share of work. As a rule it is almost impossible to train a patient with a stump less than 4 inches long to be an independent farmer or artisan. An exception is pictured in Fig. 163. Despite the short stump, this young boy was able to work skillfully in the machine shop (see Figs. 159 *et seq.*). The prosthesis shows the excellent shoulder device designed by Riedinger. As a rule the patient with the short upper arm stump can be made capable of doing lighter garden work (see Figs. 164 *et seq.*), or in suitable instances, he can be trained to work at a

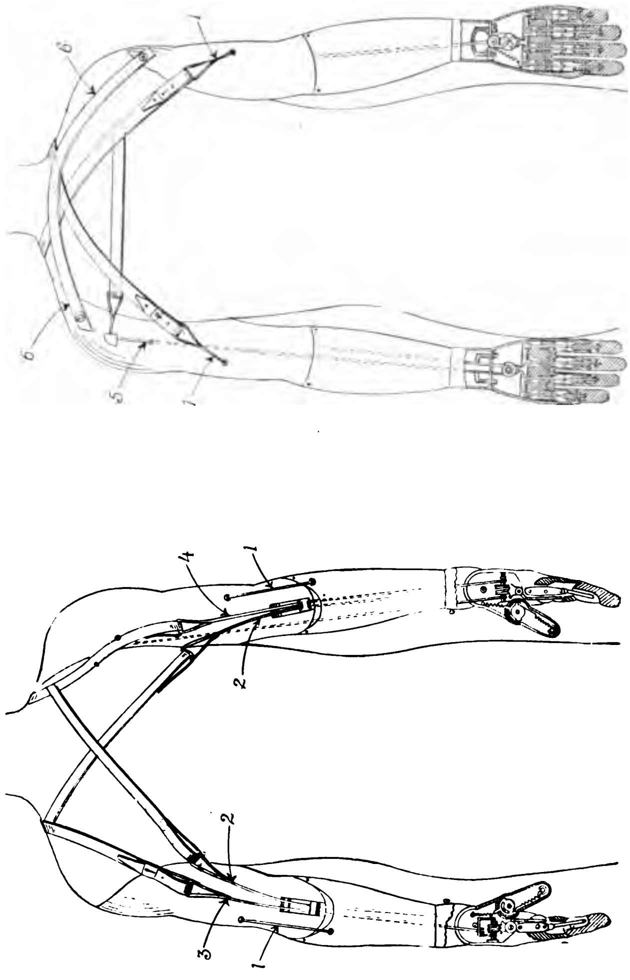
Fig. 157.—The Carnes artificial arm for the patient shown in Fig. 156.

factory machine. For this latter purpose close coöperation is necessary between physician, machinist, and the manager of the factory.

Even when the entire arm has been disarticulated at the shoulder, a prosthesis can be applied with distinct benefit to the wearer. The artificial limb is controlled by the swing of the body, and enables the amputated to wield a broom, rake, etc. In these cases as well as in the higher amputations of the upper arm, the simple device shown in Fig. 164 has proven most serviceable. It consists of a round piece of wood resembling a spool, with a strap passing over it fixed on the one side, ending in a catch on the other side, similar to that frequently used on ice or roller skates. The handle of the implement, spade, rake, wheelbarrow, etc., is fastened between the strap and the spool. There is sufficient fixation for all purposes, and at the same time enough latitude of motion to allow the wheelbarrow to be tipped, or the angle of the rake to be changed.

The Life of the Amputated.—Care of the stump and the application of the artificial limb constitute only two of the numerous problems which confront the physician in the care of the amputated. Particularly in the case of those who have lost a hand, the entire mode of life must be modified. Nothing can be done as it was previously done, and the simplest actions of everyday life must be relearned. First, the amputated must be taught to dress and undress with one hand. The question of washing gave me considerable trouble, since the amputated were unable properly to cleanse the fingers and hand of the sound arm. The simple device pictured in Fig. 167, a board fitting over the wash basin, to which scrubbing brush and nail file could be attached, solved the problem. Lacing the shoes was another difficulty. Here I was aided by one of the amputated boys of the crippled children's hospital with which I was associated. He used a single, long lace, on the same principle as that employed in lacing a whipstock. One end was firmly attached to the lowermost eyelet of the shoe. The other end was then passed through the eyelets in the usual way, and then, allowing a loop long enough to be zigzagged between the hooks, was passed beneath the lacings back to the starting point. The loop was then caught zigzag from one hook to another, and the slack taken in by a vigorous pull on the end of the lacing projecting beyond the first eyelet.

In eating, the only difficulty was occasioned by the need of cutting and using the fork with the same hand. For this purpose a number of devices are on the market. These consist of a knife-blade terminating in a fork-like projection



I II

Fig. 158.

Fig. 158.—Two diagrams illustrating the principle of the Carnes arm for a double amputation, with one arm amputated between the elbow and the shoulder, and the other arm disarticulated at the shoulder. I. View from in front. II. View behind. The functions of the different straps are as follows:

Strap No. 1. Bends or operates the elbow. This strap coming from the back, passing over pulleys in the upper arm, and being anchored to the forearm, enables the wearer to get the elbow movement, simply by moving his stump forward a little.

Strap No. 2. Locks the rotating wrist. To unlock the wrist, the elbow is bent up to the extreme. When the wrist is not locked, it turns or rotates as the elbow is bent, but can be locked in any position desired, by first bending the elbow until the wrist and hand are rotated to the position desired, then hold it in this position while pulling on Strap No. 2, to lock it there.

Strap No. 3. Opens and closes the fingers. On the amputation above the elbow, by throwing the shoulder down, a sufficient tension is had on this strap to open or close the fingers; then, by raising the shoulder, the cord is pulled back into the hand, allowing the mechanism to reverse, and then, by again pushing the shoulder down, the opposite movement of opening and closing the hand is obtained.

Straps Nos. 4 and 5. Opens and closes the hand on the shoulder or disarticulated amputation.

Strap No. 6. Simply an elastic support to hold the arm in place. For a single amputation on either side, the harness will be as shown, excepting that on the opposite side, it would simply be looped up under the good arm.

Straps No. 2 are the only ones which come across the chest and these are not tight, it being necessary to throw the arm out to the side, in order to lock the wrist.

For the diagrams and explanatory text I am indebted to the Carnes Artificial Limb Co., Kansas City, Mo.

(see Fig. 168). The blade is convex, so that the food is easily cut by a rocking movement.

When the right hand has been lost, the patient must at once be taught to write with the left. This can be learned by the average man in about 3 weeks. It is advantageous to stimulate the patients by the competition afforded by class-room work.

FIG. 159.—Patient of Riedinger with very short upper arm stump.

In hundreds of ways, the physician can help the amputated to readjust themselves to the new mode of life; and in many instances the amputated will teach the physician and his comrades new methods of usefulness.

This training in proficiency, combined with the wholesome cheeriness of physician and instructor, does more than anything else to overcome the depression under which most of the patients are laboring, and fits them for the next important step in rendering them useful citizens of their community—specialized training of the stump, for the particular purposes for which it is to be used. For this of course the men must be divided into groups depending upon the type of amputa-

FIG. 160.—The same patient as in Fig. 159, equipped with a Riedinger prosthesis. Note the broad circular pad which closely surrounds the shoulder and serves as support for the leather socket which is attached to it by a strong joint, permitting motion in all directions.

FIG. 161.—The mechanic's tools employed by the patient shown in Fig. 160. These are inserted into the slot at the lower end of the forearm piece and fastened firmly in place by a turn of the screw.

Fig. 162.—The same patient as in Fig. 160, illustrating the method of using hammer and chisel.

Fig. 163.—The same patient as in Fig. 160 at work at the turning-lathe.

tion and the nature of the work. In helping the patient to decide what work he is fitted for, the physician should have as consultant a staff of technical assistants versed in the details of all the handicrafts. Experience has shown that amputations of the forearm and of the upper arm if not more than 2 or 3 inches above the elbow, do not debar a man from becoming a carpenter, farmer, or some type of mechanician.

FIG. 164.—This patient suffered an amputation of the right arm 2½ inches below the shoulder. Equipped with the Biesalski artificial arm shown in Fig. 153 he was able to do all forms of light gardening. Note the simple contrivance at the wrist consisting of a spool over which a strap passes. This device gives a firm grip and at the same time allows sufficient play to dump the wheel barrow.

Of course, those possessing an elbow-joint have a great advantage over those amputated above the elbow. When the amputation has occurred near the shoulder-joint, it is foolish to attempt training a man for these branches. He should then be taught some handicraft allied to his previous occupation. Thus, the carpenter should be taught sufficient mechanical drawing and building construction to enable him to act as

Fig. 165.—The same patient as in Fig. 164. He is shown at work with the spade.

Fig. 166.—The same patient as in Fig. 165. The spool device at the wrist enables him to use the rake effectively.

foreman; or, if he is not sufficiently well educated to assume this responsibility, he can be taught to be a furniture polisher. In this occupation, practically all the work is done with a sweeping motion of one arm; the other hand is used simply to hold the varnish or other polishing substance—a function which is quite as well filled by a small tray placed near the worker.

FIG. 167.—A simple toilet arrangement for the one-arm soldier. To permit proper cleansing of the hand, a scrubbing brush and a nail file are fastened firmly to the board which rests on the basin.

The artificial limb can be used to advantage in many instances, but for many men the stump is the best form of prosthesis. This applies particularly to a moderately long forearm stump. This can be used for filing, almost as effectively as the normal hand (See Fig. 169); for hammering, the

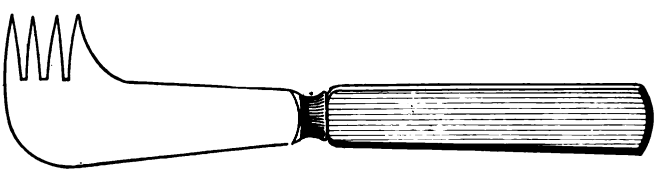


FIG. 168.—A combination of knife and fork for the one-armed.

handle is gripped in the elbow between the upper arm and the stump, as shown in Fig. 170. At the turning lathe, the stump can easily be trained to turn the adjusting swivel. In learning to use the stump, it is of great assistance to have an amputated man himself act as instructor. It is remarkable to what extent the delicacy of the skin improves. In one instance, in which I tested the fineness of perception by the two-point test, used by the physiologists in determining the number of tactile corpuscles in the cutis, I found almost the same degree of sensitiveness of the forearm stump as that normally found over the finger tips.

Those suffering amputation of a lower limb do not require the same specialized training. All they need is the proper

Fig. 169.—The bracemaker's apprentice pictured in Fig. 170. Here he is shown in the act of filing. The stump had become so hardened that he was able to use it exactly as the ordinary mechanic uses his left hand.

stump treatment and the application of a well-fitting prosthesis to render them fit to return to their community. With rare exceptions, they are able to return to their previous occupations. The exceptions are the cases of double amputation or amputation near the hip in cases of men who previously did hard manual labor. They must be taught a trade which allows them to be seated most of the time.

Far and away the most difficult problem presented in the care of the amputated is that of those who have lost both hands. Provided the stumps are sufficiently long to allow

Fig. 170.—The one-armed bracemaker's apprentice already pictured in Fig. 169. This illustration shows his method of gripping the hammer between the stump, upper arm and chest.

them to be approximated, the loss is not as tragic as it at first appears. In Fig. 171 is shown one of the teachers of the crippled children's home already referred to. He is seen in the act of buttoning his collar by means of a button hook held between the two stumps. This man had learned to dress himself alone, to eat with delicacy and grace, to write a perfect hand with more than the normal speed, and had passed the examinations qualifying him as a licensed teacher. He did all this without use of artificial limbs. I also had opportunity of meeting several other men with double amputations who used their stumps as skillfully as he.

Fig. 171.—A teacher, both of whose hands had been amputated when six years old. He had learned to be absolutely independent and had passed his examination entitling him to a teacher's license. Without artificial limb he could dress himself (the illustration shows him in the act of buttoning his collar), shave, eat with grace and assurance, write an unusually legible hand with more than normal rapidity, travel long distances alone, carry a suit case and pay his fares, just as the normal individual would. All this was done by careful education of the stump, which in his case had acquired almost the same sensitiveness as the tips of the fingers.

When, however, the stumps are so short that they cannot be brought together, then an artificial limb must be applied—either the Carnes' arm (see Fig. 157), or Judge Corley's, since with sufficient training it enables the wearer to become a reasonably independent being, whereas without it he is absolutely helpless.

The double-amputated require a school all to themselves, especially devised clothing with snap-hooks instead of buttons, trousers so devised as to fit directly to a vest (see Fig. 172), etc. In no instance, however, should the individual be allowed to

FIG. 172.—A patient with double amputation showing the vest and trowsers designed by Spitzy and a type of artificial arm attachable directly to the clothing. Note the ring hanging down from the slit of the trowsers. By pulling this upward with the hook of the artificial arm, the trowsers are closed by means of a thin chain with interlocking teeth.

feel that his case is hopeless. Even in one pathetic instance in which in addition to the loss of both hands the patient had been blinded by the explosion, much was accomplished and he left the hospital ready to assume a post in the office of a large business establishment.