

AMPUTATIONS*

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THE removal of limbs has undergone a great change in the last decades. During this period amputation has become an art which can no longer be considered a beginner's task. In emergency cases every physician must be able to perform this operation at once, if necessary to save life. But otherwise it demands the highest surgical skill, both in determining the indication and in the proper execution.

Amputation has become rare in the surgery of peace. By all possible means its use is being reduced also in war. In the great traumatic epidemics even to-day more limbs must be sacrificed, it is true, to save more lives under the stress of circumstances which it is our constant aim to alleviate. For in time of war it is our highest duty to procure as far as possible the help available in time of peace for those who stake their health, their life, for the welfare of the nation.

The progress of surgery makes it possible under the protection of a simplified and certain antisepsis and asepsis, to wait longer in treating lesions, in order to see what is in reality traumatically destroyed, and what may unexpectedly recover. Crushed parts which infection formerly made a menace to life, can now be preserved. What Lister emphasized as the guiding principle in the treatment for wounds: to let alone—has been disregarded, almost forgotten in the overactivity of our antiseptic era, very much to the disadvantage of the wounded. Von Bergmann rendered a service of incomparable value in introducing simple measures for open fractures in war and insisting with all earnestness on their use also in time of peace. Extremities whose removal seemed hitherto inevitable in consequence of vascular lesions are very often successfully preserved in time of peace by means of operations on the vessels, suture, anastomosis and transplantation. The benefits of these advances have already been extended by practiced hands to the wounded in military hospitals. The gradually increasing occlusion of the vessels, such as threatens the extremities with gangrene in arteriosclerosis, can be combated through anastomosis of the large arteries and veins. In this way the future derangement of vitality becomes a rarer indication for the removal of a limb.

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The sequelæ of acute inflammations and of chronic inflammatory changes put before us the question whether to amputate or not, irrespective of whether the fault lies with the patients or their physicians. Not only as a prophylactic in the very beginning, but also as a treatment at the height of the inflammation, the measures recommended by Bier, especially for the extremities, achieve remarkable results in removing the necessity for a mutilation. If there is any suspicion of the wounds becoming infected (they are all, briefly speaking, affected at least by an "infectio minima insensibilis") we may avert phlegmonous processes through hyperæmia induced by bandaging (Bier's hyperæmia). If they do appear, nevertheless, incisions which preserve the tissues are used together with the hyperæmia in order to prevent sequelæ and general health-endangering conditions which even to-day may ultimately require amputation. In the further development of surgical interference which has made unnecessary the removal of congenital and gradually forming *deformities*, we have learned, if contusions or inflammations were followed by strongly disturbing sequelæ, to perform operations on the bones, joints, musculotendinous apparatus and on the nerves which restore them to painless use.

The indication to amputate on account of the *formation of tumors* could be modified by resections in cases of benign tumors; also in the case of myelogenous sarcoma, plastic operations and transplantations, are aiming to replace completely the removed parts in regard to form and use. By means of radiotherapy, the powerful assistant which has come to the aid of operative surgery, we hope to be able to limit mutilation also in the case of tumors which until now, even in the early stages, offered a prospect of cure only by immediate amputation. In the case of the extremities this holds good especially for periosteal sarcoma.

The right to the judgment that a limb cannot be saved, therefore, presupposes an exceptional familiarity with the progress of our science. An equally exceptional ability is required for the execution of the amputation.

The necessity to draw upon such knowledge and ability may come to the non-operating general practitioner at any hour. He must, therefore, know the modern demands of amputation, especially with regard to the changes in the establishment of the indication. In full appreciation of the minutiae through which the very best can be obtained in clinics, we must endeavor to simplify our proceedings to the utmost with regard to the execution and the necessary remedies. The dictum of Boerhave: *simplex sigillum veri*, is peculiarly true in practical medicine and in "emergency amputation" in peace and in war; but it is also true

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in the case of "interference which is optional as regards the time of execution."

The execution is never so urgent that the demand to raise the capacity of resistance against the effect of operation could not be fulfilled. Where the date of the operation is optional, neglect of careful preparation for the purpose of increasing the strength of the patient is a gross technical error. This preparation may take days, even weeks. Here, in advance of the surgeon's skill, the physician's foresight is to come into play, especially in regulating and strengthening the heart and cleaning the air passages by prescribing both medicines and systematic breathing exercises which later on also afford the best protection against thromboembolism. In the case of emergency operations, the measures for strengthening the general health coincide for a short time with the technical preparations for the surgical interference. When treating a trauma, before the patient goes to the operating table, the heart excitants, ether and camphor, are given, with the great quieter, morphine. Where it can be done, the quantity of blood is increased by salt infusion—provided there is absolute safety against further bleeding. This may be rendered more valuable by oxygen inhalation. Above all, the bloodless need protection against loss of heat. Provision must be made for warming the operating table.

Certainly, also, the interference in itself is an injury. Possible developments that may arise (during the operation itself) must be so carefully considered in advance that death on the table during operation may be excluded, and where the case is known to be a hopeless one, the operation should never be attempted.

A mortality, caused from the amputation itself, must be absolutely excluded, even when section occurs high up near the trunk! The patient should never lose his life during operation through impairment of the circulation and the nervous functions. He must be guarded against further danger of life after the operation. To accomplish this there must be a positive arrest of hemorrhage and an absence or at least a minimum of pain in the care of the wound, and perfect technic of the operative procedure. But nowadays even more important than conserving life and bringing about a final cure is the accomplishment of a condition whereby the usefulness of the stump, as far as its strength and mobility are concerned, is attained.

Great progress in the direction of arresting hemorrhage was made by Esmarch and his achievements are all the more notable because of the simplicity of his method and the surety of its outcome. Even on the battlefield a surgeon, or in case of necessity, an experienced assistant,

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can exclude the blood from the particular member about to be amputated by applying elastic bandages and elevating the limb.

The fastening of the ligating tube requires special means in cases of high amputations and for exarticulation at the hip- and shoulder-joints. The tube applied in figure-of-8 turns can be fastened by suture and secured against slipping off by means of large needles and stick-pins. Sometimes the external iliac artery or subclavian is to be ligated; even permanently, as long as it does not endanger the vitality of the flap well provided for by collateral vessels; otherwise temporarily with a loop which will be taken off as soon as the large vessels in the turned-over flaps are cared for. In Momburg's compression of the aorta by an elastic bandage around the abdomen, which had a forerunner in Esmarch's somewhat more complicated compression of the aorta, an excellent method of prophylactic hæmostasis at the root of the thigh and of the pelvis is also given to military surgery.

It must be always emphasized that in cases of amputation the prevention of pain is an essential factor. The exclusion of the psychic factor through a general narcosis which may be brought on as early as the night preceding the operation, is a command of humanity which is to be fulfilled whenever possible. To the one patient camphor and morphine are administered before the emergency operation, to the other veronal or laminal the evening previous in order to induce a thorough night's rest. An hour before beginning the narcosis there should be given a clysma with alcohol and tea and a dose of morphine as a result of which the patient will arrive half asleep in the operating room. Afterward, for the real narcosis, *ether*, not chloroform, is to be used,—for wounded patients suffering from severe hemorrhage or shock only a minimal quantity, applied in the right way, is required. There can be no doubt in the mind of anyone who is familiar with our combined ether-drop narcosis as to its reviving effect in cases of collapse.

Other methods of anæsthesia are employed only in very special instances, *e.g.*, *Bier's lumbar anæsthesia* for amputation of the leg because of senile gangrene. Here, too, general anæsthesia has been used as long as no complication with diabetes is present which contra-indicates the cerebral narcosis on account of the danger of coma. But the use of anæsthetics in the spinal cord, though possible for the removal of the leg, can as yet not be considered for the amputation of the arm. For it is accompanied, when applied to a very high point, with a great degree of danger so that it must not be attempted unless no other remedies exist. A method very suitable for major operations on the upper and lower extremities is that of Braun; it can be perfectly performed in the brachial

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plexus for the arm, for the leg with injections into the sciatic, crural, obturator and the cutaneous branches of the femoral nerve. Harmless by itself, in connection with remedies diminishing the capacities of feeling and thinking, this method may find its place where the cerebral narcosis is impossible. Hackenbruch has shown that for the high amputation of the leg, even for Chopart's complicated operation, the injection all around the nerve may cause perfect painlessness. His method, however, cannot well be used in major operation. It is excellent for minor operations in the realm of general practice, especially because it does not largely take anatomy into account.

To encourage the *healing process of wounds* the older surgery preferred the most simple methods of removal, *i.e.*, in which smooth surfaces are formed. With open treatment, often uninterrupted cure would follow. Even to-day preference is given to the circular section for amputation in cases when the parts are greatly infected. Even to-day open treatment should be used, provided it is important to avoid any retention of secretion. Besides, the amputating surgeon must have full mastery of an asepsis which forces the quick healing *per primam intentionem*. He must work with an antiseptics which shortens the process even where the operation is to be performed in infected parts.

The decision whether the removal—even with peripheral infection—falls into entirely clean parts or not, is of first importance for the further procedure and the success. Usually it is easy. But often it is, even with experienced surgeons, not to be accomplished without difficulty. If we remove congenital superfluous parts or limited malignant tumors, we must be sure of the cleanliness in the sphere of operation. On the other hand, we are also sure in many cases to have to force our way through infectious tissue, through lymph passages carrying germs, even through larger inflammatory foci. Consideration before decision, care for the success, must rule our action in these different types of cases. Experience must tell us whether we have to sacrifice more to attain uninterrupted aseptic care, or whether we have to proceed antiseptically to save more, as well in the preparatory treatment of the parts, as in abundant evacuation of secretion, as in the after-treatment. At the same time we have to come to the decision in regard to the height and the mode of the amputation.

Where age is to be a determining factor in deciding the type of the operation we must remember that in young tissues we can count upon good plasticity for the union, whereas old tissues demand simple junction; if the question of the blood supply is to be considered, disturbances in its quality, especially diabetes, are to be considered in planning the

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technic; the chief condition for complicated operations is to have the entire region in an aseptic condition. An infection that could not be removed before demands simple procedures.

The problem of the safe protection of wounds is much greater in cases of amputation than is generally believed. The resulting wound becomes sinuous, as hardly any other one, in consequence of the irregular muscular and tendinous retractions, even when the plain circular and oblique section is used. We must always be watchful of "dead spaces." We shall hardly learn how, by any calculation as to the different retraction, to accomplish the separation so that a smooth wound will be the outcome. In the case of some amputations we know that certain positions of the joint, above and below, assist in securing a smooth wound. The rest must be done with buried sutures which unite the separated layers throughout the entire extent of the wound. Even then an uninterrupted healing cannot be expected, unless another postulate is fulfilled, namely, that the tissue layers enclosed in the healing process have not lost their vitality.

The separation of the soft parts must be done smoothly with a sharp knife. The use of scissors still crushing is to be avoided as much as possible. The soft parts are extended in the following manner: The upper half grasped by the hand as far back as possible is stretched toward the trunk, while the lower half is being pulled with the aid of an assistant. With sharp-pointed hooks we lift off the flaps, with a toothed forceps we draw down the nerves and vessels to be removed, and grasp muscles, tendons, and the edges of the skin for reunion. Every contusion is avoided, for it leaves the parts, if not directly crushed, deranged in their circulation and prone to infection. Even during the short interference of a simple operation, trifling drying and cooling are to be avoided, especially if the circulation is artificially shut off, since they tend to cause congestion and secretion from the surface of the wound. If we do not pay attention to this precaution we damage the most superficial tissue layer, as was the former rule, when applying antiseptic, corrosive remedies. With the object of preserving the tissues we omit the antiseptic, chemically necrolyzing substances even where we must pass wholly or partially through infected tissues.

Only in tying a vessel and for buried sutures we are compelled to bring an antiseptic agent into the wound. Heretofore we have not possessed a thread material which fulfils its mechanical object and is aseptic, free from antiseptic agents. The effort so often tried to use only sterile threads has always resulted in failure, in so far as the threads introduced as foreign bodies cause irritation that in turn de-

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velops germs which are present in each wound and are carried into the circulation. Threads antiseptically prepared of great durability are selected, and chloride of mercury silk prepared in accordance with Kocher's prescription is immersed in wounds which are able to heal *per primam*. It disappears, "substituted" by a very slowly advancing dissolution. In infected wounds we use catgut which is quickly absorbed, so as to avoid the formation of thread fistulas with the healing of the tamponed cavity.

Besides careful ligation of the large vascular trunks and of the visible branches, the other measures against hemorrhage, applied immediately after operation and also subsequently, are of great importance for the healing of the wound. Esmarch's artificial anæmia during the operation is for this positively an aggravation. An increased number of ligatures beyond what is necessary in another wound of the same size must be applied, if we first loosen the constriction at the wound still open, and then ligate the vessels. We cannot avoid this if we operate upon tissues the vitality of which is reduced by arteriosclerosis or contusion. Not to be obliged to bury too much thread material, we make sufficient use of torsion, the technic of which seems to be lost, at least for the text-books. It is done in the following manner: the spouting end is pulled out, then held across with a second pincette, when the former closes and pulls off the point by turning. Where we operate in really vital parts, we apply a row of sutures in the depth, then unite the skin and then loosen the constriction. To check the profuse hemorrhage arising from the blood shooting into the sewed-up stump, we make long-continued manual pressure.

In order to be assured of an uninterrupted recovery, the operation itself must be such as may be characterized by the three words, "gentle, moist, warm." Again the vessels must be well closed, which prevents the subsequent extravasation of blood and lymph and with this the collection of nourishing media for germs in void spaces.

The securing of primary union is hardly of such importance for the future function in any other wound as it is in the case of an amputation, and consequently we must be conversant with seeming trifles which, in this regard, have importance. Drainage, even when short tubes are used, is to be avoided, whenever possible; for it renders the desired fine cicatricial line broader or causes a button-hole scar. At any rate the drain ought to be removed in the first days. But each change of dressing considerably disturbs the rest which is very necessary for the amputated stump.

A very essential completion of asepsis in the amputation wound is

offered by the mode of dressing devised by me which I have called a "wound-pull-dressing." The pull-dressing of adhesive plaster was first employed by me for amputations done on account of senile gangrene. But it offers extraordinary advantages for all types of amputation. With a broad adhesive strip applied over the wound dressing and reaching far up, it relaxes the sutures, if the wound is entirely closed, compresses slightly the cap formed out of soft parts, and pulls it off from the bone and prevents, if the wound is left open, the strong retraction of the flaps of the cuffs. This dressing brings, in a very agreeable way, rest to the stump and safety from agonizing spasms, without a weight upon and bindings around it.

The careful protection of the wound prevents either circumscribed or far-reaching infection. Through many well-considered and executed particular measures, we owe the steady decrease of the former "classical" mortality.

Even on the battlefield where the time of the attending surgeon is limited, the fulfilment of the operative task has to be done within the bounds of the foregoing remarks. The risk to life through operation must be excluded *per se*. One thing, however, is to be demanded, that the mutilated must be saved from the terrible torture of amputation neuralgia. Also for this it needs but simple measures.

More than 25 years ago, Billroth requested his colleagues to communicate their experiences relative to the cure of this horrible malady which, even in the modern text-books, is frequently considered to be a result of the formation of "amputation neuromas." On the basis of examination of old amputation stumps, both in preparations as well as in living bodies, I was able then to show that the amputation neuroma, the terminal intumescence of the bisected nerve, is the result of an abortive effort of nature to regenerate the lost part towards the periphery. This attempt (of nature), which happens rather frequently, leads to the rolling up of the neoplasm in the form of roundish masses. Provided these knobs were always a sign of the amputation neuralgia, we ought to cease operating. It was shown that with stumps of patients suffering from neuralgia the cause is not the terminal intumescence, but the fixation of the nerve to the secondarily formed scar and of the latter one to the bone. At first very sensitive to pressure, as may be easily understood, the stump gradually becomes the seat of the neuralgia through irritation of the "glued together" nerve-trunks through flexion and extension. It is well known, that the neuralgia ascends the nerve-trunks—as anatomical foundation a perineuritis nodosa is found which also fixes the trunk further up and prevents it from making sufficient

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excursion in its sheath, which is a physiological necessity. This condition is not unlike the difficulty of redress which finally becomes an impossibility, as even sections and resections at the origin of the nerves in the spinal cord remain of no avail. Simple and sure was the prophylaxis which we recommended even at that time! It does not require the neurincomptis later developed by Bardenheuer, nor the cuneiform excision with subsequent very fine suture of the perineurium according to Ritter. These are methods which are at least difficult with thinner trunks and cannot at all be performed on the battlefield. We taught to save the nerve end from being fixed, for this is the cause of the neuralgias, by strongly drawing forth—that can easily be done with most of the trunks up to 4 or even 8 cm.—and by smooth separation by means of a sharp cut with the knife. We encourage our pupils to execute this manoeuvre upon the nerves always prior to division of the vessels. The end slips far back into the layer of connective tissue and later on glides painlessly with the “neurom” to and fro. This excision must be made the more carefully and higher up according to the possibility of a secondary healing of the wound.

But the demands of modern times for the success of amputations are not limited to the exclusion of danger to life, the achievement of uninterrupted healing of the wound and avoidance of the coarse disturbance of the amputation neuralgia. We have to *produce stumps of the highest usefulness*. We already possess sure and, fortunately, very simple methods to facilitate accomplishments which we formerly believed to be absolutely unattainable.

Provided we do not desire to have the stump hang useless, swinging in its capsule, and if we want it to serve actively to the motion even when directly loaded, it must be, in the first place, painless, free from pain when the soft parts are shifted or pulled at, or pressed against the end of the bone. But the stumps of the diaphyseal amputations made in accordance with former methods were rarely of this kind, and this was even more the case with the deformed stumps arising from exarticulations or amputations in the epiphysis. To bring about painlessness in the latter group, uninterrupted healing *per primam intentionem* was the necessary supposition. Stumps of the articular extremities healed by suppuration and with broad adherent scar.

The excellent investigations of Bier have shown under what circumstances a stump may be entirely painless and remain so. The conception of Bier in regard to the cause and nature of the sensibility is indeed still under dispute.

On the stump formed after the method of Pirogoff the patient, after

the cap of the heel is united with the leg, walks painlessly, resting directly upon it. It must be especially emphasized that the same is true with amputations according to Gritti. In both cases a skin heretofore little accustomed to pressure comes under heavy weight and is transformed into callosity. Bier, through a complicated procedure, leaving skin and the flap of the soft parts in connection, formed a similar covering for the diaphyseal stump. This became directly capable of bearing like the stumps of Pirogoff. With like success, but in a simple way, he formed the great flap of skin and the periosteal covering of the bone, both isolated, taking care that the weight did not fall upon the line of suture. Thus another surface scar was situated between the periosteal covering of the bone and the skin. These stumps, too, remained painless, if weight was put upon them. The undisturbed physiological connection between the flaps of the soft parts and the bone, as was the case with both Pirogoff and Gritti, is not entirely necessary, although they do lessen the possibility of the shifting of both layers against one another. But now it appeared that the same could be effected by a soft cover, derived from an adjacent tendon according to Wilms or from transplanted fascia according to Ritter. At last it was found that no covering is necessary at all, and that the stump remains painless, provided, as Bunge suggests, a part of the bone marrow is emptied with a spoon and at the same time a periosteal cuff at end of bone is removed.

Our conception of the advantage gained uniformly by all these procedures, from Bier down to Bunge, is that a swelling of the marrow freed from pressure, as must occur by vascular pressure from inside, is prevented, and that the nerve ends of the cover of the soft parts are not fixed upon an osseous foundation. If the mushroom-like outgrowth is not prevented, a rough proliferation by ossification ensues which includes the neighboring nerve-fibres. Even in primary union we have the nerve fixation which, if it concerns the trunks, leads to neuralgia and, if as in this case it concerns the branches only, to the simple sensitiveness of the stump. Thus, the painlessness of the stumps after exarticulation and after removal in the epiphysis is explained. A swelling of the marrow does not here take place.

Amputating in accordance with the methods of Pirogoff and Gritti, we obtain in consequence of the effect of the cover a stump capable of carrying weight, even if the sawing is not done, as is customary, in the epiphyses, but in the diaphyses. Instead of Gritti's operation we shall occasionally execute the original plastic one according to Bier, by uniting the anterior surface of the head of tibia with the lower end of the femur, according to Sjabanejeff. We shall make the cover in

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accordance with Wilms, using the tendo Achilles or the tendon of the triceps humeri; on other occasions the diaphyseal stump is to be treated under ordinary circumstances, certainly always by the physician in the field, after Bunge's direction. With amputations in the epiphyses it needs no cover-formation, scraping with a spoon or periosteum-removal; but here, like at the exarticulations, an improvement through removal of corners and edges may be made.

The last fear of the nerve-fixation may be removed, provided—as Hirsch suggests—we execute in all different proceedings early and methodically the shifting of the parts against each other, beginning by *massage à friction* towards the periphery, afterwards by tread-exercises or by direct loading of the stump in a provisional self-made wooden leg (Bier). It is astonishing to see, how well such manipulations for securing the mobility of the cover of the soft parts can be tolerated even after two weeks, *prima intentio* just accomplished, and how after four weeks the stump can be used as a firm support, and how a patient with both legs amputated walks around upon the stumps only protected by wrapping.

It may be mentioned that Hirsch's treatment of exercise and massage is capable of rendering stumps painless, even though they have been obtained by other methods and are already becoming sensitive, and that it works excellently after the reamputation which became necessary on account of great tenderness.

It is gratifying to note that from a complicated method we have been able to finally devise a simple one, applicable everywhere, and which affords a painless stump.

But this is not enough. A lever thus obtained tolerates, according to our wishes, direct pressure and pull in the artificial limb. It ought to move the latter as well as possible as a lever working as a whole; the most important isolated movements of the artificial limb—this is the last request—might be executed actively, dependent from the will-power in using the musculotendinous apparatus terminating in the stump. The prothesis shall be “revived” by the stump. To secure the first object it is necessary to equilibrate the lever-effect, and that is mostly done after simple calculation in uniting by suture or insertion the muscles and tendons.

Added attention given to the function of the stump has shown that disturbances were brought about through irregularity of muscle-effects, stronger on one side, producing a preponderance in the sense of motion, extension and rotation. In short stumps of the legs and thighs, but also of the fore and upper arms, the resultant positions may be an impedi-

ment even for the application of the prothesis. The contractures developed this way have been combated by tenotomies; thus, in a crude way, by disconnection of power in the lever of the stump. This is evidently wrong. On the contrary we are now striving from the beginning to avoid the antagonistic disturbance, the deficiency of a whole kind of movement, leaving sinews and muscles longer in the stump and fixing them by suture to the neighboring ones near the bone. Of especial value through its simplicity is the procedure which unites the muscles and tendons of one side, sewed up with each other and combined into a well working mechanical totality, across the stump with its antagonists treated similarly.

In obtaining such an equilibration much remains to be done with respect to the physiology of the stump. What cannot be satisfactorily achieved in the first way, must be obtained secondarily by orthopaedic operations.

Finally, we must consider the utilization of single parts of the musculotendinous apparatus for the intended transmission of movements upon the prothesis. For the leg it suffices that the stump may be supported directly and painlessly, and that it acts as a lever in good order, but for the hand we must ask and achieve more.

Vanghetti proposed to use tendons to form rings through which strings may be framed which shall transfer movements to the prothesis. This procedure is doubtless valuable. We would even now adopt it in cases of reamputation on forearm stumps, whenever such opportunity appears. Unfortunately, a longer time is apt to elapse before opportunity for such an amputation of the forearm is given. It follows that in cases of amputation at the wrist-joint the tendons of the extensor digitorum communis, of the extensor pollicis major and minor, may be united to form a single loop; the same may be done on the flexor surface. There results on the dorsal and volar side one ring for the thumb, and one for the four fingers in the skin sac. It need not be specified here, just how, after *prima intentio* has resulted, such loops based upon the principle of the ear-hole are to be made in a plastic way.

Merely worthy of mention is the attempt to produce actively movable levers out of periosteal fragments of bone, retained at tendinous insertions, as, for example, the two-step transplantation of a finger; for instance, a stiffened ring-finger of one hand as compensation for the thumb of the other, as well as the two-step transplantation of a piece of rib, originally enveloped *in loco* with skin, to the place of a thumb, an effort in which we have been successful.