Equipping the Limbless: Stumps and Artificial Limbs Some Observations, including a Report on Krukenberg Stumps and Cineplastic Work in Germany

A. L. Eyre-Brook

Postgrad. Med. J. 1947;23;263-279
doi:10.1136/pgmj.23.260.263

EQUIPPING THE LIMBLESS

Stumps and Artificial Limbs—Some Observations, including a Report on Krukenberg Stumps and Cineplastic Work in Germany

By A. L. EYRE-BROOK, M.S., F.R.C.S.
Bristol.

The management of the limbless from the very day of amputation is of extreme importance; he must be influenced from the outset to accept his disability as one that he can and will overcome and the programme to this end must be initiated forthwith.

For the double amputation, his future must appear appalling as he contemplates his condition, the morning after his operation. To these, it is a help to bring such photographs as those illustrated below (Fig. 1), showing a double leg amputation—A.K. and B.K.—walking without a stick, doing a hand stand, swimming and standing on the A.K. limb alone. These photographs make a strong impression on any patient and give a clear aim to all who wish to become independent and who have an average endowment of courage and energy. A knowledge of the accomplishments of Group-Captain Bader, now a national figure, also does a great deal for anyone finding himself similarly handicapped.

The limbless man on his own in a small hospital is, of course, at a disadvantage compared with those in a centre for the limbless, who have examples before them of fellow patients in more advanced stages of rehabilitation. The provision of a warm swimming pool is invaluable as swimming is the form of exercise par excellence for the limbless, whether of arm or leg; here, in the water, they gain more independence than they can ever evince on land. This is particularly important in the early stages of convalescence in double leg amputees.

The limbless must always be maintained at their greatest functional level. To remain in bed is harmful, psychologically and physically, once sound healing is obtained. Even a double leg amputee can be up in a self propelled chair and can go to the physical medicine department for his exercises. These are much more easily performed in a department where suitable weights and pulleys at convenient heights are available and where class work can be instituted, with the necessary competition, which should result. Three months must necessarily elapse between the amputation and the provision of an artificial limb, and during this time the fullest shrinkage of the stump is obtained and all muscles moving proximal joints are kept as strong as possible. The swimming pool, the self propelled chair and crutches, used at the earliest opportunity, make these months pass with least interference with a normal life of human contacts and physical exercise and are in marked contrast with what befalls some patients, confined to bed in a ward and subjected to a demoralizing sympathy by those who have little knowledge of the accomplishments of the limbless or the limb maker. One word in passing on the limb maker; this skilled craftsman is a specialist and the limbless provided with limbs by a general instrument maker are getting less than full measure and can ill afford it.

The stump is an exceedingly important new member to the limbless, it is not to be compared with the remains of a tree, which bears the same name. It is, to the limbless, the member on which he relies to work his artificial limb. It must, therefore, be fashioned in the light of expert knowledge and trained with this purpose in view. Details of fashioning stumps at suitable levels must not be dealt with in this article. Let me only mention that the greatest tragedy in any stump is the un-

treated haematoma ; this should be prevented by drainage for 48 hours, when the loose stitch is tied, leaving no trace of this most important step in sound stump surgery.

The treatment of the stump consists of four hourly stump bandaging, commenced once the stitches have been removed. This results in quick shrinkage so that the stump attains stable dimensions in the shortest period of time. Exercises must be given to all muscles controlling proximal joints, particularly to those mainly employed in standing and walking, and these exercises must be strenuous enough to compare with the functional demands on these muscles during control of the artificial limb, and finally, no contractures must be allowed to develop and a full range of movements must be maintained. The B.K. stump on a pillow and the maintained sitting or supine positions in bed are particularly liable to cause knee and hip contractures respectively. No pillow and the daily exercises in the prone position are the lessons to be learnt for those cases which have to be confined to bed.

1. Artificial Limbs

Material for artificial limbs

Duralum, steel and wood each has its role in the construction of artificial limbs and plastics will play an increasing part in the future, although these latter are not expected radically to change the construction of prostheses. Although wood was the first in the field, it must not be considered as an obsolete material, it has attributes which recommend it above metal in certain roles and t is still very popular on the Continent.

Artificial Legs

The standard British artificial legs, as made by Desoutter and Hangers, are fully dealt with in standard works [1 and 2] and in the manufacturers' excellent brochures. It is the purpose of this article to deal with developments in other countries and to a less extent in our own, as the latter are better known.

Commencing distally in the foot, there is the oft condemned Lisfranc amputation which has so frequently ended in crippling varus and equinus deformities. I was impressed to see a ten year old Lisfranc amputation without deformity and giving perfect function. The secret was the maintenance of the os calcis in its normal position with its *elevated* forepart and this had been accomplished with a metal footplate (Fig. 2), completed anteriorally with a felt block to replace the missing forefoot in a normal shoe. Hendrix of Brussels is a strong protagonist of the Lisfranc amputation properly cared for from the very outset—a ten year end result must convince one of the possibilities of this amputation. The transplantation of the *Tibialis Anticus* insertion laterally is often very useful but Hendrix proves that this is not essential. In Belgium, U.S.A. and other countries, the orthopaedic surgeon and mechanician have a greater experience in making footplates, an essential for the proper equipping of a Lisfranc amputation.

The end bearing stump at the ankle level, popular always in some schools in Canada and in Scotland, has regained much of its popularity in the United States. The controversy still rages but the amputations of this war, with their very low sepsis rate and more controlled after care, have resulted in a series of American stumps of the Syme's type which can be expected to stand the test of time very differently from those of the last war, of which our Roehampton limb fitting surgeons speak so disparagingly. A disadvantage of the Syme's amputation, however, still remains in the weight and unsightliness of the artificial limbs so far conceived. Women, still with much reason, dislike the Syme's amputation.

The lateral movement in the artificial foot has been incorporated by many firms, including those in our country. A rubber buffered coupling situated below the ankle coupling allows of sufficient movement to adapt to rough surfaces. The solid rubber foot yields a little in all directions but is heavy and is only used on the Continent for agricultural workers, where its immunity to moisture is a great advantage. Some argue that the refinement of lateral foot movement only introduces a fresh factor which may go wrong, and that it is not worth the advantages gained, but this does not appear to be the opinion of the limbless fitted with this improvement. The ladies of France, however, favour the most simple but shapely foot and ankle piece of the following design (Fig. 3). This shapely limb has no ankle joint nor lateral foot movement, only a rubber

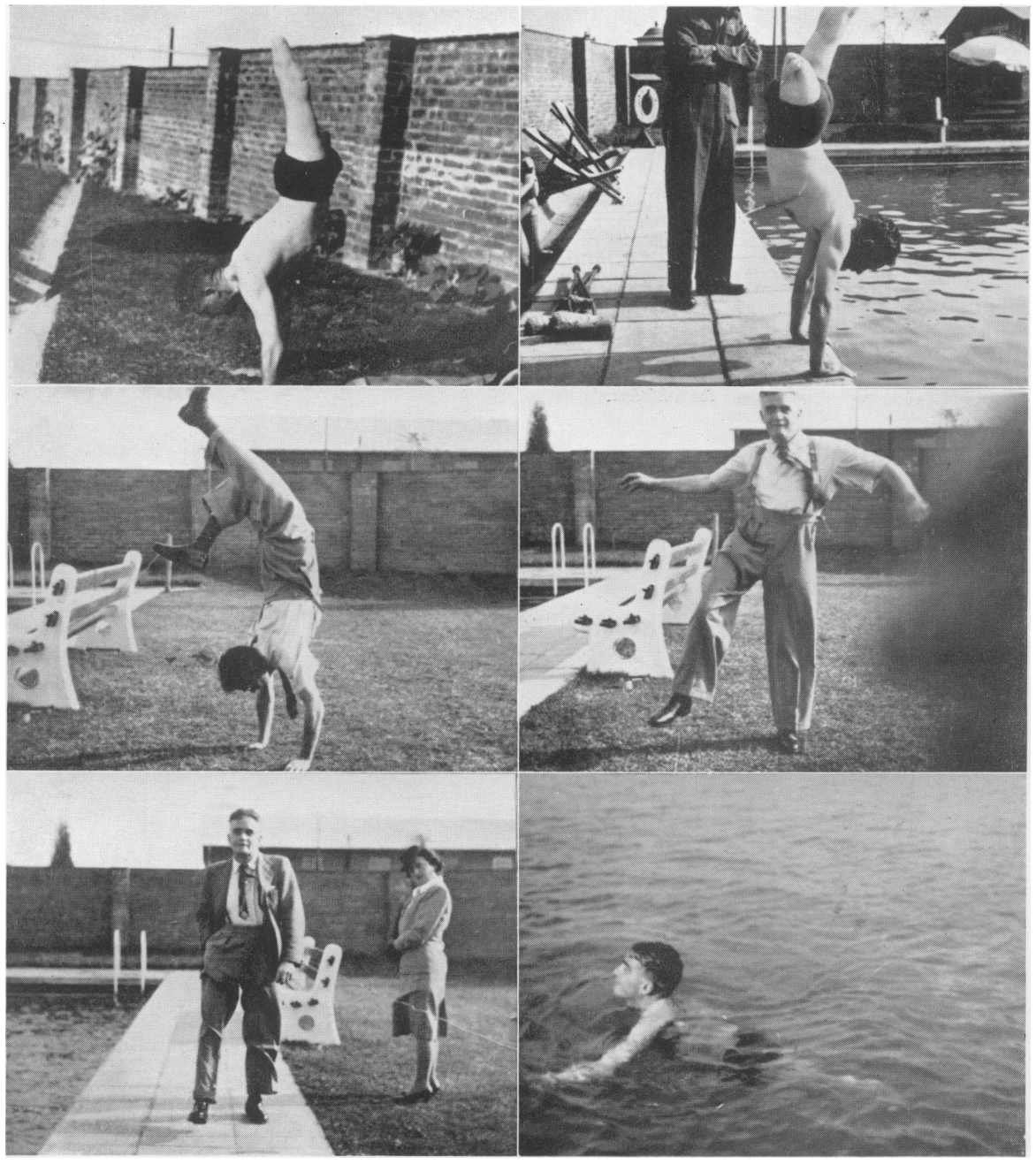


Fig. 1. What a Bilateral Amputee (A.K. and B.K., aged 45) can do.

Showing length of B.K. stump.
Hand stand with artificial limbs.
Walking easily, hand in pocket and no stick.
Showing length of A.K. stump.
Standing on A.K. leg alone.
Swimming—excellent exercise for bilateral leg amputees.

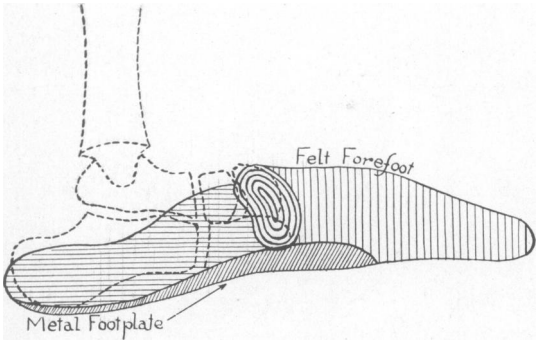


Fig. 2. Hendrix's Prosthesis for a Lisfranc's Amputation.

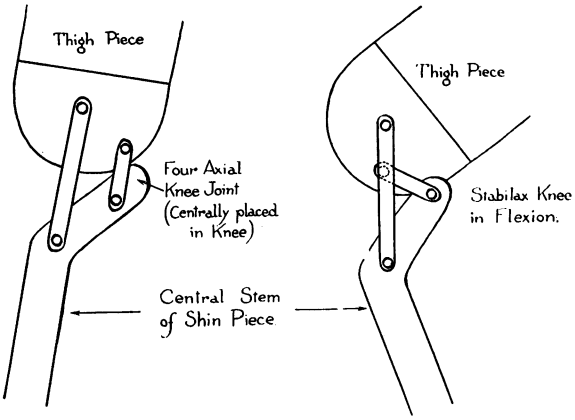


Fig. 4. Stabilax Knee (French).

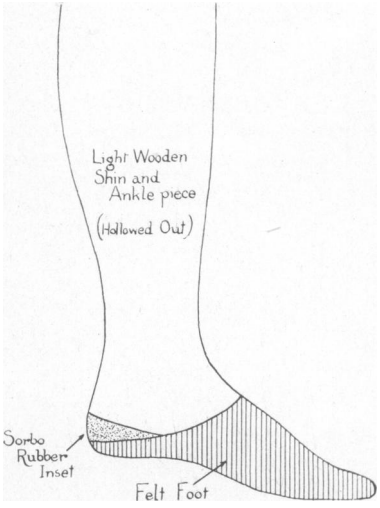


Fig. 3. Shin and foot piece popular with French women. (Only moveable parts are the yielding of the Sorbo rubber heel inset and the solid felt foot.)

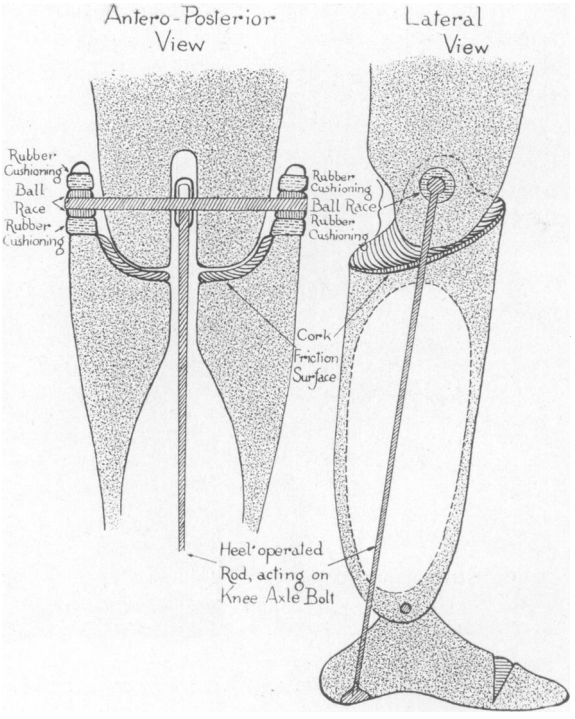


Fig. 5. Osterly Gestange Knee (German).

cushioned heel and a felt forefoot to allow of the essential metatarso-phalangeal movement.

Knees

The aim of all designers appears to be stability in partial flexion, with a distracting aim following by some, to reproduce the anatomical movements, including the antero-posterior glide of a human knee. The latter results in no advantages to the wearer of the limb, although considerable ingenuity has been expended in some of the anatomical or functional knees seen on the Continent.

The former aim is worthy of every effort. The posteriorly displaced knee joint hinge, so that the weight does not come behind this hinge until 5° of flexion has been obtained, is, of course, almost universally employed throughout the civilized world.

Two interesting knees, worthy of trial, are the Stabilax knee and the Osterly Gestange knee, the former employing a double axis and anterior glide to maintain stability up to a 15° angle of flexion, while the latter employs a friction surface knee, operated by a rod from the heel, this being pulled upon by the dorsiflexing ankle. The Stabilax knee (Fig. 4) is very popular in France but it was difficult to decide whether such good performances as were seen were not largely due to the proficiency of the wearers. The knee, however, did appear to have stability up to 15° of flexion although its action was ugly and did not simulate that of a normal joint. A gain in stability of the knee joint up to 15° is, however, sufficient to be worthy of investigation and these knees are being tried out in this country.

The Osterly Gestange knee (Fig. 5) appeared very sound in principle and a very good performance was seen in Munich. The knee was, however, a little complicated and introduced further liabilities to breakdowns, which do so much to complicate the life of the limbless. The brake action comes on as the ankle dorsiflexes, which occurs in walking when the leg passes into a posterior position, and it is in this position that the knee begins to flex. The rubber cushioned ball race of the knee axle would appear to be a weak but essential point in construction. The friction surface, employed in the Hangers and Desoutter's knee in this country, is used to vary the speed of movement of the shin piece in coming to the straight position in the 'carry through'; this movement brings the leg into the forward position before stepping on to it; the amount of friction can be adjusted easily and is merely used to slow up the movement so as to stimulate the normal action. This brake action has little affect on stability in the early degrees of knee flexion, but it greatly improves the gait. The German knee, referred to above, is the best load bearing knee so far seen and certainly needs investigation and trial, a knee that could bear weight in 30° of flexion would be a great gain to above knee amputees.

Thigh Sockets

Nugent of New Zealand has been experimenting with a thigh socket, of which the outlet varies greatly from the standard practice in this country. The standard thigh socket in this country has an ischial bearing surface sloping inwards and forwards and an ovoid outlet, while the Nugent socket has a quadrilateral outlet (Fig. 6), an ischial seating which is horizontal in both antero-posterior and lateral views, and a high anterior margin ending medially in a groove for the adductor longus tendon. This latter is designed to keep the stump back, thus holding the ischial tuberosity on the flat posterior shelf. The perineal border is deeply cut away to allow comfort without abducting the leg and the whole outlet is designed on three precise measurements, taken from the stump, rather than using a master template of approximately the size of the stump, as in the standard practice in England. These three measurements form the sides of a triangle with angles at the great trochanter, the ischial tuberosity and the adductor longus tendon origin.

Dr. Kelham at Roehampton has developed a somewhat similar socket, which is now on trial. This socket embraces the above points and has a bevelling below the edge, coming out to an increased dimension at a somewhat lower level, where there is more muscle volume to accommodate. These sockets are on trial and may prove a considerable advance in accurate fitting. They are more like the Continental outlet and much more suitable for application of the suction socket principle.

Suction Socket Suspension

A very interesting development was seen in Germany in the form of the suction and vacuum thigh sockets. The principle of these sockets is that the suspension of the artificial limb depends upon negative pressure developed in the socket below the thigh stump, thus preventing the stump from pulling out. This principle was employed in this country after the last war without any outstanding success. Men can, however, be traced who have worn this type of limb since the early twenties, their gait is excellent and their comfort much greater than those with a pelvic band or shoulder suspension. This fitting has, however, never become a standard fitting in this country and the number of such limbs supplied has been very few. With modifications in thigh socket design and in details of fitting, suction thigh sockets are in very general employment in Germany with much success. The only difference between the vacuum and suction socket is that the former employs a non return valve by means of which the stump in weight bearing forces out any air which has entered the socket while the limb was being carried forward. To release the vacuum, the valve is unscrewed from its seating. The suction socket uses a spring valve which is operated when expressing air, as when first taking weight after sitting for some time, or when admitting air, in removing the leg. The German thigh sockets were all of wood, quadrilateral in shape at the outlet and high fitting and all made to shaped plaster moulds of the stump. A fleshy stump of good length is best, although suction sockets have been fitted to stumps as short as 4 in., measured to the perineum.

The only stump covering is a lady's stocking (Fig. 7), and, in applying the artificial leg, the loose end of the stocking is passed into the socket and out through the valve seating, from which the valve has been removed. The stump is then eased into the socket by pulling on the stocking end. This important technique leaves no folds of skin above the socket and the stump is well pulled down. The stocking is partially pulled off in this manoeuvre of pulling the stump into the socket, and the end of the stocking is then pushed into the empty lower part of the socket and the valve screwed into its seating. With further shrinkage of the stump the suction becomes less effective and a pelvic band of a simple type is worn by many. The suction socket principle does involve very accurate socket fitting and adaptation to shrinkage at more frequent intervals. The fitting must be most accurate in the upper 3 in. of the socket where movement is least in the rocking of the stump in walking. The German cases and our few cases in this country appear to prefer wood for these suction sockets; it is less hard and warmer for the naked stump and can probably be worked to a nearer perfect fitting. Skin soreness and terminal oedema do not seem to present any serious problem and the additional security of the fitting, the sense of the artificial leg being really part of the limb, must be a tremendous advantage to the wearer.

Corset Suspension

Corset suspension is being developed in this country by Dr. Craft of the Research Department at Roehampton. A number of B.K., A.K. and tilting table limbs have been fitted with corset suspension, accurately moulded to the individual patient, strengthened with whale bone and fitted with quick release straps. The wearers, mostly women, appear delighted with this improvement on the shoulder strap or pelvic band suspension. In the A.K. limb, the prominent extrinsic hip joint hinge is dispensed with, the limb being attached to the corset by only a posterior strap and the anterior knee pick up. The wear of clothes is thus reduced and an objectionable prominence is removed. An extension of the use of corset suspension, with a narrower type for men, is to be expected in this country.

Sword Belt Suspension

A narrow sword belt suspension (Fig. 8) was in very general use in Germany and will be tried out in this country. It may prove more attractive than corset suspension to men, and appeared to be adequate in those suction socket cases which required some additional suspension. The illustration shows the metal loop which is attached to the outer side of the thigh socket and which follows the outlines of the great trochanter. To this loop is attached a 3 in. leather band which passes round the

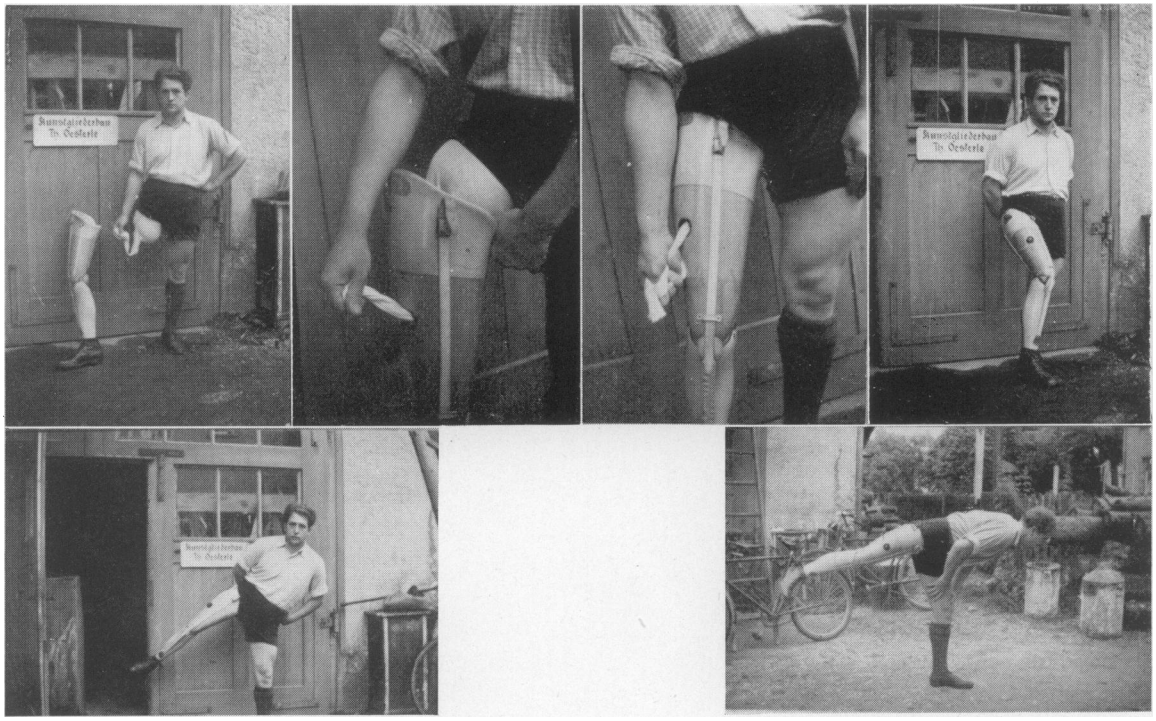


Fig. 7 The Suction Thigh Socket.

Note lady's thin stocking on stump.

End of stocking passed out through valve seating, from which valve has been unscrewed.

Stump being pulled into socket, as stocking is partially pulled off.

Function with suction suspension alone.

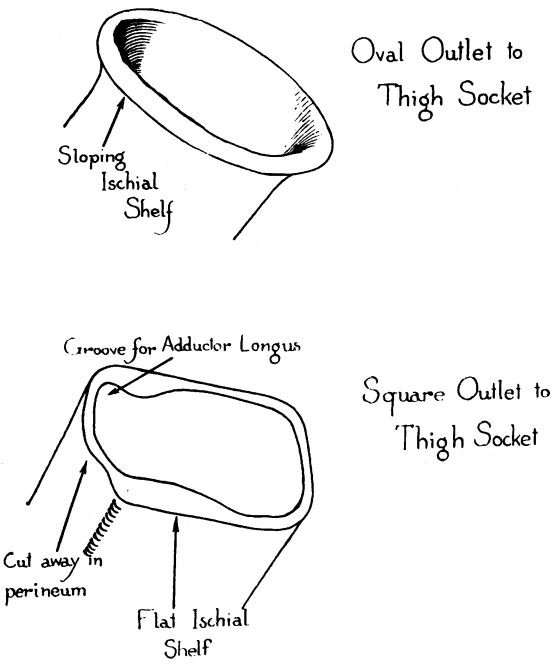


Fig. 6. Oval and square thigh sockets.

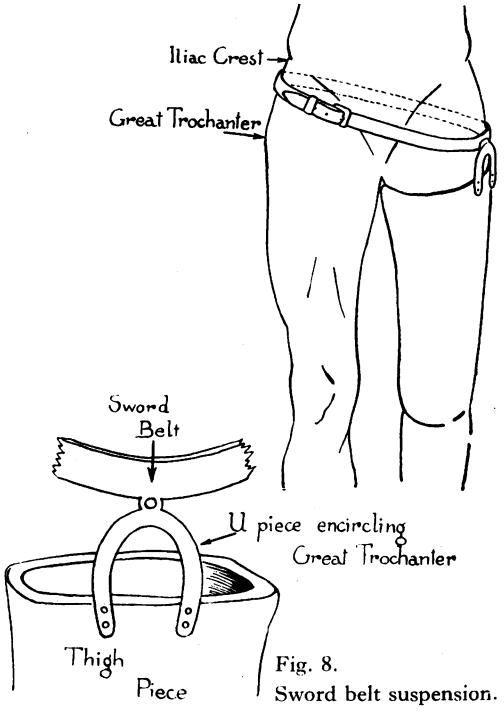


Fig. 8.
Sword belt suspension.

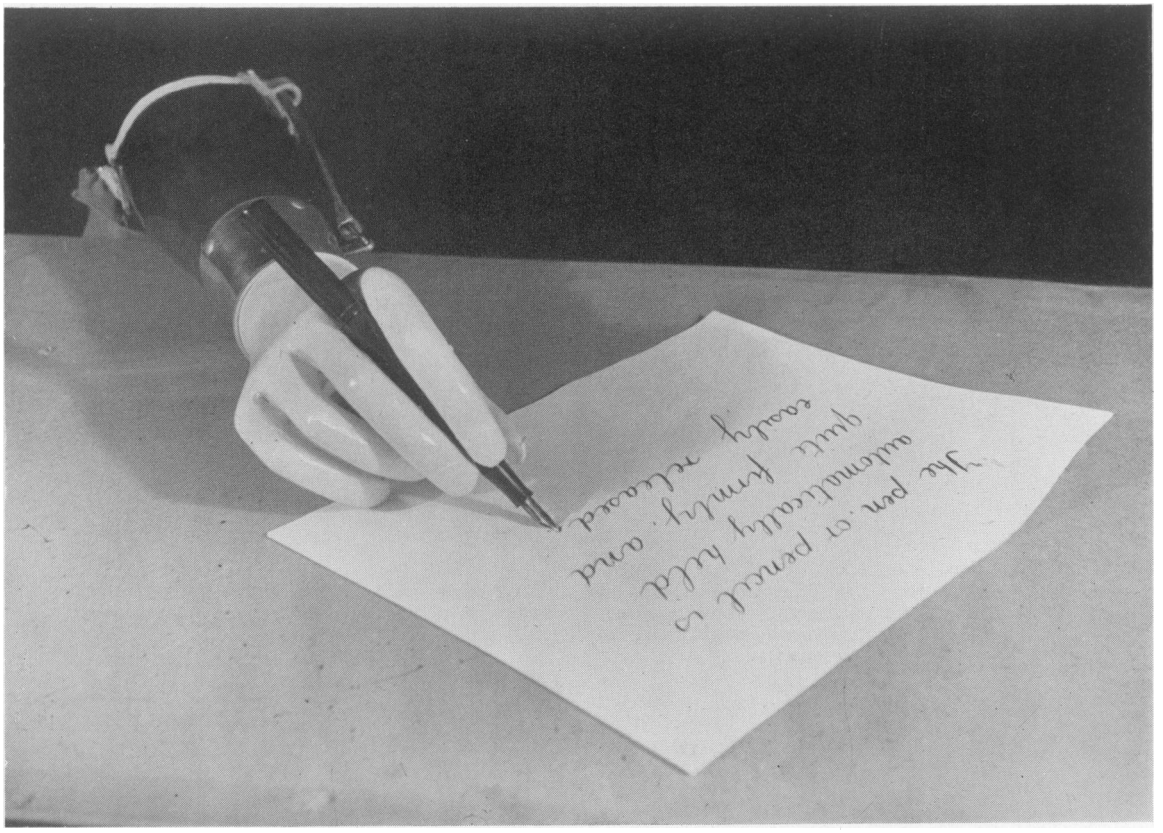


Fig. 9. The new writing hand (British).

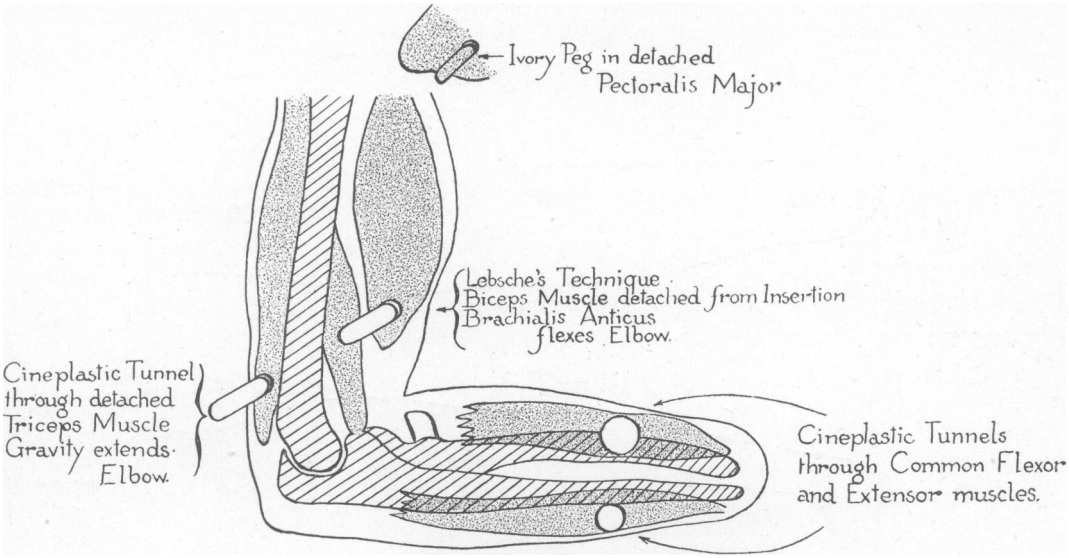
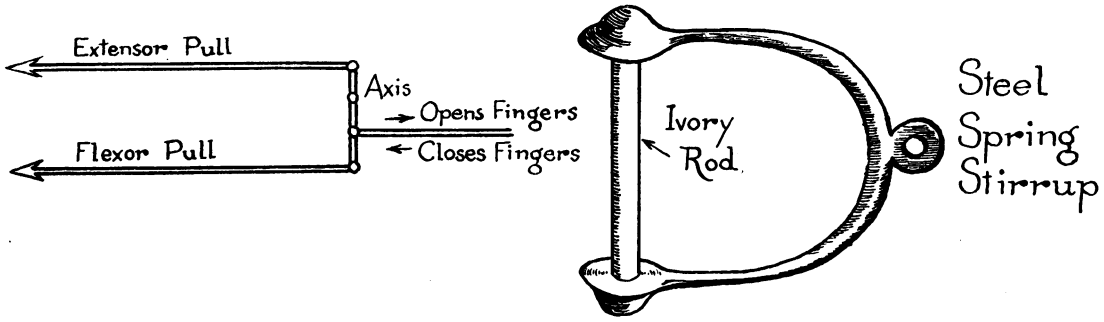


Fig. 10. Cineplastic tunnels in 5 usual sites.



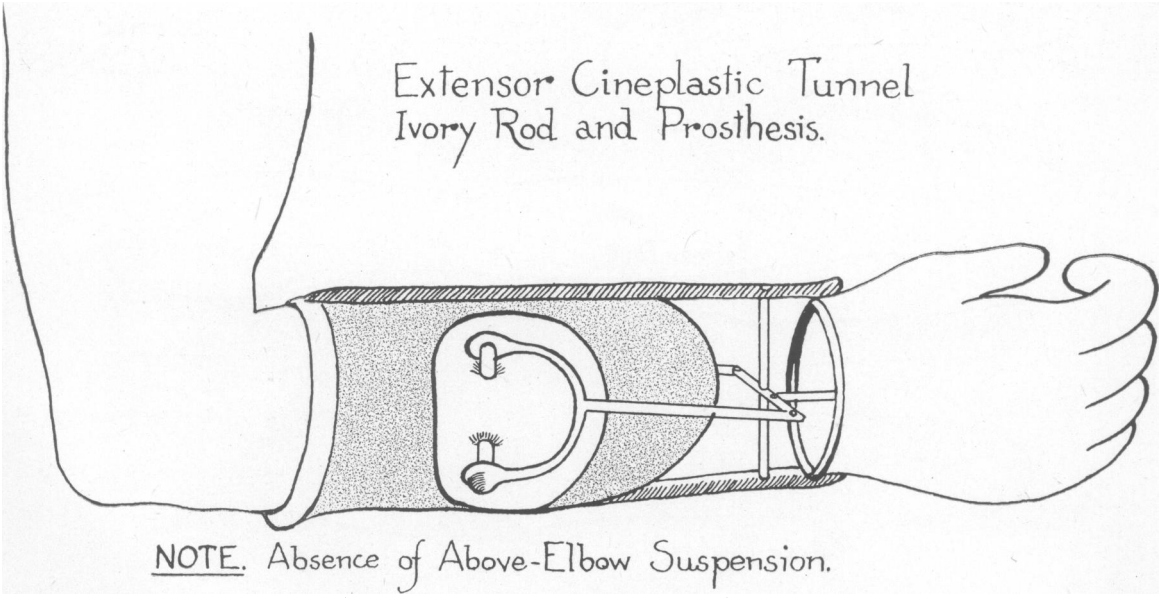


Fig. 11. Sauerbruch's arm (or Huffner arm).

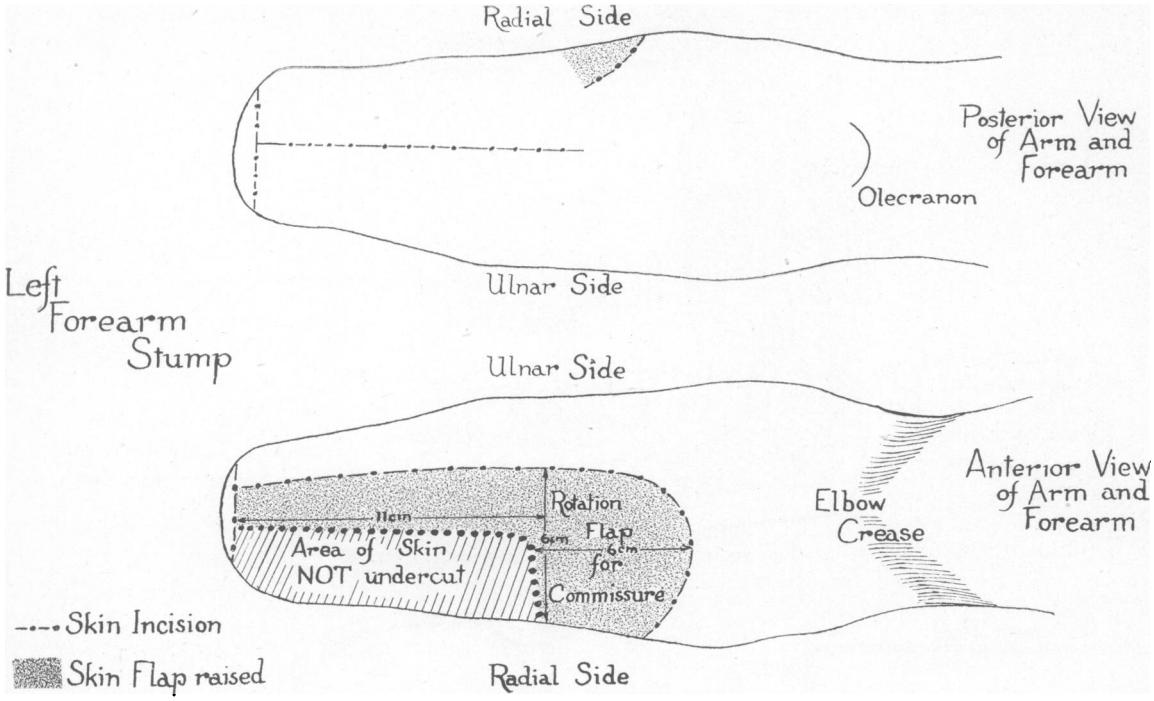


Fig. 13A. Incisions for Krukenberg claw hand.

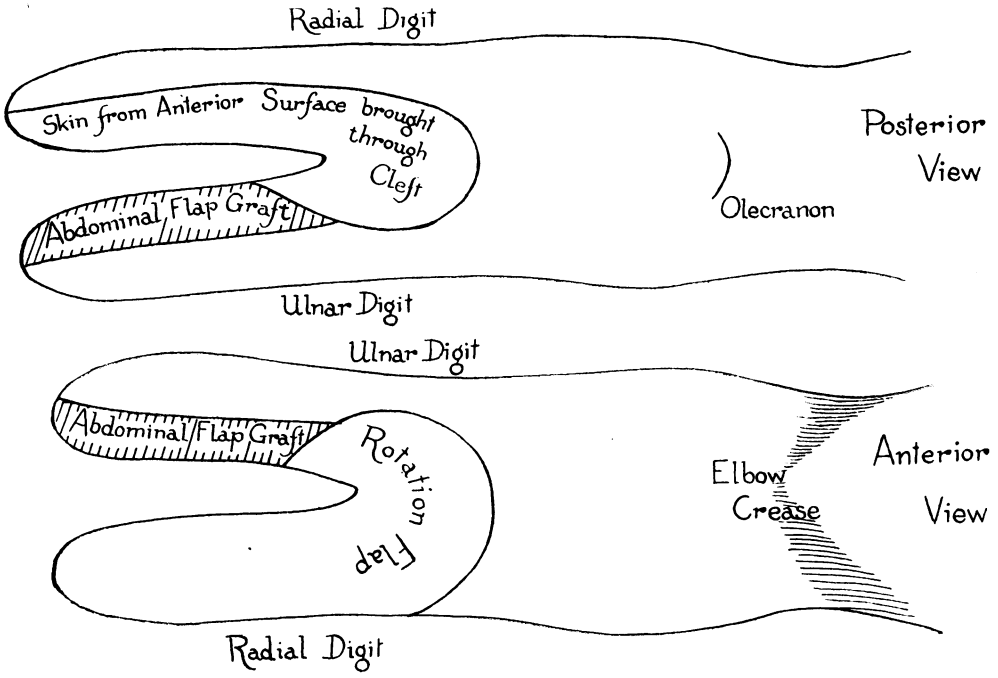


Fig. 13B. Left Krukenberg claw hand.

opposite side of the pelvis between the great trochanter and the iliac crest and is buckled in front.

Artificial Arms

As in the case of artificial legs, the standard practice in this country is well dealt with in the books referred to at the beginning of that section. Artificial arms, as used in England, appear well in advance of any in use on the Continent and much research is proceeding to improve the selection of instruments and gadgets with which the carrying or dress hand can be replaced. The usual arm has a detachable hand with a centrally operated push rod, housed in the clip-on sprocket. The hand has a movable thumb and the various instruments which can replace the hand can similarly be operated by the push rod, the instruments and the hand being easily changed by pressing on a stud catch and pulling them off. The centrally operated push rod keeps all cables safely housed within the apparatus. The usual 'motors' employed are the forward movement of the shoulder on the sound side, pulling on a posterior harnessing, and the upward shrug of the shoulder on the amputated side. Other motors are visualized but where the amputation is above the elbow, elbow movement has also to be powered and controlled. The cineplastic operation can provide us with a number of motors which probably deserve an extended trial.

One of the most useful products of the Research Department at Roehampton is the writing hand (Fig. 9) which is now available for general issue. The pen or pencil passes down a channel between the index and middle fingers and the channel has rubber studs so that adaptation is allowed for differences in circumference. The pen is firmly held by the mobile thumb and writing is so easy and natural that men who have adapted to left hand writing for 20 years are returning to writing with an artificial writing hand. So much of writing occurs from the shoulder and elbow that right handed men who lose their right arms are encouraged to write with these artificial writing hands. The results are very satisfactory.

Rubber washing forearm sockets with simple washing attachments have been constructed for the double B.E. amputee, who can now perform his own toilet where formerly he could only wash a limited anterior portion of his face and body, using both his stumps. Another gadget enabling a double forearm amputee to use toilet paper gives these men independence in a personal matter where it is very painful to be otherwise. The Research Department at Roehampton has developed a considerable amount of new apparatus, including a telephone holder, and each new contribution adds something to reduce the handicap of the limbless.

The split ring is probably the most useful general purpose instrument but is far from satisfactory so long as it makes no pretence at concealing the wearer's loss. The range of instruments which can be clipped into the forearm is now considerable but the more universal the tool, the greater the advance, and the more the mechanical hand can supersede these tools, the nearer we approach to perfection. The ideal mechanical hand should open and close actively, be capable of gripping articles of very different sizes and the grip should be maintained without effort by the operation of an automatic catch. This involves much ingenuity in design and at every point one meets with the problem of weight; the more distally the weight is found the more serious are the disadvantages. Many are working on these mechanical hands in America and in this country but so far no really satisfactory result has rewarded their labours.

The appearance of the artificial hand has recently been greatly improved by the introduction of a rubber glove simulating a natural hand in colour and texture, even to the reproduction of the subcutaneous veins. This is an American invention and very few specimens have so far been seen in this country but the improvement in appearance is really outstanding.

2. Cineplastic Stumps

We now come to some very interesting work in Germany. The cineplastic operations consist of tunnelling a muscle belly with a skin tube. By means of an ivory peg, held in a metal stirrup, the movement and power in this muscle can be utilized to move an artificial hand or other joints of an artificial arm (Fig.

10). The cineplastic operations were originally developed in Germany by Sauerbruch, but Lebsche of Munich appears now to be the finest exponent in that country. Much criticism has been raised against the cineplastic stumps and many failures have occurred in the past, chiefly because these operations have not been performed by surgeons adequately equipped with experience in plastic surgery.

The present practice in Germany is a great advance on Sauerbruch's original design in that skin tunnels through the muscles are no longer lined with skin graft but with normal skin, while the split skin graft is now used to cover the superficial defect, resulting from the employment of a flap (2½ in.-3 in. wide) to line the tunnel through the muscle. A large tunnel is very important (2½ in.-3 in. in circumference) so that hygiene may always be satisfactory and that the rods may operate loosely with a minimum of trauma. Lebsche has introduced a further advance in detaching the chosen muscle from its tendon of insertion and carefully closing it over. The stump of the muscle thus presents no rough surfaces to form adhesions and, being detached from its tendon of insertion, is given a greater range of movement in accomplishing its new purpose. Such a muscle, tunnelled in its lower third, may have a range of tunnel movement of 2 in.-3in. The biceps can be so treated, leaving the brachialis anticus to flex the elbow, and similarly the triceps, leaving gravity to extend the elbow. Pectoralis major can also be employed in a similar manner. These cineplastic tunnels do more than provide a motor for the hand and wrist movement, they also provide effective suspension of the limb, so that a forearm amputation needs no above elbow corset. An extension of this purpose is the provision of a skin tunnel in the subcutaneous tissue, simply to maintain the artificial arm in place in a short B.E. amputation. By no other means can so short a B.E. stump be employed with normal control of elbow movement. The artificial arm in use in Germany with these cineplastic stumps is the original Sauerbruch arm illustrated here (Figs. 11 and 12). The opening and closing of the hand will be understood from the diagram, both may be powered by muscles or the extension may be controlled by a spring. The grip cannot be very powerful, largely because the stiff fingers fail completely to adapt to contour and give a very limited contact with an object, but the power of the grip will naturally vary with the muscle employed, the travel of the cineplastic tunnel and efficient control of intervening joints. The cases seen which were fitted with Sauerbruch arms and cineplastic tunnels were naturally not engaged in any hard manual work; however, one was a felt hat maker, another was an R.C. priest who was able to take Mass unaided. All were completely independent of help in personal matters, dressing, eating and toilet, even the bilateral cases. Professor Lebsche demonstrated his complete programme for arm amputations at different levels:—

1. Through wrist amputation—no cineplastic tunnels but he used the pronation and supination, through a bevel mechanism, to work the push and pull rod in the Sauerbruch hand.

2. Long forearm amputation—these men had the choice between cineplastic tunnels in the forearm flexor and extensor muscle bellies and a Krukenberg operation.

3. Medium forearm amputation—cineplastic tunnels in forearm flexors and extensors for opening and closing hand. Opposite shoulder harness for pronation and supination.

4. Very short forearm amputations—subcutaneous holding tunnel on flexor surface of stump kept the artificial arm in position and allowed of normal control of the elbow, biceps cineplastic tunnel for closing hand, spring for opening hand. Pronation and supination by opposite shoulder harness.

5. Above elbow amputation—biceps tunnel for closing hand, and triceps tunnel for opening hand. Elbow flexion by opposite shoulder, elbow extension by gravity. Pronation and supination by shrug of shoulder on amputated side.

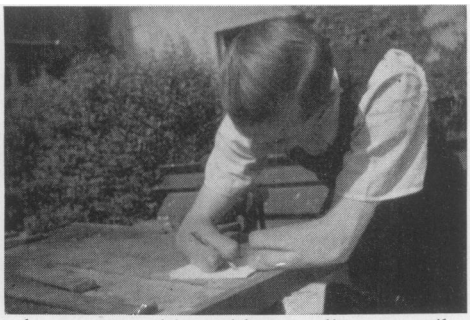
6. Short above elbow amputation—pectoralis major tunnel for closing hand, spring for opening hand, elbow flexion by opposite shoulder harness, elbow extension by gravity, pronation and supination by shrug of shoulder on amputated side.

7. Bilateral amputation—as for two single amputations but for a good length B.E. am-

Fig. 15. The Krukenberg stump.

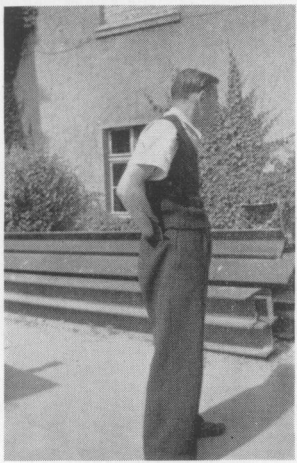
Full active separation. Gripping the handle bars. Throwing a tennequoit.
Full active closure. Tying his tie.

The Krukenberg stump. Learning typing, using hammers on wedges in the early weeks of training.



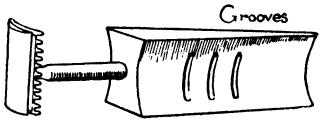
An expert, writing with an ordinary pencil.

Lifting a chair by direct upward pull.



Removing wallet from hip pocket (the importance of normal sensation).

Fig. 16.



Safety Razor on Wedge

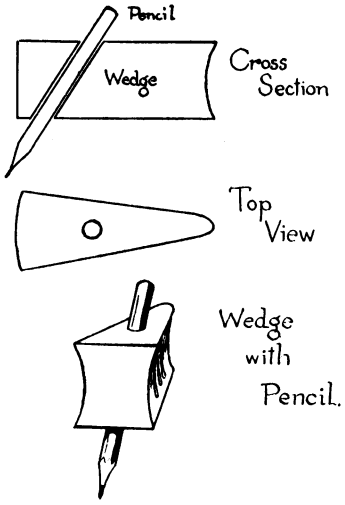


Fig. 14. Wedges used in training the Krukenberg stump or claw hand.

putation in a blind case, a Krukenberg's operation was strongly advised.

From the cases seen, and the film demonstration, it was evident that considerable dexterity was possible with the Sauerbruch arm, powered by these tunnelled muscles; the tunnels were undoubtedly robust when fashioned correctly with normal skin, unscarred openings and of a size sufficient easily to allow the introduction of the little finger; there did, however, appear to be considerably less power than in the artificial arms fitted in this country.

Undoubtedly there are cases in this country very suitable for the Sauerbruch operation, as modified by Lebsche, and a great point to be remembered is that the stump is not mutilated for use with the standard limbs if the cineplastic procedure does not meet with the success anticipated. The cineplastic operations are not difficult but a sound training in plastic surgery is needed for their successful accomplishment, as scarring must be reduced to a minimum and full allowance made for all contractures.

The Sauerbruch hand is not detachable from the forearm and the Sauerbruch school frown at the idea of replacing the hand by tools to increase efficiency. There does not, however, appear to be any reason why the general practice of fitting arms as used in this country, cannot be extended by the employment of additional 'motors' by cineplastic operation in certain suitable cases.

3. The Krukenberg Operation

The Krukenberg operation is designed to produce a claw 'hand' from the forearm stump by separating a radial from an ulnar digit, to each of which muscles are left attached. These muscles will open and close the cleft, as well as retaining pronation and supination of the forearm.

The greatest exponents of this operation in Germany at the moment are the staff of the Oskar Helene Heim—a hospital in Berlin which appeared to be their equivalent of Queen Mary's Hospital at Roehampton. This staff has performed 500 Krukenberg operations on the amputees of the 1939-45 war. When one recalls that they recommend this operation only for bilateral forearm amputees, and only for those of a suitable length, one may justly feel appalled at the toll of amputations inflicted on the German people during this war.

The basic principles expounded by the staff of the Oskar Helene Heim are that the remaining stump provides the best prostheses for a forearm amputation, that the preservation of the sense of touch is all important, and that, where the forearm amputation is unilateral, the stump itself, without any operation, provides the most useful 'helping hand.' The training required for a Krukenberg stump takes four to six months and it is found that as a rule a unilateral forearm amputee will not apply himself adequately while he has a normal hand upon which to rely. The Krukenberg operation is performed in two stages with an interval of two weeks. The skin incisions and flaps are shown in the drawing (Figs. 13a and 13b), and the following notes cover the procedure.

Flexor digitorium sublimus is split, the median nerve identified and excised up to the antecubital fossa, blunt dissection down to the interosseous membrane, the membrane is cut up as high as 6-8 cm. from the elbow, forceful splitting beyond this to allow of 5 in. separation of the bone ends, the tourniquet is then released. Haemostasis is secured, the deep fascia is sutured to deep fascia along each side of the cleft but a 1 in. separation remains between the dorsal and ventral fascial edges. No tendon transplantation is performed. The extensor digitorium is the most important muscle in closing the cleft and is split between the ring and middle finger components (the power of this muscle in closing the cleft was demonstrated by electrical stimulation).

The radial digit is covered with the radial skin flap and the proximal rotation flap completes the commissure (the soft ventral skin stretched to allow good rotation and can still be stitched back). A flap is now raised over the lower ribs anterolaterally, pedicle upwards and the defect is closed after adequate undercutting. The forearm is now placed across the suture line and the flap used to cover the skin defect on the ulnar digit, being sutured to the rotation flap, the dorsal skin edge and along the end of the digit. Dressings are applied and the arm is fixed to the chest wall by plaster of Paris embracing both.

Two weeks later the pedicle of the chest flap is severed and the closure is completed.

Training is commenced as soon as healing is complete and the wedges illustrated (Fig. 14) are used during training, although they are discarded later.

As regards the capabilities of the Krukenberg stump in a bilateral amputee, these were impressively demonstrated by the young trainer and others at this hospital. Their performances included (Figs. 15 and 16) :—

(a) Tying a tie.

(b) Writing.

(c) Threading a needle with twine.

(d) Buttoning a coat.

(e) Cycling with confidence.

(f) Playing vigorous hand ball and tennis quoits.

(g) Vigorous exercise with the punch ball.

(h) Lifting 70 lb. by direct upward pull with the straight elbow.

The men were trained to be completely independent as well as receiving vocational training in heavy or light occupations. The stumps undoubtedly stood up well to the strain of hard use in most cases. In cases seen with a Krukenberg stump on one side and a Sauerbruch arm (cineplastic) on the other, the patients appeared to prefer the former. In these cases, the cineplastic operation had been performed on one side because the forearm stump was too short for a Krukenberg operation. It is noted that the Krukenberg operation is only suitable for forearm stumps over a certain length, variously computed as from 12 cm. to 17 cm., with an optimal length of 22 cm. The Krukenberg and Sauerbruch operations were thus employed in a single plan of procedure, the bilateral case and the blind being the cases in which the Krukenberg operation particularly recommended itself.

The basic principle enunciated at the Oskar Helene Heim for forearm amputation—' that the most useful prosthesis is the stump '—was well illustrated by a short (4 in.) B.E. amputee employed as a blacksmith. His short stump, which he used to help in holding sledge-hammers, etc., was grooved and cornified in a most impressive manner. One could not help but be impressed with the importance of the preservation of the touch sense in the blind and the general conclusion was that the Krukenberg operation gives to the stump a greater usefulness than is accomplished by any other procedure. This stump may be rather unsightly but for function it appears unsurpassed both in power and in precision of action.

As in the case of the cineplastic operation, the Krukenberg stump can still be used in the standard prosthesis used in this country so that nothing need be lost in attempting what appears in many cases to be a great gain. For the blind bilateral forearm amputation, the Krukenberg operation would appear to offer great possibilities. Here the preservation of the sense of touch is invaluable. The use of the Krukenberg operation in native races, where no artificial arm is to be expected, deserves consideration, but would there be sufficient application in training, a factor of more importance even than the surgery, and would there be any facilities for training ? The occasional case loses both facilities and example and is, I fear, doomed to failure. In the Oskar Helene Heim, the surgery was excellent, the morale very high, the training first class, and each new case had the invaluable example of those more advanced in their training.

4. Conclusion

Little has been said about the standard artificial limbs made in this country but there are adequate sources of information available to the reader. Advances are being made from year to year. This paper deals largely with observations made in other countries during the last two years. It has touched on many problems of the limbless, some of them virtually solved, others remaining in the experimental stage while the solution of many has yet to be found. The work in Germany shows that not only the artificial limb but also the amputation stumps themselves present further possibilities. The Krukenberg stump for the bilateral blind amputee undoubtedly provides a great advance. The idea that the remaining forearm stump is the best form of prosthesis, even for the sighted, deserves careful attention. We know the importance of touch in peripheral nerve lesions of the hand, has this been underestimated in the case of the forearm amputation ?

The cineplastic operation provides simple suspension of the artificial limb and a fresh

source of motors for the prosthesis. There is no question that these procedures work well in the hands of the expert, technical difficulties have been overcome and the limbless are provided with a mechanical hand operated by these motors. An improved type of hand for the cineplastic stump would be a great help as the Sauerbruch hand is a poor mechanical hand. But is there any gain over the shoulder operated artificial limbs used in this country, the power is greater in these latter but the suspension not as simple ? Professor Lebsche employs both cineplastic motors and shoulder action, and the cineplastic operation must at least be kept in mind as a means of providing further motors in certain cases and as a help in suspension with very short stumps.

The suction and vacuum sockets and the quadrilateral outlet to the A.K. socket appear to be definite advances. Further experience of both is needed before one can fairly judge their value. In Germany the suction sockets were very popular in the hands of over 30 limb makers who were visited, and we have cases in this country who have worn them for 20 years with great success.

The art and science of equipping the limbless owes its antiquity to the fact that amputation must be one of the oldest of operations, but it has, as yet, reached no finality. The surgery, the limb fitting, the mechanics and the engineering present further problems and the ingenuity and the labours of many are being utilized in their solution.

My thanks are due to Professor Pomfret Kilner and to Dr. Craft of the Research Department at Roehampton for most of the excellent photographs illustrating this article.

REFERENCES

1. A MINISTRY of PENSIONS' publication (1939), 'Artificial limbs and their relation to amputations.' His Majesty's Stationery Office.
2. LANGDALE-KELHAM and PERKINS (1942), 'Amputations and Artificial Limbs,' Oxford University Press.