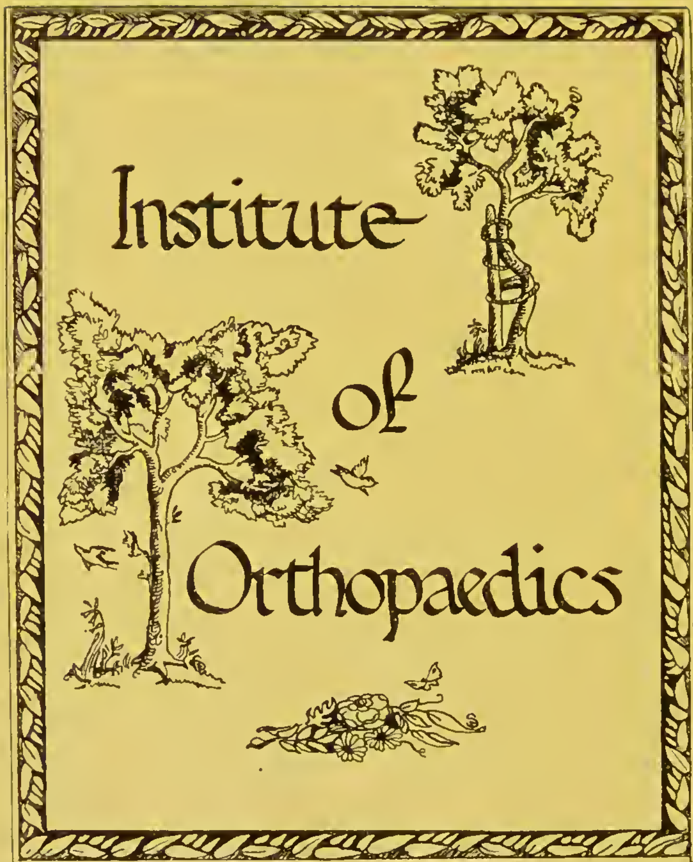
ARTIFICIAL LIMBS AND AMPUTATIONS

HEATHER BIGG


Institute
of
Orthopaedics

ARTIFICIAL LIMBS

AND

AMPUTATIONS.

The following is the series of works written or preparing by the Author which deal with all the various deformities of the body that are amenable to treatment, and which will, when completed, constitute an entirely re-written Fourth Edition of Orthopraxy.

I. On Curvature of the Spine, including its Origin, Classification, and Mechanical Treatment.

London: J. & A. Churchill. 1882.

II. On Artificial Limbs, and the Amputations which afford the most appropriate Stumps.

Published by the Author. 1885.

III. On Deformities and Deficiencies of the Trunk, including Hernia, Prolapse, Displacements of the Uterus, &c.

Shortly ready for Press.

IV. On Deformities of the Hip-, Knee-, and Ankle-joints, Paralysis of the Muscles of the Legs, Clubfoot, and Deformities of the Toes, &c.

V. On Deformities of the Head and Upper Limbs, including Wry-neck, Deformities of the Shoulder-, Elbow-, and Wrist-joints, Paralysis of the Muscles of the Arms, &c.

With the Author's compliments

ARTIFICIAL LIMBS,

AND

THE AMPUTATIONS WHICH AFFORD THE MOST APPROPRIATE STUMPS

IN

CIVIL AND MILITARY SURGERY.

BY

HEATHER BIGG,

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Illustrated by the Author with numerous Pen-and-Ink Drawings.

LONDON:

PUBLISHED BY THE AUTHOR AT 56, WIMPOLE STREET.

1885.

PRINTED BY J. E. ADLARD, BARTHOLOMEW CLOSE.

PREFACE.

This book forms another part of the series I have undertaken which deals with those deformities and deficiencies of the body that are amenable to mechanical treatment.

At the commencement of this year I had intended to bring out the part that treated on Hernia, it being then nearly ready for press, but several circumstances induced me to change my mind.

The country had been for the past few years engaged in a series of wars which had sent home numbers of unfortunate men minus limbs, for many of whom it had been my duty to superintend the construction of the Government appliances. After the late Egyptian campaign I had the opportunity of seeing a number of maimed men at Netley Hospital, and at the instruction of Surg.-Gen. J. T. C. Ross, who was acting for the Princess of Wales's Branch of the National Aid Society, of devising such special appliances as that splendid charity granted. Further, I received the Queen's commands to perform a similar duty for certain soldiers in whom Her Majesty had been graciously pleased to specially interest herself, when she made a personal visit to cheer and comfort the wounded in her Royal Hospital at Netley last May.

Having had these recent opportunities of very attentively considering the subject, it appeared to me that a work on Amputations and Artificial Limbs would not be out of place, the more so as no special work has appeared on the subject since the period of the Crimean War. The Government Regulation Appliances having also remained unchanged since that date, it seemed to me that, following the progress of the times, certain obvious improvements could now be pointed out and might possibly be introduced. Further, the exact relationship that should exist between an amputation and the artificial limb that is to be subsequently worn has not, I think, been clearly shown in existing works on General or Military Surgery, an omission which has often led to inappropriate amputations being performed, as is proved both by the correspondence quoted that passed between Brigade-Surgeon Tobin and myself on this matter, as well as by other experiences.

It was the consideration of all these points which led to my writing this book. It is divided into seven chapters, six of which are devoted to general amputations and the most improved forms of prothetic appliances, while the last one is dedicated to Military Amputations and Government Appliances. It has been condensed as much as possible, and the plan of padding up the bulk of its pages with a lengthy series of cases has been purposely avoided, those only being given which it is trusted aptly illustrate and support statements that are made.

HEATHER BIGG.

56, Wimpole Street, London;
Dec. 1*st*, 1885.

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ARTIFICIAL LIMBS.

CHAPTER I.

AMPUTATIONS GENERALLY.

An artificial limb is rendered necessary either by (1) congenital malformation, (2) accidental mutilation, or (3) surgical operation, and the difficulties presented in adapting an artificial limb to the body vary, as a rule, in these three cases. In the first case there is no knowing how far malformation may disagree with nature, nor how peculiar may be the shape and disposition of that part of the body to which the artificial limb has to be applied; and consesequently very great obstacles to success have sometimes to be encountered. In the second case, namely, that of accidental mutilation, what is left of the injured limb is usually natural in structure, and it is only a matter of adding to the body that part which has by accident been removed; but since the natural limb may be accidentally lopped off at any spot, and perhaps at that most inconvenient for the reception of an artificial one, it is obvious that in such instances certain difficulties are likely to present themselves, although these can invariably by skill be overcome.

In the third case, where a portion of a limb has been removed by surgical operation, there should be the least amount of difficulty in adapting an artificial substitute for the lost part, seeing that the spot at which amputation is performed can be elected and the difficulty would be still more reduced if those operations which left the best and most suitable stumps were more fully recognised and practised.

I propose, therefore, to run over the various operations on both upper and lower limbs, and to briefly explain what I have found by experience to have yielded stumps most efficient for receiving the adaptation of an artificial limb.

There are, however, one or two broad and general rules that apply to all cases, and perhaps more particularly to the lower limb, and these I will briefly allude to.

As regards the **point of amputation,** it must be remembered that the natural limbs are jointed members, and that therefore their artificial imitations have to be jointed in a similar way and at similar places. In order that the joints of the artificial limbs should be durable they require a certain amount of space for their mechanism, and therefore it may be stated as a broad rule that it is usually preferable not to amputate through a joint nor too near to one, but to leave a sufficient space for the mechanism of the artificial joint.

The amount of space needed will be presently specified in each particular instance.

If amputation is to be done below a joint a **sufficient length of stump** must be left beyond the joint to be of service in governing that part of the artificial limb beyond that joint; and if this cannot be done it is frequently better to amputate above the joint. The reasons of this are that a short stump beyond a joint, if not used continuously to govern its part of the artificial limb, simply contracts in the direction of the stronger muscles and becomes a hindrance.

This rule varies in its application. With the lower limb a very short stump below a joint is generally useless; with the upper limb the shortest stump may be of service. For example, below the elbow-joint a very short stump may still be efficient for the control of the artificial forearm, seeing that the flexors and extensors of the natural forearm are inserted so high up that they may be unaffected by an amputation of the forearm near the elbow.

The amount of covering to be left over the end of the stump should not be excessive, indeed, the less left the better, provided it be sound; for it is a rule never to take any bearing on an operative end of a stump if it can possibly be avoided. The exceptions to this rule are rather apparent than real. For instance, in the appliance used after Pirogoff's operation, bearing can be entirely taken on the end of the stump, but the stump end in this case is a natural surface and not an operative one, the operation being practically an excision of the foot between the ankle and heel, and the heel is therefore left.

With amputation through the ankle (Syme's) or through the knee-joint some bearing can generally be taken on the stump ends although the ontiro weight of tho body cannot usually be borno on thom, but in theso cases there is not a true operative surface such as exists after the shaft of a bone has been sawn through. Henco, wherever actual sections of bones exist in tho stump end, boaring cannot bo taken, and a full and padded covering is useless. The old idea of having a very full covering to the stump ond is erroneous, being based on the antiquated impression that bearing can be taken on it, but bearing cannot as a rule bo taken on such stump ends, and even in those rare instances in which it might at first be possible, the compression to which such a soft stump end is or would be exposed, soon causes absorption of the softer tissues, and after some time a covering is finally left which could easily at the outset have been made. Further, bulbous ends to .stumps are extremely disadvantageous.

Another very important point, and one which certainly does not as a rule receive the attention it merits, is that the greatest care should be exercised in **rounding the ends of the cut bone**. It is astonishing how many cases present themselves for the adaptation of artificial limbs in which the ends of the bones aro sawn sharply off with either clean cut edges, or, with what is worse, actual projecting points or spiculi. This fault could, I believe, be easily obviated in these days of slow operations by submitting the ends of the bones to the action of a concave osteotome of the kind figured in tho diagram (Fig. 2). This osteotome could be made of several sizes, and by being rapidly rotated over the bone ends would grate off the sharp edges and leave a tolerably rounded extremity over which the flaps would lie. Or the ends of the bone could be filed or rasped on that aspect that becomes the cutaneous when the stump is healed. These remarks particularly apply to the tibia and the bones of the forearm.

The best **method** of operation need not be gone into here, whether flap or circular or other plan be adopted, because in the hands of various operators equally good results aro obtained by different methods, and further, the selection of the method is not a subject that falls within the scope of a work like this.

Indeed, it might at first sight appear presumptuous to lay down any laws on operations at all, while looking at limbs for the purpose of applying artificial substitutes to them; but Teale long ago set the example to surgeons of regarding

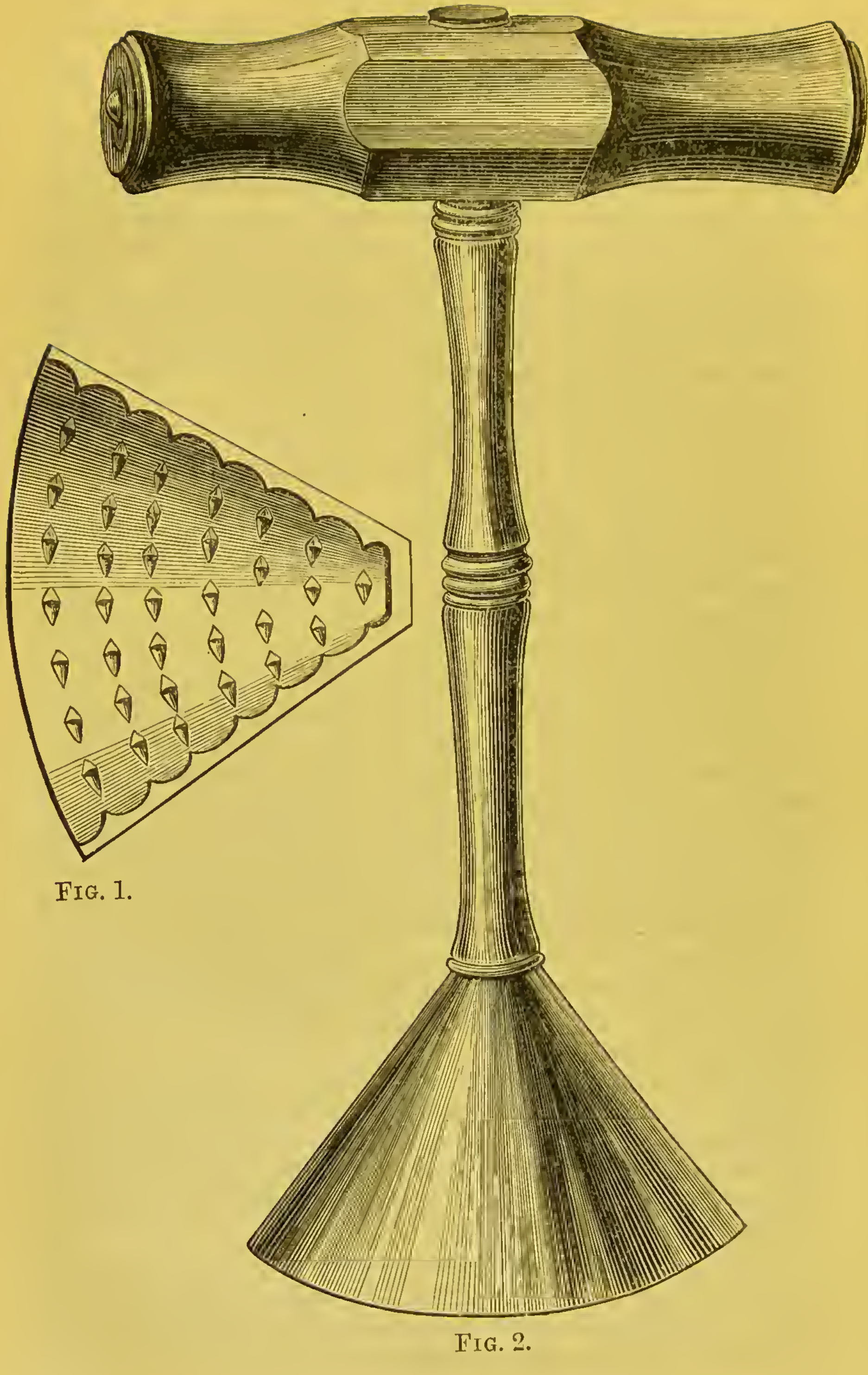

FIG. 1.

FIG. 2.

operations on the limbs from a mechanical as well as a surgical standpoint, and of considering **the requirements of the limb-constructor** whilo determining the point of operation. And as the standard hand-books on surgery do not go very fully into this point, no apology is needed for doing so here.

In taking operations on the limbs into consideration the actual mechanical parts that are essential ought to be borne in mind, and this is moro particularly so in the case of the lower limbs, because it is these parts, and these only, that it is necessary to preserve as far as possible. This consideration should form the key to all operations which are undertaken with a view to giving the designer of the false limb tho chance of artificially restoring the patient to his former condition with the greatest perfection, and of superadding a substitute which in appearance, action, and use shall simulate as nearly as possible the natural limb.

At the same time, be it distinctly understood that in laying down the mechanical laws for operation it must not be imagined that artificial limbs cannot be adapted to almost any and every stump that can arise. Indeed, such is the variety of cases that may inevitably be presented, that probably every possible kind of stump has had the correct form of artificial substitute that can be adapted to it, thought out and perfected. Still some stumps afford much greater opportunities than others for the application of a durable and efficient artificial limb, and it is with the aim of obtaining such stumps that I would lay down the mechanical rules for operation.

Alterations in Stumps after operation.—All stumps after the satisfactory completion of operation, as well as after the adaptation of an artificial limb, undergo a series of changes in size. These changes occur in a regular order and from causes very oasily explained, and they are most marked in the lower limbs. First, it is very usual for a stump to increase in size immediately after operation, at all events in those cases in which some exhausting disease has reduced the weight of the patient and has been the compulsory cause of the operation itself. Next, after an artificial limb has been accuratcly adapted there is a diminution in the

FIGS. 1 and 2.—These figures represent a form of osteotome intended for rapidly rounding off the cut ends of long bones in amputation. It really is a concave rasp, with a powerful handle. The figures show this instrument both in profile and in section.

size of the stump progressing for a variable time, but generally for about ten or fifteen months, and this is followed in its turn by a gradual increase again in size. These changes take place in persons whose bodies are stationary as regards bulk and size; but the stump of an amputated limb likewise participates in all general changes, such as increased or diminished bulk of the entire body.

Apart however from general changes in the body, the special changes in the stump previously alluded to take place, and every patient should be fully made aware of this, because an artificial limb which at the outset fits with absolute perfection, will almost invariably require alteration in the size of the sheath that receives the stump, and it is not till the completion of about two years, as a rule, that the stump reaches its definite and unvarying size.

Patients, therefore, who are ignorant that such is the case will not infrequently have a perfect artificial limb constructed and fitted to them, and will find that although at the outset they have learned to walk very well, yet gradually and in a few months' time their control over the limb gets less, and walking becomes more difficult, until sometimes, from misunderstanding the reason, they arrive at the conclusion that they will never walk properly with an artificial limb, and resign themselves to some cruder and less efficient appliance, when really a slight alteration in the sheath of the artificial limb would have effected all that was necessary and have enabled them to walk with perfection.

The changes that take place in the stump must then be fully realised, and are easily followed and accounted for.

The increase in size immediately after amputation, when there has been some exhaustive disease going on which has led to the necessity for amputation, is easily understood. The patient has thinned down under some drain on the system, and when once this cause has been removed, the bodily weight and bulk runs up again. In such instances where there has been very great loss of flesh and weight, it is better perhaps to wait some little time before measuring for an artificial limb, and to allow a certain restoration in size to take place. This restoration as a rule progresses rapidly. For example, in a case recently sent me by Mr. W. D. Spanton of amputation through the tibia, where there had been originally disease of the great toe, recurring after amputation of that part, the measurements of the thigh increased in five weeks (from the 27th of June, 1885, till the commencement of August) about 1½ inches, and that of the calf in similar proportion, the thigh circumference rising from 17½ to 19, and that of the calf from 10½ to 11½, and this increase only represents part of the change which had been going on since the operation some months previously.

On the other hand, it is well known that in some cases where amputation has been performed after accident or otherwise, and where the patient is a normally sized person, it is very frequent to find a great decrease takes place in the stump through muscular atrophy ensuing on disuse, and in these cases also it is often wise to wait for a few weeks to allow the stump to settle to a definite permanent size before applying the artificial limb.

Immediately after the application of an artificial limb there is invariably a diminution in girth at the spots where the limb holds or presses. This is due to the absorption of subcutaneous fatty and other tissue under pressure, and in well-nourished and heavy people this is frequently very great. Thus, for example, in the case of Mr. W—, a young man of seventeen, about 5 ft. 11 in. in height, and about thirteen stone in weight, amputation of the leg through the knee-joint was performed by Mr. F. M. Corner, of Poplar, and an artificial limb was applied in December, 1883, which at the outset accurately fitted the stump, this latter measuring from above downwards 21½, 17½, 14½ at equidistant circumferences. The stump, however, speedily began to shrink for the reasons given, while Mr. W— had to increase the woollen covering he placed over the stump to intermediate between the skin and the sheath of the artificial limb. By February, 1885, the limb had so decreased in girth that the same circumferences were respectively 19, 14½, 12. His walking in the meantime had become more and more laboured owing to misfit, but as soon as the sheath that received the stump was refitted to the diminished circumferences, then perfect walking powers were regained. This case is perhaps an exaggerated one, and is only quoted to show how much shrinking may take place.

After this shrinking, due to absorption of the subcutaneous fat and atrophy of disused muscle, has reached its greatest limit, a change begins in the opposite direction, and slow increase of girth takes place owing to the fact that as the full powers of walking are gained so the muscular substance of the stump is used and called into play, and begins to increase in bulk with this increase of function; and this goes on until a maximum is reached, after which the size of the stump remains stationary, changing only, if it changes at all, with such general changes as affect the body throughout.

These facts suggest the question of how long it is wise to wait before applying an artificial limb, and the answer to this must, I think, be, that in most cases it is better to put the artificial limb on as soon as possible, excepting in such instances as those I have referred to in which the patient is much wasted prior to operation and begins rapidly to make flesh afterwards. With this exception, however, it is, I feel sure, best to apply an artificial limb the moment the stump is healed and sound enough to bear it, and this is frequently only a few weeks after operation.

In addition to the changes in general bulk of the stump, changes in shape frequently occur through the contraction of muscles. This would naturally be the case where the insertions of certain muscles had been destroyed, while those of their opponents had been left, and in consequence the muscular balance around any joint had been upset.

The most common of these contractions are, that of the tendo Achillis, so often seen after Chopart's operation, that of the flexors of the knee in cases where a short stump has been left below the knee, and that of the hip-joint in a direction of either flexion or abduction.

The contraction of the heel in Chopart's operation is not perhaps so much to be explained by the loss of the muscles antagonising the tendo Achillis as by the loss of the tread of the foot. For in everyday life the pressure of the ground on the tread of the foot is always tending to force the heel down, and to stretch the back muscles of the leg; and when the tread of the foot is gone, this extending force is no longer exerted and the calf muscles consequently contract. A very common cause of contraction at the knee in certain cases that present themselves for the adaptation of an artificial limb is, that the patient has been using a kneeling leg previously, and that the knee has been thereby constantly and persistently flexed, hence the hamstring muscles, no longer stretched by extension that formerly was exerted, contract.

CHAPTER II.

AMPUTATIONS IN THE LOWER LIMB.

Considerations bearing on Amputation in the Lower Limb.—The natural leg, like the artificial one, is an automatic piece of mechanism. Its muscles are used, it is true, to steady and to guide it, but in walking on level ground they are used for little else, hence on level ground an artificial leg will perform all the movements and do all the duties that the natural one can do. The bones and ligaments of the natural leg form independently of the muscles an automatic piece of mechanism, which is put into action by the muscles of the hip alone, and is only steadied in action by those of the thigh, leg, and foot. In an artificial limb the mechanical representation of the bones and ligaments is perfectly attainable, and the mechanism is easily given steadiness without any attempt to reproduce artificial muscles, those latter up to the present never having been imitated (although I see no reason to doubt that with future advances of science artificial muscles with nervous or electrical communication with the body may be attainable). For the moment, however, muscles may be ignored, as none are required for walking on level ground, excepting always those which govern the hip-joint and swing the leg forward, and these of course are left sufficiently intact, unless amputation has been performed through the hip-joint, in which case an absolutely perfect artificial leg is an impossibility. In all other amputations on the leg, however, a perfect substitute can be constructed, but with greater accuracy and wearing powers if the laws to be presently laid down are followed.

Taking the leg as a mere piece of machinery, its essential parts in order are as follows : (1) The tread of the foot with the ankle-joint and tendo Achillis, (2) the heel, (3) the knee-joint, (4) the hip-joint, and lastly, of course, the solid bony connections between these parts which keep them in due relationship.

It will be observed that I class the tread, ankle-joint, and tendo Achillis as one combination, and take the heel as a separate essential. This will be found to be a mechanically correct view, the reasons for which are given later on, and I merely now state as an illustration in passing that its *rationale* is exemplified in Pirogoff's operation, where the tread, ankle-joint, and the tendo Achillis are sacrificed, while the heel is preserved, and that I regard the heel as the lowest part of the entire limb, and the foot-lever (*i. e.* the tread, ankle-joint, and tendo Achillis) as being inserted between the heel and lower end of the tibia, and as being excised from that place in Pirogoff's operation.

The hip-joint swings forward the whole leg by muscular power; the knee-joint automatically and without muscular effort swings forward the lower leg; the heel automatically takes the first bearing on the ground while the leg is the leading leg, and the tread of the foot automatically takes the last bearing on the ground where the leg is the following one, and on leaving the ground preparatory to being swung forward as the leading one. Operations on the leg should therefore be guided by these facts.

The **general rules** may be put as follows: If possible, preserve the tread of the foot; if this cannot be done preserve the heel; if this is impossible preserve the knee with sufficient of the lower leg to utilise it, and if this cannot be done preserve the hip-joint with sufficient of the thigh to utilise that joint. And putting this more completely still, the rules may be epitomised thus,—save the tread of the foot; if this is impossible save the heel and do Busk's modification of Pirogoff; if the heel cannot be saved save the knee-joint and its due length of stump, and amputate somewhere in the middle third of the lower leg (tibia); and if the knee and its functions cannot thus be preserved amputate as low in the middle third of the thigh (femur) as possible.

As will be presently seen, these rules sweep away several old-established and long-recognised operations about the foot, but these operations which, looked at from a mechanical standpoint, should certainly become obsolete, have been standard operations rather on account of their surgical facility than on any other score, and surgical facility has not in the present days of anæsthetics and antiseptics the importance that it previously justly held.

And for similar reasons, the old conservative axiom of performing amputations as far as possible from the trunk cannot have the same weight as heretofore, and therefore need not be (within certain bounds) so rigidly kept to. And while asserting this, I am not criticising old surgical rules, but am most anxious to establish the point that with the present advance of science and the increased facility of successful operation, mechanical rules may be taken into greater account than they previously could be.

Nowadays ample time is allowed for perfected surgical operations, and the amplest chances are given for more speedy and safer healing of the wound; and it is consequently much more possible to exercise greater forethought in following the mechanical rules for points of election, than before the general use of anæsthetics and antiseptics, when the older statistics based on Crimean and previous experiences were considered infallible guides.

I will now go with a little more detail into the actual operations themselves, taking them from the toes upwards.

Amputations on the Foot.—It may seem rather a bold statement to make, that unless the tread of the foot can be functionally preserved it is better to remove the entire foot, but it is, nevertheless, assuredly true.

For the foot itself is, as nearly everyone knows, a lever with its trio of essentials, of which the ankle-joint is the fulcrum, the tendo Achillis is the representative of the power, and the tread the recipient of the weight. If the tread is lost, or incapable of action, then the trio is dissolved, and the lever no longer exists; the foot ceases to be of further service, is an impediment, and is best removed. This will be more apparent still when the artificial appliances themselves come to be considered.

Presuming then that a case arises in which the heel can be left intact, but in which it is necessary to remove at least a portion of the foot, what parts must be left to suffice to give this accommodating tread, because, as before said, if they cannot be left it is better at once to remove the foot bodily?

Now, the tread of the foot depends on the great toe as a whole, not only on the ball of the great toe, but also on its continued phalanges. As a rule, therefore, removal of the great toe, whether with or without its metatarsal bone, ruins the tread of the foot, although cases do sometimes occur in which the remaining toes will become strengthened, and notwithstanding the loss of the great toe a good tread is still left. The little toe with its metatarsal bone may easily be removed without interfering with the tread, as also may one or more of the other toes. If all the toes are removed, as sometimes is done in cases of gangrene or frost-bite or crushing injuries, the tread of the foot is lost, and experience has shown me that it is better therefore to remove the whole foot. And if this is the case how much more, *a fortiori*, is it better to remove the entire foot than to perform any such operations as Hey's, Lisfranc's, or Chopart's? For in all of these the heel is left, but in front of the heel remains a portion of the foot of greater or less length, which is absolutely useless, and is very much in the way of any mechanism which may be devised with the purpose of restoring artificially the tread that is so necessary for natural walking. In all cases, therefore, in which a portion of the foot has to be removed up to the limits of these previously mentioned operations, it is better not to perform them.

There are, however, certain cases, such as disease of the bone, in which excision of some of the bones of the foot can be performed without injuring the tread of the foot at all, and in such cases the operative results are frequently excellent, for although mechanical aid may or may not be needed to give strength to the parts at which excision has been performed, still, if the elements of natural walking have been left, viz. the heel and the tread, the conditions laid down will be fulfilled and neither the utility nor function of the foot will be impaired. The condition which must determine, however, whether excision is preferable to amputation in such cases, is whether between the heel and the tread there will be left a connection of sufficient strength to enable the heel and the tread to work in conjunction with one another. To excise the entire tarsus and to leave the tread of the foot unconnected with the heel, would obviously be to destroy the use of the tread; so that while it has been laid down that the possibility of maintaining the integrity of tread, heel and ankle-joint forms the key to what amputation should or not be undertaken, it must also be remembered that these three parts are correlated and dependent on one another and that a strong functional bony connection between them must also be maintained.

Supposing, therefore, for the reasons previously given, it is held wise to remove the entire foot, it being impossible to preserve its tread, what operation affords the best stump for the application of an artificial limb? The choice lies between Syme's and Pirogoff; (the subastragaloid operation being left out of the question as most disadvantageous on account of the room that the astragalus takes up below the tibia and its monopolising, therefore, the space which is requisite for mechanism). Of the two Syme's is tolerably good, and perhaps may be considered, for surgical reasons, the better; but from a mechanical point of view there is none like Pirogoff's; further, Busk's modification of Pirogoff gives better results than the operations as originally laid down by Pirogoff himself.

The reason why a Pirogoff is so good is obvious. It has been stated that one can can rarely get any bearing on a stump end whose bone presents an operative surface. Now, Pirogoff's operation being really and practically, as before remarked, an excision of the foot between the heel and the lower part of the tibia, the surface left at the end of the stump is the actual heel, and it would be impossible to get any better end for bearing than that which nature has already provided. With Syme's, on the other hand, it is quite exceptional to find that the bearing, especially with heavy subjects, can be taken without some inconvenience to the end to the stump, even when the leathern sheath into which the lower leg is received is so shaped as to take some of the bearing just below the tuberosities of the tibia close to the knee, and to so relieve the stump end; and even when the most careful padding is used at that portion of the sheath on which the stump end rests, it is not unusual to find that great difficulties arise by reason of the over-sensitiveness of this latter surface, so that there cannot be two opinions about the fact that Pirogoff's operation is the very best, and the most perfect walk is obtained with the appropriate mechanical appliance which will later on be described as being used in such cases.

Amputation through the Tibia.—Next, with respect to an amputation which, from the nature of the case, must be undertaken through the leg—what is the mechanical range of election? This question, put in other words, is how low is it permissible to amputate so as to leave a full amount of room for the mechanism of an artificial ankle-joint, and how high will an amputation leave a stump of sufficient length to govern the lower leg portion of an artificial limb? It is obvious that one must not amputate too low, because a certain amount of space is required for the ankle-joint mechanism (and this space is at least about four inches from the ankle-joint or six inches from the heel). It is also obvious that if the amputation is performed too near the knee, then the stump left below the knee is of little or no service in governing its portion of the artificial leg; nay, further, a very short stump below the knee almost invariably contracts in a flexor direction, and becomes therefore a great inconvenience rather than the reverse. In an adult for the stump to be of any service at the very least four inches below the knee should be left. The absolute range of election is therefore from four below the knee to four above the ankle, but practically it is about the middle third, and the lower in this the amputation is performed the more perfect will be the government gained over the artificial leg. Consequently the actual point of election will be a little lower than half way down the tibia; while if it is impossible to leave a stump up to four inches length, then it is perhaps better not to amputate through the tibia at all, but higher up.

Before leaving amputation through the tibia there is one point that is so almost invariably neglected that I cannot too strongly draw attention to it, and that is sawing or rounding off the end of the bone, particularly that point where the anterior ridged border of the tibia terminates. It is generally left to project as a sensitive thinly-covered point on the anterior extremity of the stump, and as it is exactly on this anterior extremity that great pressure bears when the stump swings forward the lower leg of the artificial limb, it can easily be imagined how important it is to leave a rounded and not a pointed extremity to the bone (*vide* Figs. 3, 4 and 5).

Amputation through the Knee-joint.—And next comes a rather knotty point which I will do my best to elucidate, and that is whether amputation should be performed through the knee or by preference through the thigh (it being always borne in mind that these considerations are viewed rather from a mechanical standpoint than a surgical one).

Amputation through the knee-joint may have its

FIGS. 3, 4, 5.—These figures represent the stump end, produced by various modes of trimming the tibia in amputation, whether it be sawn straight across only (Fig. 3), or with the anterior aspect bevelled (Fig. 4), or with the entire end rounded by an osteotome (Fig. 5).

FIG. 3.

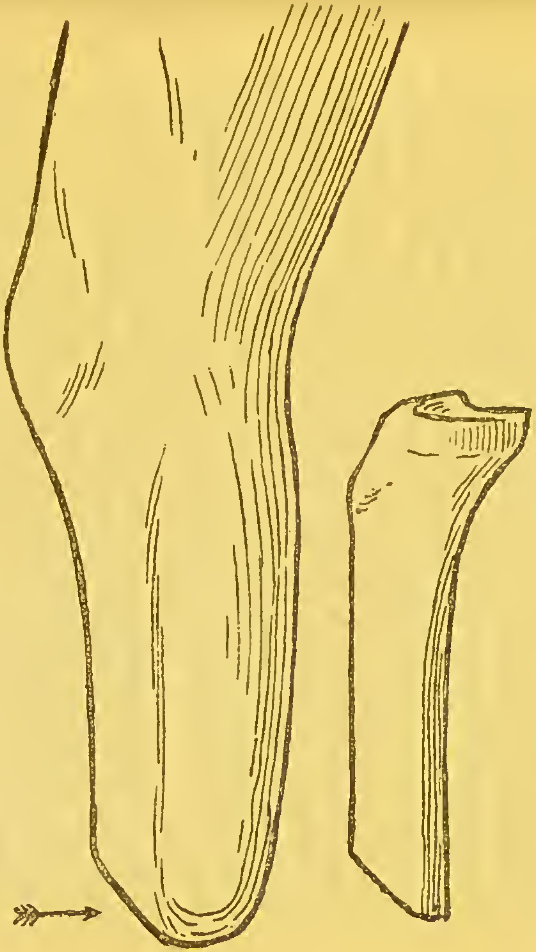

FIG. 4.

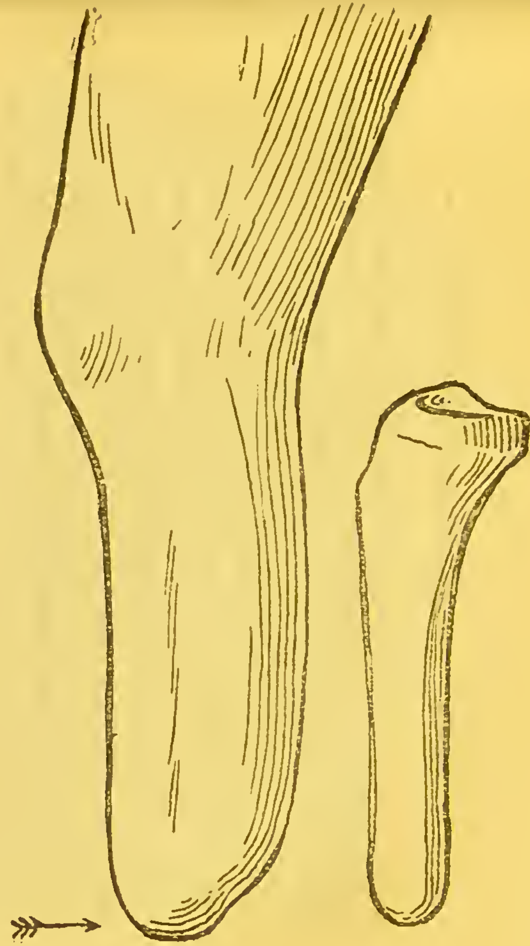

FIG. 5.

advantages from a surgical point of view, but it has this great mechanical disadvantage, which it shares in common with all amputations performed through the joints, in contradistinction to those performed above the joints, that no room is left for the complete and durable mechanism of an artificial joint. For although there is no difficulty in constructing a perfect artificial limb when amputation has been performed through the knee-joint, yet from the considerations to be presently mentioned, the joint of such an artificial limb is less durable, in the proportion of about 40 to 1 than in cases where full space is left for that artificial joint that can be constructed if the lower end of the femur is cleared away.

The axis of the knee-joint of the artificial limb must truly correspond with the axis of the knee of the natural limb, so that the artificial one may be identical in motion with its natural fellow of the other side (since usually only one leg is lost at a time). The sound limb and the artificial one must be alike both in appearance and in movements, both in outline and in axis. Now, the axis of the natural knee-joint may be accurately taken to be a line drawn through the condyloid eminences, or in other words above the joint itself. If, therefore, amputation is performed through the knee-joint it is obvious that in constructing an artificial limb a hinge-joint cannot be carried right across the leg at the right position of the axis, for the mass of bone bounded by the condyles of the femur lies in the way.

As a consequence of this an artficial joint can only be obtained by putting two lateral rods (*vide* Fig. 7) along the sides of the limb with rule-joints in the true axis of the knee (that is at the line through the condyloid eminences). And the durability of such rule-joints as compared with a complete joint (*vide* Fig. 8) right across the axis of the leg is easily calculated.

The rule-joints work on rivets about $\frac{3}{16}$ inch in diameter and $\frac{1}{4}$ inch wide; the hinge-joint works on a bolt about 4 inches in diameter and $\frac{1}{8}$ inch wide. And as the areas of cylinders are as the squares of their diameters the proportion of surface which bears the weight of the body and withstands the influence of wear and tear is in the one case as compared with the other represented by the following $4 \times (\frac{3}{8})^2 : \frac{1}{2} \times (\frac{3}{16})^2 :: 4 : 173$ or as about 1 to 43.

This reasoning at first sight may seem a little complicated and difficult to follow, but if gone over carefully it will be found to be absolutely true, and the advantages of amputating above the knee-joint as balanced against amputation through the knee-joint are for mechanical wear and tear as 43 to 1. No argument, therefore, could speak more forcibly for electing the former plan.

Further, under the rule-joint system steel works against steel, while under the hinge-system the steel bolt works (p. 8) against a leather bushing, and the latter arrangement every engineer knows is infinitely better for wear than the former, this law of letting the friction take place between different materials being carried out on the bearings of engines, &c.

Hence it may be summed up that the limb for amputation above the knee-joint through the femur is much more durable than that for amputation through the knee-joint, and that therefore for heavy people and those who have to walk much, and who are not in a position to pay for constant repairs, amputation through the femur is better than that through the knee-joint.

I have reviewed these operations again at page 57 and suggested a novel operation as giving the best knee stump.

Amputation through the Thigh, as with that through the lower leg, is governed by a similar range of election. The operation must not be performed so low as to trench on the room needed for the mechanism of the artificial knee-joint, nor must it be performed higher than possible, as the greater the length of stump that can be left the greater is the control obtained over the whole artificial limb. As before said the artificial limb is automatic, provided only that muscles are left to throw it forward and to steady the body at the hip-joint in its balance over the artificial leg.

The amount of space that is absolutely necessary to leave room for the mechanism of the artificial knee-joint is about three inches. It is possible to do with a little less, and in one or two instances I have been enabled to get the mechanism into two inches, but that is difficult, therefore it may be laid down as a law that in amputating through the thigh the stump should not reach nearer the previous position of the knee-joint than three, and this of course means sawing the bone an inch higher up, as an allowance must be made for the tissues covering the bone, therefore the bone should be sawn at four inches from the joint.

And in stating this I do not mean from the axis or centre of the joint which, as before stated, is a line through the supracondyloid eminences, but from the condyloid surfaces of the joint.

About the point of amputation in the other direction the longer the stump is the better, and therefore the farther from the hip-joint; this is self evident.

Amputation through the Hip-joint does not of course leave any bony stump at all, and although the fatty and fleshy mass that marks the previous position of the limb may be called a stump, it is under no muscular government, and consequently a perfect automatic artificial limb cannot be adapted to it, although a fairly useful leg can be arranged, which is swung forward by lurching of the entire pelvis, just as the limb is moved in the common case of ankylosed hip-joint after hip disease.

CHAPTER III.

ARTIFICIAL APPLIANCES FOR THE LOWER LIMB.

The lower limb is, as has been previously pointed out, automatic on level ground. Excluding the muscles of the hip-joint, no muscles are necessary in ordinary walking except for steadying purposes, and the bony and ligamentous structures of the leg are so arranged that such should be the case. No generation of force other than that in the muscles around the hip-joint is needed, and consequently an efficient artificial leg can be easily constructed, because the difficulty of generating force has not to be overcome. With the arm it is different; the elbow is bent and the fingers grasp by generated force, hence unless some method is employed to generate such force the arm and hand cannot be successfully imitated.

In examining the **mechanical structure** of the leg with a view of getting the key to the construction of an artificial one, muscles may therefore be disregarded.

As has also been pointed out, the structural essentials of the lower limb are the hip-joint, the knee-joint, the ankle-joint, with the tread of the foot and the heel, together with the structural connections between the parts.

And in examining the essential mechanism of the natural limbs a clear distinction must be drawn between anatomical and mechanical structure. It is the habit of profound anatomical workers to dwell with lengthy admiration on the marvellous manner in which every bone is specially adapted to the mechanical requirements of the limb in which it happens to exist, and, for example, to view each separate bone of the carpus or tarsus as a masterpiece of mechanical ingenuity. Such anatomists would probably express the opinion that if nature is to be imitated, each bone, each ligament, and each muscle should have its representative in the artificial imitation. This idea is absolutely erroneous.

Nature in constructing men's limbs has not been able to start *de novo*, otherwise she would have gone to work more simply, but she has had the elements of the vertebrate type to mould into utility, and, as Darwin as shown, she has not had to work on elements of her own choosing, but to take those that already existed and then model them as best she could to the requirements of the animal she constructed.

Hence it cannot be too strongly insisted that in giving man the power of walking, just as will in later years be found in giving him the power of flight, it is not anatomical imitation that is to be aimed at, but mechanical. Therefore, as mechanical structure has been shown previously to be the key to the points of election in operations, so also it is the key to construction in the artificial substitute.

I will therefore examine each of the essentials of the natural limb in detail, and show what it is that has to be reproduced, as well as the perfection with which such reproduction can be effected in the present day.

And I say advisedly in the present day, because it has taken continued progressive efforts on the part of mechanicians to reach the present point. I have in my possession a series of limbs constructed at different times during this century, and it is curious to note how very crude the artificial limbs were only fifty years or so since, and how step by step they have approached nearer and nearer truth to nature. The fact is that the mechanician of the past was not an anatomist, and did not pick as it were the body to pieces in order to be guided in his efforts at artificially reconstructing portions that might be lost. He only copied vaguely by the light of external structure and through his own instinctive intelligence. The strong professional feeling that so long existed against the surgeon and mechanician being combined in one person has strongly militated against improvements in this direction, at least such is my respectful opinion.

The Hip-joint is, as everyone knows, a ball-and-socket joint, that is to say, it combines with hinge movement several other ranges of motion. In ordinary level walking, however, it is more nearly used as a hinge-joint, or more correctly as a monaxial joint, working as such on a single axis which runs horizontally through both hip-joints at about the level of the top of the great trochanters.

The hip-joint has very rarely to be artificially imitated seeing that amputations through the hip are not so common.

Further, when amputation at the hip has been performed, all the muscles of that joint have of course been destroyed, and these having been previously explained to be the very muscles and the only muscles needed for the working of an artificial limb, it becomes next to impossible to give perfect walking powers by an artificial limb adapted to the short boneless and powerless stump that is left. Notwithstanding these disadvantages, however, limbs have not infrequently been adapted to the surface left after amputation through the hip, the stump being received into a leathern sheath, which latter is connected by a monaxial hip-joint with the rest of the limb. So that if the hip-joint has to be imitated for such a purpose, the imitation is effected by a monaxial hinge-joint, and not by reproduction of the ball-and-socket joint which exists in nature. Of course the voluntary movement which is imparted to such an artificial limb has to be effected by a lurching of the entire pelvis, which moves then as it does in the case of an ankylosed hip-joint after hip disease, where the limb is advanced by the movement of the entire pelvis in the absence of any possibility of motion at the hip-joint. This method of advancing the limb is well known to those familiar with hip disease.

The Knee-joint (although in nature admitting of slight movements in several directions, as, for example, rotation of the tibial on the femoral surface) is to all practical purposes in level walking a monaxial hinge-joint.

It is, further, a joint with such an excentric disposition of its parts that when it is fully extended and receives the weight of the body, it is both stable and self-locking, and requires no muscular effort to be maintained so. This is well known, and can easily be proved by the fact that the patella (knee-pan) can be moved freely about, when a person is standing quite erect, showing that no muscular force is exerted to prevent the knee-joint giving way, but that, on the contrary, the special structure of the osseo-ligamentous parts of the joint suffice unaided to maintain the weight of the body and the fixity of the joint. If muscular force had been requisite in nature, then the knee-joint could not have been artificially imitated, since at present no exact method of reproducing muscular force is known. But as it is, the knee-joint is easily and perfectly imitable by an analysis and reproduction of the precise plan that exists in nature. To understand this reference can be made to the adjoining figure, which is a diagram of the joint and of its lateral ligaments. The rest of the structures may be ignored as they only represent the motor mechanism, and, as I explained before, no motor mechanism is wanted in ordinary walking, excepting that at the hip.

Now, the natural knee-joint when examined displays two special provisions for maintaining automatic stability when the body is standing erect, and also when in walking the bodily weight is being carried forward on the single "leading limb," while the "following" limb is being swung into its place to become in its turn the leading one. These two special provisions or dispositions of structure are the following. First, the joint surfaces are so arranged that the centres of these movements are behind a line drawn through the shafts of the femur and tibia, and the result of this is that when the weight of the body comes to pass through these bones to the ground, the knee-joint has not the slightest tendency to give way or flex ; on the contrary, it tends to over-extend, and, indeed, would do so were it not for the second provision. The second provision is the disposition of the lateral and posterior ligaments of the knee-joints. The arrangement of these lateral ligaments is peculiarly beautiful from a mechanical view, as their action is a check to over-extension, and has been fully explained by several observing anatomists. The curve of the facets of the femur is not circular but parabolic, increasing in its radius from the centre of motion as the knee is extended, and to such a degree as to tighten the lateral ligaments, and these when once taut effectually prevent further extension. But the eccentric disposition of the joint surfaces with respect to the shafts of the bones preclude flexion. The joint cannot therefore flex and it cannot further extend, and it consequently becomes fixed and stable. Nothing is easier then than to reproduce those two essential points in the construction of the knee-joint of an artificial limb. All that is wanted is a form of joint which shall have its axis posterior to the direction of the shafts of the bones, so as

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FIG. 6 is a diagram explaining the self-loeking meehanism of the natural human knee-joint, and it shows the position of the axis of motion posterior to the line of weight (dotted lines) there by indueing over-extension, and also the eheek to over-extension effeeted by the lateral and posterior ligaments (dark lines).

FIGS. 7 and 8 show respeetively the same principles earried out in the knee-joints of an artifieial leg for amputation below knee, and one for amputation above knee.

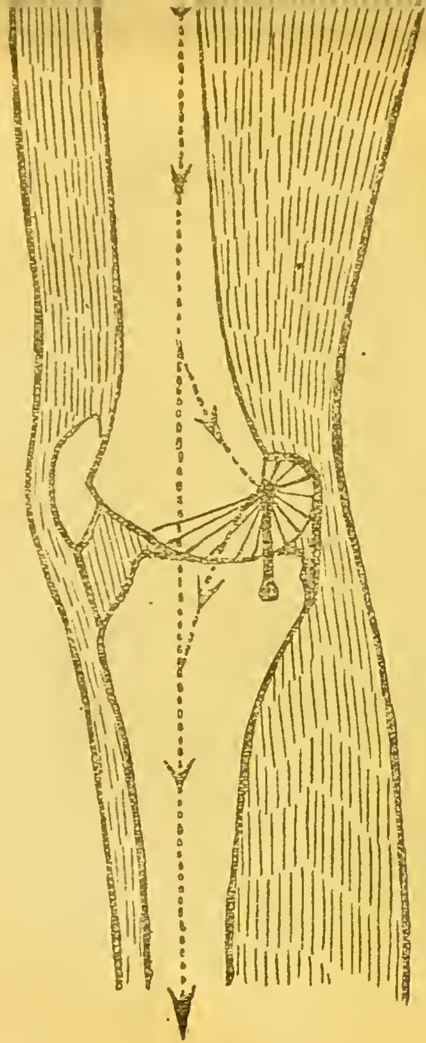

Fig. 6.

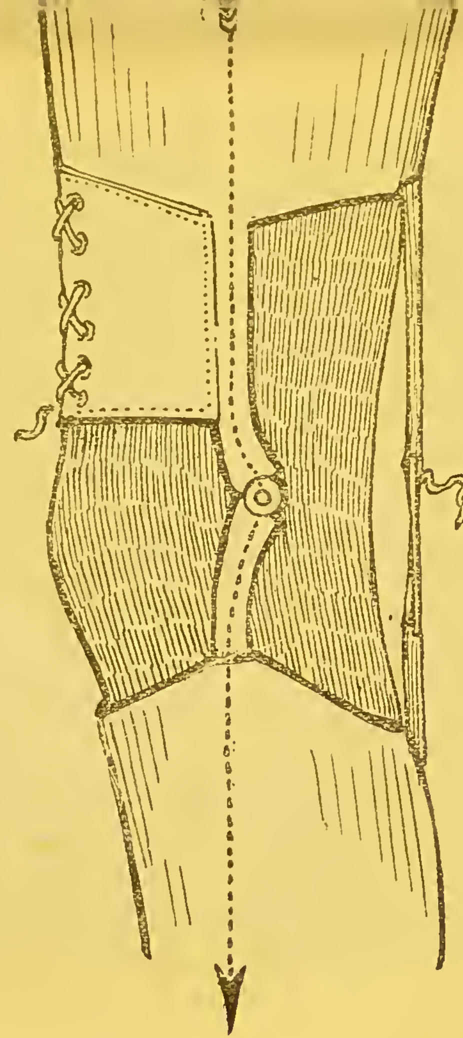

Fig. 7.

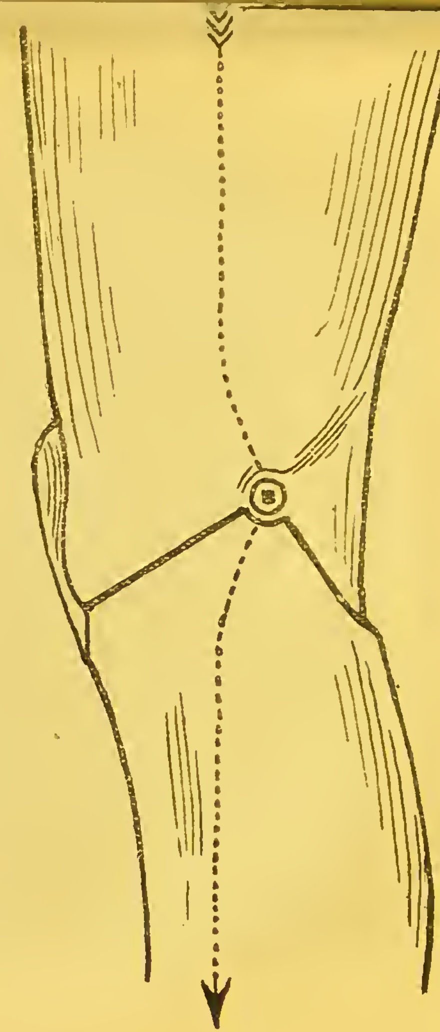

Fig. 8.

to bar any chance of flexion, and a check or stop of some kind to bar over-extension, and then the conditions of stability will be fulfilled.

These conditions are carried out in both the knee-joints figured: the one being the form of joint used in amputation above the knee (Fig. 8), and the other that in amputation below the knee (Fig. 9). In both of them the arrangement is identical, only that where the natural knee has been left, the material of the artificial one has to be disposed as lateral steel rods one each side of the natural one, while when amputation has taken place above the natural knee, the material of the artificial one can occupy the whole of the space which the natural knee did, and a more durable and stronger point can be gained, a point which as has been stated must be taken into consideration (p. 26) in determining the point of selection when amputating near the knee; because if a stump of sufficient length cannot be left below the knee to govern the lower part of the artificial limb it is better to amputate above the knee and by removing the natural knee to leave room for a strong and durable artificial knee-joint extending the whole transverse diameter of the knee, in lieu of one composed only of the two light joints in lateral rods.

The ankle-joint may really be said to be a joint of the ball-and-cup type, the cup being represented by the lower articular surfaces of the tibia and fibula, and the ball by the upper facet of the astragalus. It is of course only a modified and irregular cup-and-ball joint, not a complete and perfect one like the hip-joint. The ankle-joint is the pivot on which the whole body moves forward in walking, while the foot is adapted to the ground as a stable base supporting this ankle pivot; and it is this adaptation of the foot to unevenness of the ground that the natural ankle-joint is constructed to admit of.

In ordinary walking on level ground as on a pavement the ankle-joint may be said to be only used as a monaxial hinge-joint; where, however, the ground is not level the ranges of lateral movement of which the ankle-joint is capable come into play, and the foot is thereby adapted to uneven surfaces. And it may be stated at once that the ordinary method of imitating the ankle-joint in an artificial limb has until recently been to construct a pure monaxial hinge-joint. The plan I, when possible, adopt by which lateral accommodation of the foot to the inequalities of the ground is permitted is an exceptional one, and its advantages are not, I think, as fully understood nor esteemed as perhaps they should be.

It is perfectly true that a mortieed monaxial ankle-joint to an artificial limb gives very good power of walking, but it only imitates the natural ankle-joint in part, while the "Heather Bigg" ankle-joint whieh my father invented and described ('Orthopraxy,' 3rd ed., p. 604), allows lateral aecommodation of the foot to the surface of the ground, and imitates the natural ankle-joint in all its details of motion, eonsequently gives perfect walking power.

In seeking, therefore, to imitate tho ankle-joint artificially somo provision should, if possible, be made for the lateral movements of tho foot, and this it will be seen is very amply done in the "Heather Bigg" ankle-joint.

The Foot, and more particularly the "Tread," are the next essential points to be considered. The foot as a whole is the base on which the body rests while pivoting over on an ankle-joint. When, however, the leading limb has been swung into position and the bodily weight is about to be transferred to it, the foot of the following leg has to leave the ground, and it does so through the medium of the "tread" of the foot. Without the tread of the foot perfect walking cannot be performed, hence, I have laid it down as an operative law that if the tread of the foot cannot be preserved it is best to sacrifice the entire foot and perform Pirogoff's operation, at all events if natural walking and a naturally shaped foot is required after the operation.

Following this rule of eourse means sacrificing the ankle-joint, but if the perfect base with its tread cannot be saved then the ankle-joint is of no further service and may go too, as I will now show.

For the foot, when resting on its tread and bearing the weight of the body prior to leaving the ground, is, as everyone knows, a lever, and as such must possess the essentials of all levers, namely, fulcrum, weight, and power. The ankle-joint (which has been fully gone into) is the fulcrum, the tendo Achillis embodies the power, while the tread of the foot is that through which the weight is borne. If any of these three are lacking the triple combination is gone, and the lever no longer exists. If, then, tho tread of the foot has to be removed or is lost the rest of the mechanism is useless, and must be removed and replaced by an artificial reproduction of the whole. And this fact, which is put theoretically here, is fully carried out in practical experience.

The reason, however, that I lay such stress on the tread of the foot and do not consider the tendo Achillis of such paramount importance is this, that the tread of the foot once gone cannot be artificially replaced in a satisfactory manner, while if the tendo Achillis is functionally useless its power can be supplied without having recourse to amputation of the whole triple system, but by merely adding to the unmutilated foot a simple apparatus of the kind used in paralysis of the calf muscles. Therefore, while deficiency of the tendo Achillis is replaceable, loss of the tread of the foot alone cannot be artificially made up by any simple mechanism while the rest of the foot is left *in sitû*. I have several times tried to do this by means of a boot with a stiff tempered steel sole, but without, in most cases, being able successfully to restore the free walking power that is possible with the apparatus used after Pirogoff's operation. The same attempt is made in the Government so-called "Chopart" apparatus (*vide* p. 118) which is used indiscriminately for cases after Hey's, Lisfranc's, and Chopart's operation, and the results are generally of the most unsatisfactory kind. Therefore, I maintain the operative rule I have laid down is a correct one.

This being settled, the next point is what are the essential points to be imitated in constructing the foot of an artificial limb. They are the tread, the tendo Achillis, the ankle-joint (which has been considered), and one other minor matter which I will presently allude to.

The tread, although of such importance to the natural foot, is in an artificial foot very easily imitated. The old-fashioned plan of imitating the tread used to be to construct a hinge-joint across the foot with its axis at the heads of the metatarsal bones. This is utterly unnecessary, as a leather sheath, having the shape of the front of the foot, and being firmly stuffed with cotton-wool, gives a very perfect tread, which possesses both firmness and springiness, and adapts itself completely to the surface walked on as the foot leaves the ground.

In imitating or representing the **tendo Achillis** it must be fully understood that in ordinary level walking it, together with the muscles of the calf, only acts as a strong check ligament to prevent the body pivoting forward on the ankle-joint beyond a certain point. When that point is reached, then it comes into play as a check and the lever system of the foot just alluded to is brought into force. In its action as a check ligament in this lever system, it has to bear a strain which is easily calculated to be about three times the weight of the entire body, or about 450 lb. at each step. The muscles of the calf only passively support it in this duty in ordinary level walking. In running and jumping, of course, the muscles of the calf are brought into forcible and rapid exertion, but as muscular force cannot as yet be imitated, so *natural running* and jumping cannot be reproduced with an artificial limb (with some few exceptions). On the other hand, *natural walking* can be perfectly imitated.

The other minor point also in the imitation of the foot that has to be recognised and provided for is that when the natural leg is being swung forward the toes or front of the foot are raised so as to swing clear of the ground. This is done in the natural leg by the front muscles of the foot, which are not particularly strong ones, and when these chance to be paralysed the toes scrape the ground at each step. The same scraping of the ground would take place in an artificial leg unless some provision was made for imitating nature and raising the toes. This is easily done by a very light elastic or by a spring so placed that its force is expended in lifting the front of the foot when the leg is swung forward and the foot is relieved from the weight of the body.

From what has been said then it will be seen that to imitate artificially the natural foot there must be an imitation of the tread in the way given, and there must also be some powerful check (whether a catgut check ligament representing the tendo Achillis, or any other form of check) capable of standing a strain of at least 450 lb., and there must be a light-elevating power to raise the toes when the artificial limb is swung forward.

The heel was stated while discussing operations to be one of the prime essentials of the lower limb, and it is so from an operative point of view, because of its tolerance of pressure, *it being the only point in the entire lower limb on which the whole weight of the body can be taken, excepting the ischium ;* and, as will be presently seen, if the heel cannot be preserved, the artificial limb must be carried right up to the ischium to receive through it the weight of the body. From an imitative point of view, however, the heel is of no importance, it is easily reproduced as part of the artificial foot.

The parts I have just described constitute, in conjunction with the true bony substantial structural union between them, are the essentials, and the sole essentials, of both a natural or artificial leg for ordinary walking. I will now proceed to the actual appliances themselves in detail and to give cases which exemplify their use.

The Appliance for loss of Toes.—The loss of a phalanx of any particular toe does not require any attempt at functional or formal replacement to be made, seeing that the tread of the foot is not interfered with; and the same may be said, though to a less degree, even of loss of entire toes at the metatarso-phalangeal-joint. The great toe, however, which to a large extent plays a part as an accessory in the tread of the foot, must be excluded from this assertion, and it not infrequently happens that entire loss of the great toe incapacitates the patient from proper walking, destroying the right elasticity and grasp of the tread as the foot leaves the ground in walking.

Going further, the metatarsal bone of an outer toe may be removed without destroying the tread of the foot, but removal of that of the great toe will probably destroy the tread. Removal of all the toes at the metatarsophalangeal-joints will entirely destroy the tread, and therefore, following the rule I have previously laid down, it is better to perform a Pirogoff than to trust to leaving a useless remnant of the foot which is incapable of fulfilling those duties which the foot as a lever does. Or, in other words, wherever the natural foot cannot be preserved in such intactness as to act perfectly as a lever (of which the tread, ankle-joint, and tendo Achillis are respectively representatives of weight, fulcrum, and power), it is better to excise it and replace it by an artificial lever with correct representatives of these parts. I can only repeat what I have before said,

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FIG. 9 represents the form of boot with a tempered steel sole plate between the leathers of the ordinary sole, which can sometimes be successfully used in cases of amputation of the toes, and partial destruction of the tread of the foot.

FIGS. 10 and 11 show a better appliance for similar cases, Fig. 10 being a sketch of its appearance, and Fig. 11 a diagram of its principle.

FIG. 9.

FIG. 10.

FIG. 11.

that though such a rule runs counter to all the more conservative ideas of surgery, still it cannot be doubted that it is a correct one mechanically considered.

As, however, cases constantly arise in which the tread of the foot has been rendered functionally useless either by intentional or inevitable operation, I will consider briefly what appliances can be schemed to ameliorate the walking powers under such circumstances.

The problem then offered is what means can be adopted to give an artificial and auxiliary tread to a foot in which the natural tread has been, not entirely removed, but partially injured. The simplest of all methods is to apply a laced-up boot with a steel spring-tempered plate inserted between the two leathers of the sole, and this may answer tolerably well. In a case I recently had under my care, where the great and second toe had been removed, leaving a somewhat sensitive cicatricial covering at the point of amputation, this method answered perfectly well (Fig. 9). The explanation is that when the weight of the body came on to the tread of the foot, the stiffened, springy elastic steel plate forms an artificial and supplementary tread which diffuses the pressure to the other remaining toes, and prevents it coming with pointed acuteness on the tender surface that covers the spot of amputation.

Quite as frequently as not this simple plan fails, and then a more complete attempt to restore lever power to the foot has to be made. The appliance by which this is done is shown in Fig. 10.

It consists of a steel band round the calf strapped in front of the leg, and attached to two lateral rods which run down the sides of the limb to the boot, where they terminate in a steel plate which runs the entire length of the sole between the outer and inner sole of the boot. These lateral rods are jointed at the position of the natural ankle-joint, and the joints further are of the kind known as "stop-joints," that is, they are so arranged that they only allow movement within certain limits, and when further movement beyond these limits is attempted the entire rod above and below the joint becomes rigid. This form of joint is well known as the common rule joint. There is further a false tendo Achillis made of trace leather, which reaches from the heel of the boot to the calf band of the appliance, and which can be tightened at will. A glance at this appliance will show that it aims at supplying all the elements of the lever represented by the natural foot, and as a matter of fact it supplies even beyond what might be expected to be wanted.

For the calf band of the appliance gets a firm hold on the natural leg, while the lateral rods become virtually artificial tibia and fibula. When the leg then in walking is pivoted at the ankle, the joints in the lateral rods allow the pivoting until the tibia becomes perpendicular over the ankle-joint, at which point the stops of the joints check further movement. The result of this is, that as the body continues to move forwards on the leg, the pivot of motion is no longer at the ankle but at the tread of the foot, and at this point the strain is borne by the metal plate between the two layers of the sole of the boot, and consequently no pressure or bearing is taken on the mutilated tread of the natural foot, which lies thus protected within the boot. As a greater security, and to soften the sudden jar on the stops of the steel joints, the false tendo Achillis comes into play, and being of somewhat elastic trace leather gives that elasticity and spring of tread that the tendo Achillis does in the case of the natural uninjured foot.

This form of appliance is a most valuable one, not only for the cases under consideration, but also for those injuries to certain portions of either the ankle-joint or any of the tarsal joints which render strain on the foot beyond a certain point injurious. I have several times used it for cases of excision of some of the bones of the tarsus, in which instances it is of service for similar reasons. It is, in short, a kind of external artificial foot which in great part performs the duties and bears the strains that fall on the natural foot in walking.

Its disadvantage is that, being put outside and over the natural foot, it takes up room, and is therefore unsightly. Of course it is concealed by either trowsers or dress, still it has not the advantages of the appliance used after Pirogoff's operation, which does not show at all, so that the foot can be exposed in a dress sock below the trowsers without any evidence of artificiality being presented.

Appliances for amputations about Foot and Ankle.—I now come to the appliances used after the various operations which remove the whole or the greater portion of the foot (Hey's, Lisfranc's, Chopart's, Pirogoff's and Syme's), and as these appliances are all identical in principle and vary only in details of construction, I will consider them together generally before taking each separately.

In each appliance a leathern sheath, accurately moulded to a previously taken cast, invests and closely fits the leg up to the tuberosities of the tibia. In each appliance also an artificial foot constructed with all the mechanical elements of the natural foot is appended by means of lateral rods to the leathern sheath. In each appliance further the bearing is taken by the end of the stump resting on the bottom of the leathern sheath, and in no case can the stump end be considered of any other use than for the purposes of bearing. The more tolerant, therefore, the stump end is, the better the power of bearing will be; and other things being the same, the more room that is left below the stump end for mechanism the greater will be the opportunities for perfectly, strongly, neatly, and unconspicuously appending the artificial mechanical foot.

Now, with respect to the tolerance of the stump end and its capacity for bearing the weight of the body, that which is left after Pirogoff's operation is indubitably the best, for even with the bare and uncovered stump "patients can run" (Erichsen); or to put this into other words, can bring the stump end into rapid, repeated, and forcible contact with the ground, without suffering injury thereby. And this cannot be said of the stump ends left by the other operations under consideration; indeed, in those operations in which the ankle-joint is left intact (Hey's, Lisfranc's, and Chopart's) and in which the tendo Achillis is liable to contract and to throw down groundwards the anterior tender scarred portion of the stump, rendering it the initial point of bearing, pressure often is very badly tolerated, if at all.

Next, with respect to the room left for the mechanism of the foot, a glance at the accompanying sketch will show without further comment the advantages of the Pirogoff and Syme's, and the gross disadvantages of the other operations, and although the Pirogoff stump is longer than the Syme's

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FIGS. 12, 13, 14, 15.—These figures are diagrams to show the amount of space left for mechanism within the limits of the natural limb, after the various amputations about the foot, exhibiting, even from that point alone, the advantages of a Syme and a Pirogoff over a Chopart and a Hey. The respective figures are Fig. 12 Hey, Fig. 13 Chopart, Fig. 14 Pirogoff, Fig. 15 Syme.

Fig. 12.

Fig. 13.

Fig. 14.

Fig. 15.

"to the extent of the thickness of the portion of the os calcis left in it," still it is not so long as to in any way interfere with the mechanism of the artificial foot.

It will therefore appear as the result of the above reasoning that the best appliances could be made after Pirogoff's and Syme's operations; while great difficulties lie in the way of those that have to be constructed after Hey's, Lisfranc's, or Chopart's operation. And this is proved by practical experience to be the case. Now, although the appliances after any of these operations are constructed on similar principles and in similar manner, still they fall into two kinds. In the one (Pirogoff and Syme's) the facilities for construction are so straightforward that both the form and action of the natural foot can be easily reproduced. In the other (Hey's, Lisfranc's, and Chopart's) construction has to cope with the greatest disadvantages, seeing that the mechanism has to be distributed *round* the useless relic of the natural foot, and consequently the size of the appliance must exceed that of the portion of the foot which lies within it. In both instances perfect walking power is secured only at the sacrifice of shape in the one case, whereas in the other, shape is perfectly secured.

The Appliance used after Hey's, Lisfranc's, and Chopart's operations is in artificial leg construction known generically as "a Chopart appliance." While treating of the Government appliances I shall describe a "Government Chopart appliance;" this is, however, made only to crude measures and on the crudest mechanical principles, and this is necessitated by the fact that the wearer is neither seen nor fitted by the constructor. The "Chopart appliance" now under consideration is quite different, and consists of an accurately fitted leathern sheath investing the leg as high as the tuberosities of the tibia, which it embraces. This sheath is moulded on a cast previously taken of the leg and therefore fits absolutely, unless intentionally loose over some tender spot which is intolerant of pressure. It is laced down the front of the leg and consequently can be made to hold with any desired power. In it the leg reposes, taking its bearing, while standing, principally on the end of the stump, but if this be tender then in great measure on the tuberosities of the tibia, especially on the inner one. On each side of this leathern sheath is attached a steel lateral rod, which terminates in a stop-joint (of the kind previously described) at the position of the axis of the natural ankle-joint. By this joint the sheath is connected with the foot mechanism. The artificial foot consists of a sheet steel foot-sheath enveloping but not touching the leather investment of the remnant of the natural foot. To this steel foot-sheath are attached two short lateral rods which meet the lateral rods of the leathern sheath at the stop-joints previously referred to; while to the front of the steel foot-sheath is attached a representative of the fore part of the foot either of wood jointed across the tread or of stuffed leather. The whole appliance is completed by a strap representing the tendo Achillis, which in walking takes the strain off the stop of the stop-joint; and by a light elastic mock muscle to raise the toe portion of the artificial foot in walking and so prevent its catching the ground at each step.

From this description it will be seen that the remnant of the natural leg has to be invested with mechanism which, no matter how lightly constructed and how closely fitted, must take up a certain amount of room, so that the artificial foot, being built up round the remnant of the natural one, must be larger than natural. Further, since this mechanical investment passes underneath the remnant of the natural foot, the length of the injured leg must be proportionately increased, necessitating a compensatory increase on the height of the boot on the sound foot, and it is obvious that this superfluous length of the injured leg may even be greater still when the fact is borne in mind that with these stumps the tendo Achillis often contracts, pointing down the fore part of the remnant of the foot as in talipes equinus.

Lastly, special provisions have to be sometimes, nay often, made for the extreme tenderness of the stump where the flaps of operation are hyperæsthetic, or the tender seam of union lies so as to be involved in transmission of the bodily weight through the stump in walking.

When the difficulties of making such an appliance have been conquered walking is perfect, but the difficulties and drawbacks are often so great that when these, together with the unnatural bulk of the foot, are borne in mind, I can only reiterate what I have previously strongly maintained, that it is better to have recourse to those operations which I will next consider.

The Appliance used after Pirogoff's or Syme's operation is one of the most perfect in the range of mechanical appliances. It consists, as the last one did, of a leathern investing sheath laced to the leg as high as the tuberosities of the tibia; as the last, also, it has steel lateral rods terminating at the position of the natural ankle-joint in an artificial ankle-joint. This, instead of having to consist of two slight lateral joints on the small central rivets of which all the strain and wear and tear comes, can be carried right across the breadth of the ankle. Seeing that the natural ankle has been removed, and consequently the space it occupied is free when this is done, *a steel bolt between two and three inches long works in a leather bushing*, and a joint is thereby formed which presents a very large surface for the sustenance of weight, and is therefore most durable on this score alone, to say nothing of the advantages gained by the working of steel against leather, instead of steel against steel. The joint is also provided with the necessary stops, both by a front stop constructed between the artificial ankle and its foot, and also by a false tendo Achillis, so that the great strain which falls on the ankle when the bodily weight comes to be borne by the tread of the artificial foot in walking is most fully provided against.

The foot itself is constructed of light woodwork. This foot can be made of exactly the same size and shape as the sound one, all the mechanism being easily kept within these bounds. Hence, with this form of appliance the greatest durability is attained, together with perfection of shape, and exact mechanical performance of the act of walking. It is indeed the most excellent appliance that could possibly be made, because every condition that is required to be fulfilled to obtain perfect walking is fully attainable.

That such is so may perhaps be exemplified by the following instance:

Mr. F. G. R— on landing at the docks had his foot accidentally crushed by one of the small engines in use on the quay. He came under the care of Mr. F. M. Corner, of Poplar, who in October, 1881, wrote to me:

MANOR HOUSE, POPLAR, E.

DEAR SIR,

Will you kindly look at Mr. R— and devise something for the stump of Bush's modification of Pirogoff? There are a couple of sinuses, but I think with gentle exercise they are more likely to recover than by disuse.

I shall feel obliged by your giving him every attention, and

FIG. 16.—This figure represents a man wearing the proper appliance after Syme's amputation: the case is described in the text, p. 49.

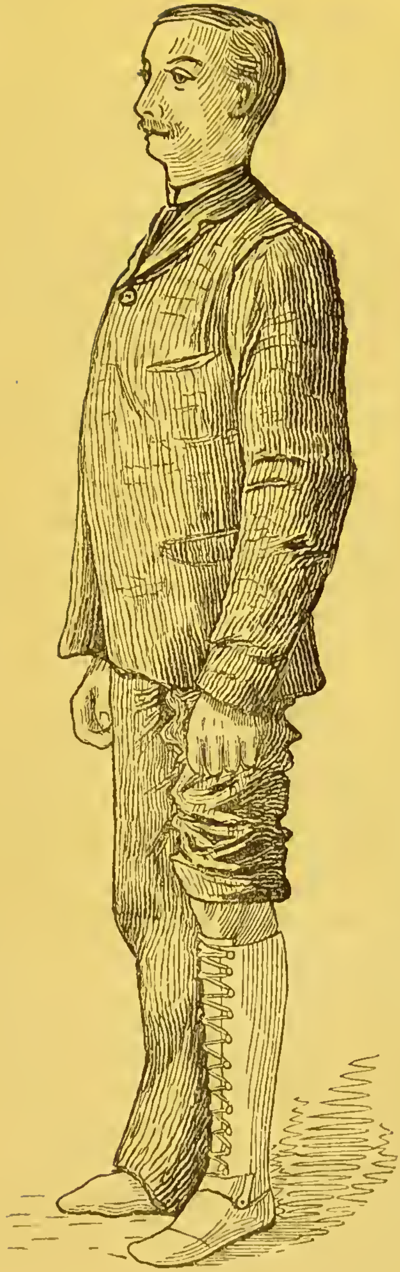

Fig. 16.

scheming him as perfect a substitute for the original foot as possible.

Faithfully yours,
HEATHER BIGG, Esq., C.E., &c. F. M. CORNER.

The appliance just described was put on, and not only proved what can be mechanically done when a perfect stump is presented, but also showed the justice of Dr. Corner's surmise about the healing of the sinuses under use of the part, and the consequent advantage of not waiting too long after operation before applying the substitute. Shortly after, Mr. Corner wrote "I had an opportunity of seeing what you had done and the perfect result. He walked in such a way that I could not have easily told which was the defective side." And it is not beyond the mark to say that all cases after this form of operation should be equally successful.

Fig. 16 is a sketch of a man wearing the appliance for Syme's or Pirogoff's operation. The case is that of one of the wounded in the late Egyptian campaign, whom I saw at the instruction of Surgeon-General J. T. C. Ross, acting for the Princess of Wales's branch of the National Aid Society. The following is the official report of his case:

Abstract of the Case of 2216, *Private F. Fane*, 19*th Hussars* (from detailed Med. His. Sheet).

Gunshot wound; left foot amputated. Came to this hospital on the 22nd inst. from the Nile, where he had his foot amputated owing to an accidental self-inflicted wound of the left foot with a pistol at Gakdul Well. The wound is doing well. He says he shot himself through the foot while cleaning a revolver, a bullet from one of the chambers passing through the foot which was amputated.

R. W. RAWLINGS,
Alexandria, May, 27th, 1885. Surgeon, M.S.

The operation was a Syme, and the man passed through Netley Hospital in the ordinary course, having a very excellent stump, on which he can walk well with the appliance shown.

After a Syme's amputation the appliance is identical, it has the same mechanical elements of success and in very many cases answers equally as well as when it is used after Pirogoff's. The measure of success does not therefore depend on the appliance at all, but on the stump end, and very often, even if at first there is a certain amount of tenderness, this with use of the appliance may disappear, and a most tolerant stump result.

Fig. 16 represents a man wearing an appliance after Syme's amputation.

Principle of Appliances for amputations higher up.—On taking leave of the operations at and below the ankle-joint, there is a most important principle that must be explained; and it is this, *that all other operations higher up require that the bearing of the artificial limb should be entirely taken on the very top of the thigh, and more particularly on the ischial tuberosity or sitting bone.* Experience has shown that bearing cannot be borne on the end of any stump which encloses an operative section of either of the great bones of the leg, viz. femur and tibia.

It is true that in operations through the lower part of the tibia, as I shall mention in dealing with and condemning the Government socket leg (p. 113), attempts have been made to get efficient bearing under the tuberosities of that bone, but although in very exceptional cases such has been found to be possible, still in the vast majority the attempt is a distinct failure, and an occasional and rare exception will not impugn the rule I have laid down.

Again it is also true that after operation through the knee-joint some bearing can be taken on the stump end, there being no sectional or cut surface of the bone left in the stump end, and here again experience has shown that only partial bearing of the weight of the body could be tolerated; in addition to which amputation through the knee has those certain disadvantages which I have already explained.

Hence it may be insisted that in all amputations above the ankle the artificial limb must reach to the ischium or, in other words, must enclose and embrace the full entirety of what part of the natural limb is left from the buttock downwards.

This fact, namely, the necessity of carrying the artificial limb as an ensheathing appendage to the natural one right up to the top of the thigh used to be entirely ignored by the old artificial leg makers, who thought form meant function, and therefore that all that was necessary to be done was to superadd to the remnant of the natural limb the exact portion that was missing : hence the egregious failure of the older artificial limbs for walking purposes. It may be laid down, therefore, as a rule that it is absolutely imperative to make the artificial limb reach to the pelvis,

Fig. 17.

and so to transmit the weight of the body directly from the pelvis to the ground without the intermediation of any part of the remnant of the natural leg, this latter lying within the artificial one, and while to some extent governing its movements, never transmitting the weight of the body, at all events to any appreciable amount.

The Artificial Limb for amputation through the Tibia is the same in construction, no matter at what point amputation has been performed. The tibial stump, however, is serviceable in proportion to its length.

I have given previously the spot at which amputation leaves the most useful stump. If the stump is too long and reaches low enough to interfere with the mechanism of the artificial ankle-joint, it is most inconvenient. If it is too short it is of no use whatever. For the use of a tibial stump is to govern the knee-joint of the artificial limb, and to aid the automatic mechanism of the leg in walking, as well as to flex the leg in sitting. The best length of stump to do this with is one about half the length of the tibia; it should not reach within four inches of the ankle-joint, nor be shorter than four inches, if it is to be of good service. Still there is no difficulty in constructing the artificial limb, no matter what length of stump is left, only in one case the government over the knee-joint will be better than in the other.

The design of the artificial limb for amputation through the tibia is as follows (Fig. 17):

A leathern sheath accurately fitting the thigh extends from the level of the ischial tuberosities, great trochanter, and fork, down to within four or five inches of the knee. To this sheath are attached two lateral tempered steel rods terminating at the axis of the natural knee-joint in eccentric

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FIG. 17 is a sketch representing Pte. R. F. Cooke, and is one of the cases the Queen, on her visit to Netley, took personal notice of. I received Her Majesty's command to see him and to devise an artificial limb which she graciously presented to him. This man, who was in the Army Medical Staff Corps, was shot in the foot when the Arabs surprised a party forming zareba four miles this side of Tamai. After the enemy had been beaten off he was borne into the zareba, his limb amputated half way down the tibia on the following morning, and he was carried in this condition with the other wounded to the base hospital, a journey of some eight hours. He was subsequently on the Ganges for three weeks, and then sent home to Netley. He can now walk most admirably, and is following his trade of paper-hanger, to which he was apprenticed prior to entering the service.

stop-rule joints constructed on the principles laid down (p. 32) as being those of the natural knee-joint. From these joints are continued downwards two other lateral rods, which are attached to the "calf" of the artificial limb. This calf is a thin light wooden sheath loosely encasing the tibial stump, and continuous below into the ankle-joint at which the foot is attached to the leg. The foot itself is of light wood in its heel and hinder part, and of stuffed leather in its fore part.

From the description this may seem to be an extremely simple appliance to construct, but as a matter of fact it requires considerable skill and experience to know how to put these parts into such relationship that walking may be facile and that the artificial limb may be "lively," as it is technically expressed. The line through which the weight of the body is transmitted has to be in definite relation to the knee- and ankle-joints, and these two joints again must have their centres and their stops "pitched" in a manner that cannot be laid down by rule, but which varies in every case, and is only determinable by experienced inspection.

Artificial Ankle-joints.—There is one point, however, that it is worth while entering on now, and that is the differences between the kind of ankle-joint in most general use, and that one invented by my father, and used in what is known as the "Heather Bigg" leg; or, to put it broadly, the difference between a hinged ankle-joint and a ball-and-socket one. Until a little more than twenty years since the ankle-joint of an artificial limb was always some variety of hinged joint, but about 1860 an American leg was invented in which a small marble with five surrounding tendons was made the representative of the natural ankle-joint. A little later my father invented his ankle-joint, which is a modified ball-and-socket joint, and this may be taken as the present perfection of the ball-and-socket idea, while that form of ankle-joint used in the so-called "Anglesea" and other similar legs may be viewed as the perfected hinged joint idea. I am in the habit of using both these joints, since there are some cases suited to one kind and some to others, but there can be little doubt that for facility in walking and for correct imitation of nature the ball-and-socket is pre-eminent.

The hinged joint, no matter with what variations of tenon and mortice it is made, allows motion only in one direction, having only one axis of motion, and the result of this is that there is no adaptability of the artificial foot to any irregularities of the ground. The ball-and-socket joint, on the contrary, admits of this most freely; if a stone or any other irregularity is trodden on, the foot tilts to it just as the natural one does, without in any way tending to disturb the balance of the leg that rests on it. There is another point also, which is this, that in natural walking there is, as a step is taken forward on the natural leg, a certain amount of rotation in the ankle-joints, only small, but still perceptible. This slight rotation cannot take place at the hinged ankle-joints at all, but with the ball-and-socket one it can as freely as in nature. Again, the hinge joint has no "give" in it when subjected to the weight of the body, the ball in the ball-and-socket joint rests on india-rubber cushions, and these yield to some extent, just as the india-rubber buffer does in the Government "pin" legs, and the consequence is that jar and concussion are avoided in stepping.

All these previous points show the superiority of the ball-

Fig. 18.

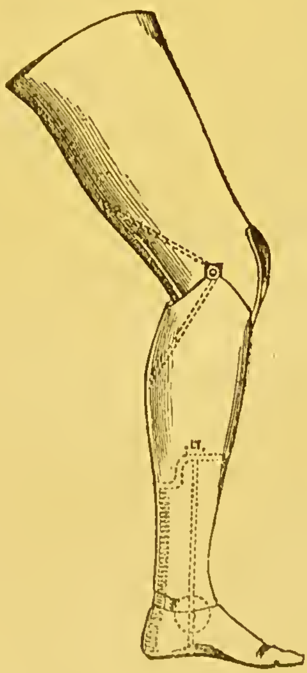

Fig. 18 is a diagram of the "Heather Bigg" leg from 'Orthopraxy,' by H. Heather Bigg, 3rd ed., p. 604; where a full description of its invention will be found and-socket joint, and this is borne out by the experience of those who have tried both kinds.

I do not find fault with the hinged joint; it is good, but in many respects the ball-and-socket is better. The latter does not seem to me to be so durable, but this is to some extent accounted for by the fact that walking being easier on a ball-and-socket ankle, much more walking is done; if three times as great a distance were daily walked with the one, it would be expected to wear out three times as quickly, *ceteris paribus*.

The hinged joint has this advantage, however, that it is made on so simple a principle and of such simple materials that in out-of-the-way parts of the world, where a colonial carpenter or even a man's own ingenuity are all that can be relied on to effect repairs, there is greater ease in setting it right if it breaks down.

Taking all these points into consideration, one may say that for the well-to-do, for those who wish to walk with ease, and as nearly as possible to appear natural, for those that live within accessible distance for workmen for repairs, the ball-and-socket or "Heather Bigg" ankle-joint is the best. On the other hand, for durability and greater simplicity the hinge-joint is best.

With respect to the length of the tibial stump, it is occasionally left so long as to reach almost to the axis of the ankle-joint, in which case great difficulty may be experienced in getting room for the artificial joint. It might at first sight seem possible to adapt to so long a stump the appliance described as used after Pirogoff's operation, but the stump end containing an operative bony section cannot tolerate the bearing, and therefore the leg must go up to the ischium. Perhaps in the future some mode of operation may give stumps tolerant at their ends of the bodily weight; at present it is not so. Length of stump has nothing to do with it, for I have a patient, a case of congenital malformation, whose left leg is normal to the knee, but is abortive below, the part presenting precisely the appearance of an amputation just above the lower third of the tibia. In the stump end are abortive foot bones with a certain play on each other, and on this end she can rest the entire bodily weight with ease. The result is that an appliance similar to the one used after Pirogoff, is, and always has been, worn with perfect results, and there is no necessity to go to the ischium for bearing. If the end had been an operative one no other course would have been open.

Short tibial stumps are particularly inconvenient. They are frequently left so short as to be useless for voluntarily extending or flexing the artificial knee, and can then only be regarded as hindrances. Sometimes they cannot be completely flexed, and at other times they are immoveably fixed at right angles to the thigh by contraction of the hamstrings. In the latter case I usually have the leathern thigh-sheath carried completely over the knee and short flexed stump, the wearer practically kneeling in the thigh-sheath; when this is done a special provision of the calf-piece of the artificial limb has to be made to allow complete flexion of the artificial knee. As a proof of what can be done with a case of amputation through the tibia I will mention one example because it is a very perfect one. Mr. S. D—, an officer in the Royal Engineers, had his foot and ankle shattered by a gun accident a few years since. Amputation was performed very low down the tibia, so low indeed as to render it extremely difficult to get sufficient space for the artificial ankle-joint. He came to me with a very perfect, well covered and well healed stump end, and the entire stump appeared only slightly shorter than would have been obtained by Syme's operation. Following, however, the rule I have laid down, it was found useless to attempt to obtain bearing on the stump end itself because, being a sectional operative surface it would not tolerate the transmission of the entire bodily weight. The artificial limb was therefore carried right up to the ischium and constructed in the manner I have described, what was left of the natural limb being entirely encased in the artificial one. The results were satisfactory to a degree; he could, after a few weeks' practice, not only walk in a way that defied the detection of the injured side, but could also do what is somewhat exceptional, run upstairs quite naturally, or, in other words, could get a spring off the artificial limb. At the expiration of his sick leave, he was examined as to his capacity for performing all his ordinary military duties, and could prove that he was competent to carry them out as well as before the loss. As a consequence of this he still retained his position in his regiment, and is at present on service in precisely the same capacity as any other officer.

The Artificial Limb for amputation through the

Knee-joint is somewhat similar to the previous appliance in construction, consisting of a leathern sheath investing the thigh, of lateral rods, knee-joints, leg, ankle and foot, which need not be described again. The leather sheath, however, forms a complete investment of the thigh and stump end, and the bearing, in addition to being taken on the ischium and round the top of the thigh, can also be borne to a considerable extent on the stump end.

It is worth while, however, to review the operation through the knee mechanically, and to compare it with the operation just above the knee, that is, through the thigh with a long stump. In both cases bearing has to be taken on the ischial circle at the top of the thigh, only in the case of amputation through the knee some of the bearing at all events can be borne on the stump end, while in that above the knee none can be so borne, therefore from this point of view that through the knee is better. But from another standpoint the advantages are reversed. In considering the artificial ankle-joint, I described two kinds (p. 46). The one consisted of a bolt right across the transverse diameter of the limb working in a leather bushing, and this kind of artificial joint could only exist when the natural joint was absent, seeing that unless the natural joint had been altogether removed so as to leave room, it was impossible to put this strong kind of artificial joint, because the latter occupied the position and place of the former. The other kind of joint consisted of lateral rods, with rule-joints which were situated on each side of the substance of the natural limb and its joint; and this kind was necessarily much less durable.

So it is with the knee; if amputation is performed through the knee-joint the whole mass of the lower end of the femur stands in the way of any bolt passing across the limb in the true axis of the joint, for the axis of the knee-joint is at the supracondyloid eminences. Hence, in amputation through the knee lateral rods and rule-joints have to be used. But in amputation above the knee the lower end of the femur is removed, and therefore a bolt-joint can be put in its place and the durability of this bolt-joint is to the rule-joints as 43 to 1, as I have shown (p. 26).

As, therefore, after the supracondyloid operation a much more durable joint can be obtained, I am inclined to think that it is preferable to the operation through the knee-joint, especially in heavy patients whose weight throws great strain on the joint at the knee. Likewise in persons in mediocre positions, to whom the expense of repairs due to wear and tear are a consideration, the supracondyloid operation is best (always remembering that this is looked at from a mechanical point of view).

The beau ideal of operation at the knee-joint would, however, be to amputate through the knee and excise about two inches of the femur just above the condyles. I do not think such an operation has ever been suggested, nor do I give any opinion as to its practicability, but its advantages would be evident, for while, on the one hand, bearing could be gained on the end of the stump, on the other hand, a strong bolt-joint could be used below the shortened bone, and the fullest advantages gained.

If it is considered, such an operation resembles Pirogoff's at the ankle where a portion of the tibia is removed and the tolerant heel surface grafted on to the shaft. In this one a portion of the femur would be taken away and the tolerant knee surface grafted to the shaft.

The Artificial Limb after amputation through the Femur has just been in part described. It consists of a sheath or bucket of thin wood or thick leather (preferably wood as it is more durable), reaching well up to the ischial circle and closely embracing the top five inches of the thigh. This bucket terminates below in a strong bolt-joint, arranged eccentrically and with a "stop" on the principles that have previously been shown to govern the construction of the natural knee. Below the knee the two lateral steel rods that hold the knee-bolt are affixed to the artificial calf, which is continuous inferiorly with ankle-joint and foot of the construction previously given.

The bucket or thigh sheath is generally by preference made of thin wood, because that material has this advantage over leather, that it is much more durable under wear and tear, and is not so liable to injury under the constant damp of perspiration. It is true wood has a tendency to crack, but this is easily prevented by binding the bucket with either a thin copper ring or with stout canvas. The wooden bucket is also more firmly made continuous with the woodwork of the artificial knee-joint. A wooden bucket has this disadvantage, that it has to be more bulky and thick than a leathern one, but as in amputation through the thigh the muscles of the part invariably become wasted to some extent while the opposite sound limb becomes greater through over-use, there is no disparity in size between the two legs even when a wooden bucket is used. As regards weight there is very little difference between wood and leather.

The length of the stump varies in different cases. With a fairly long stump the muscles of the hip-joint are usually perfectly good and competent and have full control over the artificial limb. With a short stump two difficulties are met. The one is that from over-contraction of some of the muscles at the hip an oblique direction may be given to the remnant of the femur, so that instead of its having the normal inclination in relation to the trunk it may point in almost any direction. When this is the case the thigh bucket has to be so hollowed that while the thigh stump reposes in it in an abnormal direction, the artificial limb must nevertheless be set on the body in a true relationship to the trunk, a task which though presenting some little difficulty, is with care generally certain of accomplishment.

Another disadvantage of a very short stump, especially if it be covered with much flabby tissue, is that when the remnant of the femur is swung forward the stump simply works out of the thigh bucket and the artificial limb, instead of following the femur, hangs pendent and useless. This point is met by carrying the sheath well up on the anterior aspect of the stump and by affixing to the top edge of the sheath a pelvic strap which passes round the body in the small of the back and makes the top of the sheath a fixed point in relation to the pelvis. By this plan a very short stump can compel the artificial limb to swing forward and to follow the dictate of the remnant of the femur without chance of the stump slipping out of the sheath. I tried this plan some years since for the first time in the case of Dr. R. J—, of Birmingham, and his report on it after a few days' use was: "I am now able to say that it

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FIG. 19 is a sketch of Pte. J. G. Marshall, 1st Berks Reg., another man whom I received the Queen's command to see, and to whom Her Majesty graciously presented an artificial limb. He was shot in zareba near Suakim, March 22nd, 1885, and the wound dressed by Surgeon Creagh, who made a skilful attempt to save the limb. The man was sent home, but unfortunately hæmorrhage set in and continued on the homeward passage; it was therefore found necessary to amputate after the man's arrival at Netley Hospital. The amputation was successfully performed by Surgeon-Major Codrington, a very excellent stump resulting, to which the artificial limb, shown in the figure is appended. The man walks perfectly.

Fig. 19.

answers the purpose for which it was intended perfectly." Since that time I have often adopted this plan with success.

The Artificial Limb for Amputation through the Hip-Joint is the last one that remains to be described, and owing to the increasing frequency and success with which this operation is now being performed it is one that is much more usually called for than in past years.

In this instance, as with all others, the first point is to get a secure hold on the body by which to append the artificial limb. This is done as follows: A leathern sheath is fitted to a carefully made cast of the tissues covering the point of amputation, and the stiff leather of this sheath is carried well round the pelvis, being strapped over the opposite hip. The hold being thus stably secured, all that remains is to append the necessary mechanism of the leg. A joint is constructed just below the sheath, and as near the pelvis as is possible, having a back stop, but flexing freely in a forward direction. This joint has a spring lock which can fix or free the joint at will; and in ordinary walking the joint is fixed, it only being freed when the wearer wishes to sit down; and this is then affected by touching the spring that governs the locking mechanism. The rest of the limb is of similar construction to those previously described, only that sometimes it is necessary that the knee should also have a lock, which is used in a similar way to that at the hip-joint, that is fixed in walking and freed in sitting.

A limb so constructed gives very excellent walking powers, only it must be distinctly understood that as none of the femur nor its muscles are left, the limb has not the advantage of that bone to govern it, so that the artificial leg has to be swung forward by a lurch of the entire pelvis, an accomplishment which the wearer after a little practice readily acquires. This concludes the description of the artificial appliances which restore the walking power after operations on the lower limb, but there are one or two points left which also relate to this subject.

There is one other point about the construction of artificial lower limbs to be considered, and that is the **method of attachment to the body**.

In the case of those substitutes which have been described as used in operations about the foot and ankle, and which do not extend higher than the top of the calf, the lacing of their sheath round the small of the calf suffices to hold the whole artificial appliance securely to the body.

With the other artificial legs, which extend right to the top of the thigh, some firmer method of appending them has to be adopted. As with the present moot question of suspending clothing, such as trowsers, petticoats, &c., to the body, so with artificial legs; they may either be slung by braces from the shoulders, as Fig. 19 shows, or suspended by some kind of belt or band from the hips. Which is the better plan depends entirely on the case; indeed, it is often not quite possible to say in any particular instance which is most suitable and comfortable till both have been tried.

Where there is a fair waist, and a not over-prominent abdomen, where in short the hips have a shape that diminishes appropriately towards the waist, then a belt accurately moulded to the shape of the hips will afford a very firm hold, and from this belt the suspensory straps can pass to the "sheath" or "bucket" of the artificial limb. With women their ordinary stays, if they fit firmly and accurately to the hips, may be made the medium by which the suspensory straps of the artificial limb take their hold on the body. The method of hanging the limb to the hips has this advantage, that it relieves the spine of bearing a weight which if suspended from the shoulders by braces, naturally is transmitted through the spinal column, and taxes and wearies the spinal muscles. I may say in passing that the same remark applies to clothing, although some hygienic authorities insist on suspension from the shoulders as being the better method, and they do this under the impression that any band round the hips necessarily involves waist-constriction. With a well-shaped form this is not the case, and a pelvic band can easily be fitted to the hips without pressing injuriously on abdominal organs; so that suspension from the hips is certainly the best with weak-backed people.

In cases, however, where the hips are straight in contour and devoid of natural slope, and where the abdomen is portly, and being prominent would be intolerant of the pressure of a pelvic band or belt, it is better to suspend the artificial limb from the shoulders by braces rightly made for the purpose.

Whichever way the limb is suspended, whether from hips or shoulders, the suspensory straps require a great nicety of adjustment both in position and tension, as their arrangement in great degree contributes to the precision and facility with which the artificial limb is swung forward to become the "leading leg" in walking.

Learning to walk with an Artificial Limb is a thing that takes some few weeks to perfectly acquire. The moment an artificial limb is put on the wearer can generally walk at once, but he has to keep his mind concentrated on the limb and on the sequence of actions which give that power, until after some days it is performed mechanically and "instinctively" and irrespective of conscious mental supervision. It is the same with every other locomotive power that involves balance, as skating, bicycling, or dancing. Everyone who dances remembers the time when he began after his first lessons to attempt to guide his partner round the room, and he must recollect that his mind was at first centred on his feet to the exclusion of all other ideas. Finally, however, the act became an unconscious one by constant repetition. So it is with walking with an artificial limb, the movements of which, although automatic, have to take place in ordered sequence before the weight can be confidently trusted to it, and the body carried forward by it. With those appliances used for operations below or at the ankle, and in which a foot only is superadded to the natural limb, the wearer very soon "feels" his way to walking, and "picks up" the power in an hour or so without any tutored movements. But with artificial limbs used for operations higher up, a certain definite set of actions have to be learnt, and they are best graven on the mind so as to become unconscious acts, by counting them as one would a musical bar. They follow in order thus :

1. "Swing the limb forward" to the length of the step and let the heel go to the ground, and let the steps be short to begin with.

2. "Lock the knee-joint" which will not stably support the weight of the body till the eccentric self-locking action of the artificial joint is brought into play just as it has been shown to be in the natural knee-joint.

3. "Bear the weight of the body on the artificial limb and step forwards," an act that is easily performed as it ordinarily is on the natural limb. The sound limb then becomes the leading one, performs its step, and the three actions are performed again by the artificial one. This method of teaching, counting the "one," "two," "three," trains the pupil into proper walking, and it should also be performed at

first, along some definite straight line, as a seam of the carpet, or the line on flooring, because just at first the injured limb has a little lost its power of direction owing to disuse subsequent to operation, and prior to putting on the artificial limb.

It is of the very greatest importance that a patient should learn to walk properly at the very outset, because the first style attained is a very permanent one, and if a wrong habit is acquired it is most difficult to break it. This is one of the reasons why I disadvise what is sometimes done, namely, giving a patient first the ordinary pin leg of the Government type, and telling him to learn to "stump" on this, and then later on applying the actual perfect artificial leg. What happens is that he continues to "stump" instead of walking. Stumping and walking are quite different things, as can easily be verified by watching a Chelsea pensioner. He swings the leg not forward but round, the end describing a kind of semicircle, instead of going directly forward in the direction of walking. If once this habit is acquired it is most difficult to break, and it is quite possible to get into the habit of misusing a perfect artificial limb in this way, instead of going through the three actions which constitute proper walking.

At first two sticks may be used while walking is being learnt, or even crutches if the patient has them, but both these are speedily cast aside, although in the case of a very short thigh stump one stick may be retained as it inspires greater confidence.

I will now describe **the method of taking measurements** for an artificial leg. These consist of two sets, one taken on the sound leg in order to ensure the artificial one being identical in size and length, and the other taken on the injured one in order that the artificial limb may fit it with exactitude. The general mode of proceeding may be formulated into a set of instructions.

For all cases of amputation above the ankle-joint, the artificial limb must, as I have pointed out, reach to the ischium, and the measurements will be taken as follows:

1. Let the patient sit with the limbs denuded of all clothing on a large sheet of thick paper which has been placed on the floor or some other level surface, and let a very careful tracing of both sound and injured limb be taken with a vertical pencil (*vide* Fig. 20, *A*).

2. Let the circumferences of the injured limb be taken,

(*a*) at the fork; (*b*) at the middle of the thigh; (*c*) three inches above the knee; (*d*) at the knee over the centre of the patella; (*e*) three inches below the knee; (*f*) round the calf; (*g*) near the termination of the stump. Those circumferences would all be required in amputation through the tibia, but if amputation be higher, some would naturally be omitted as not existing.

3. Let the circumference of the sound limb be taken from the joint above the amputation on the fellow limb, including the circumference just above the ankle prominences.

4. Let the sound foot be placed flat on the paper and a tracing with a vertical pencil be made of it (Fig. 20, *C*).

5. Let the shoemaker's measures of the sound foot be taken, viz. round the tread, instep, heel, and ankle (Fig. 20, *B*).

6. Let the patient stand upright on the sound limb and let the vertical measures be taken (*m*) from the fork to the ground, (*n*) from the foot to the end of the stump of the injured limb.

7. Let the patient sit on a chair and the knee of the sound limb be flexed so that the tibia is at right angles to the femur, and let the vertical measures be taken of the upper surface of the knee to the ground, and from the under surface of the knee to the ground (Fig. 20, *D*).

8. Let all the measures be taken on the nude limbs.

9. Send a boot that is the fellow to that worn on the sound leg.

In addition to the measures a cast of the stump taken in either gutta percha or plaster of Paris is of great service though not always necessary.

In cases of amputation at or below the ankle-joint, measurements above the knee will not be required, otherwise the same rule holds good, namely, to take on the sound leg the dimensions of those parts that are missing from the other, and to take on the injured one the accurate dimensions and relations of the stump. Also in all these latter cases a cast of the stump up to the knee is required.

FIG. 20.—This figure is a diagram explanatory of the measurements needed for the construction of an artificial leg, and is fully described in the text.

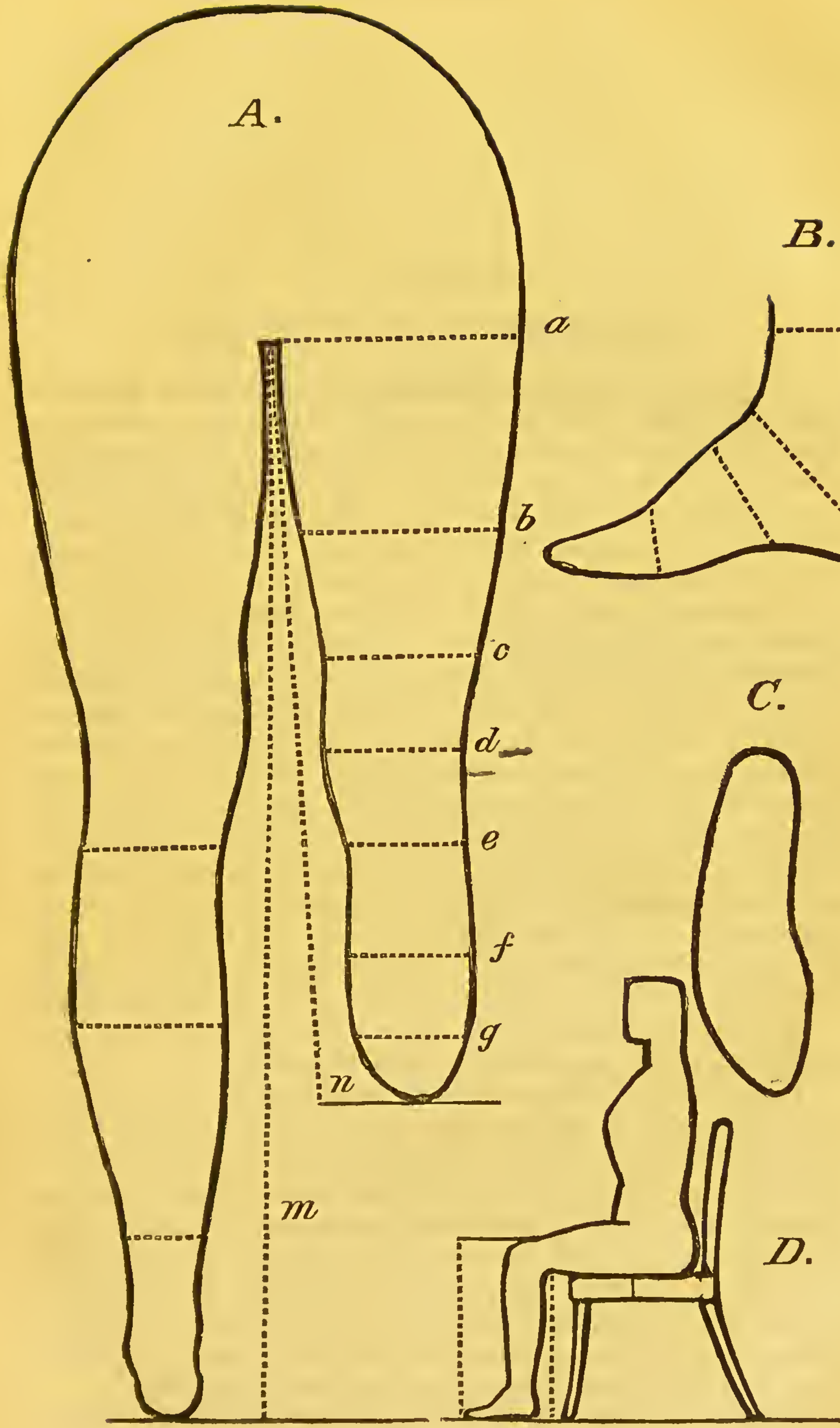

FIG. 20.

CHAPTER IV.

OPERATIONS ON THE UPPER LIMB.

There are several **great differences between the arm and the leg.** The mechanism of the leg is, structurally speaking, entirely automatic, with the exception of requiring those muscles at the hip-joint which swing it forward and steady the body over it, and therefore an automatic mechanical representation is easily produced. The arm, on the other hand, as an organ of prehension, is not in any way automatic, each action requiring voluntary effort and stimulation for its production. Again, with the leg, if one removes a part of it, the mechanical substitute can perfectly restore in action that which is lost, and therefore one can sacrifice liberally and freely a good portion of the natural limb to the exigencies of mechanism. With the arm every part almost that can be saved is of service. Again, the only essential muscular part of the leg has been shown to be the muscles about the hip, and these being at the proximal end of the limb are the last to be lost. The reverse is the case with the arm, as its most essential part as an organ of prehension are the fingers. These are at the distal end of the limb and are therefore the first to go.

Hence, as a general rule, operations on the upper limb should be of the most conservative character.

There is another point of difference also between the leg and the arm, or rather between the foot and the hand, namely, that while the foot is habitually concealed (in this country) by the boot, any addition to it is easily hidden beneath the dress; the hand, however, is more often exposed than gloved, but unless a glove be worn all additions to it are very obvious, for it is next to impossible to get in an artificial substitute a perfect resemblance of flesh, nor even were this possible could the junction between flesh and its representation be completely concealed.

And even differences in the pecuniary position of patients do not entail a distinction between operations on the upper limb in the same way that they are shown to do in the lower limb; the like operative rules apply therefore with almost equal force to both rich and poor.

The correct rules for amputations on the upper limb seem to be much more fully recognised, and further, much more frequently kept to than those on the lower limb. Indeed, this is so much the case that in considering operations on the hand it will be rather a matter of quoting standard authorities than of suggesting anything fresh.

The broadly general rule will be to remove as little as possible, but this consideration has to be somewhat diversified by the value set by different people on appearances as balanced against utility, and also by the station of life which the patient fills.

The **distal phalanx** if bodily removed can always be reproduced by a simple substitute fitted in thimble fashion on to the middle phalanx.

The **middle phalanx** is on this account valuable, and in injury of the terminal part of this bone, if half of it can be saved, the stump, small as it is, will be useful provided the insertion of a flexor tendon is left.

For the next rule I cannot do better than quote Mr. Erichsen's dictum, "Amputation between the proximal and second phalanges as a general rule should not be done; because as no flexor tendon is attached to the proximal phalanx it is apt to remain permanently extended, and a good deal in the patient's way. In the case of the index finger, however, it will be better to leave the proximal phalanx, the stump of which forms a useful opponent to the thumb."

As is well known, an **entire finger** may be neatly removed, and so naturally is the hand used afterwards, and so readily do the remaining fingers accommodate themselves to the loss, that it would be absurd to attempt to replace the missing digit by an artificial one. Hence, when the middle, ring, or little fingers are subject to such injuries as would seem at first sight only to require the removal of the two most distal phalanges, it is perhaps better to remove the entire finger, including the head of its metacarpal bone, than to leave the proximal phalanx standing as a stump on which to adapt an artificial finger. In passing, the recognised rule may be mentioned, that in removing the digit the head of the metacarpal bone is left in the working classes, so as to get the breadth and strength of the hand unimpaired.

With the **index finger** the more that is left the better, and this point applies with even greater force to the **thumb**, so that the rule in both these cases will be to remove as little as possible, especially as appearance and utility can be very excellently restored by artificial substitutes. Indeed, it is rather a common case to have all the fingers gone and a good thumb left, and in these instances a most excellent artificial hand can be constructed (*vide* Fig. 22).

When once the thumb and fingers cannot be saved the hopes of getting voluntary prehensile power from the hand have to be abandoned, although recently I have made experiments towards utilising the muscles of other parts to gain voluntary power over the fingers of the artificial hand, and have had fair success. However, from an operative point of view voluntary prehension may be looked upon as gone, and the next object in amputation will be to save the movements of that portion of the limb that is left, in order that it may be utilised in the commoner acts of everyday life such as eating, &c. For this purpose the action of the wrist-joint, and the movements of pronation and supination in the forearm, are most important. In order to keep for the artificial hand the movement of the wrist-joint, as much of the **carpus** and **metacarpus** as possible should be preserved, as these parts do not in any way interfere with the mechanism of the artificial hand, and the latter is easily built up in a sightly manner round them, so that they are ensheathed in the body of the substitute.

Next in cases that arise where the **hand** has entirely to be removed, **operation through the wrist-joint** gives this good result, that pronation and supination are left. It is especially in the act of feeding oneself that those motions are requisite, since to bring food from the plate to the mouth by a spoon or fork which is fixed in the artificial hand it is necessary to turn the point of the spoon or fork towards the mouth as the arm is raised, and on this account alone the amputation through the wrist is to be commended in preference to one higher up. Quite recently I had a case of double amputation after a machinery accident, in whom in one limb the operation had been performed through the wrist-joint, and in the other limb about an inch or so higher, and this gave me an opportunity of comparing the usefulness of artificial hands adapted to either kind of case, and there can be no doubt that the operation through the wrist is the better mechanically considered. In amputation through the wrist it is wiser if possible always to attempt to completely cover the bone ends with a palmar flap, as this is composed of stronger, tougher, and more tolerant tissue than that of the back of the hand which covers the bone when the dorsal flap is adopted. I need scarcely add that it is also wise to spend a little time in freeing and shortening the nerves, as if this is done it obviates difficulties which may otherwise arise when an artificial limb is afterwards fitted to the stump.

If amputation has to be performed higher than the wrist, and pronation and supination cannot be saved, then it is better to operate two inches off the wrist so as to leave ample room for an artificial wrist-joint whereby flexion and extension and pronation and supination movements can be given to the hand, although not voluntarily. The rule with the **forearm** will therefore be to amputate as low as possible down to two inches off the wrist-joint. Even the shortest forearm stumps are serviceable, since the flexor and extensor muscles are inserted so high up the bones that a very small forearm stump will give voluntary control over the elbow-joint of the artificial arm. It may be mentioned that in amputating low down the forearm particular care should be paid to trimming the bones, and to shortening the nerves, as at this part there is very little fleshy covering to be obtained for the stump, and extreme tenderness of the stump end is very common unless these precautions are taken.

When no forearm stump can be preserved, amputation **through the elbow-joint** is not open to the objection that was urged in amputation through the knee-joint. In considering the latter point it was explained that there were two kinds of mechanical joints given to artificial limbs, one kind in which there were lateral rods along the sides of the limb, and the other kind in which a more solid bolt-joint involving the entire diameter of the limb was employed. For the wear and tear of the leg, the bolt-joint is eminently suitable, but it could only be applied if several inches of the lower end of the femur was removed to leave room.

But with the elbow-joint of an artificial arm, the rule-joints and lateral rods are amply strong enough, hence there is no actual objection to the operation.

Amputation **through the upper arm** or humerus should always be performed with a view of leaving the longest possible stump for the control of the substitute. Unfortunately the upper arm stump is never very strong even at the best, the biceps and triceps being severed in amputation and their control over the shoulder being thus largely lost.

Finally, in amputation **through the shoulder-joint**, although an artificial arm can be adapted, it is really only a pendent representation of the form of the natural one, and has very little actual use other than the restoration of appearance and the prevention of that curvature of the spine which invariably follows the disturbed balance of the body that ensues on loss of the upper limb.

Before leaving operations on the upper limb I would consider one question, namely, the justifiability of **amputating the arm for deformity**, when there is no call to do so either for injury or disease. Cases do sometimes arise when an artificial limb may be better than a deformed or inefficient natural limb. For instance, some three or four years since a young University man came to me whose right arm had been wasted since infancy, having grown only to about half its natural size, and all its muscles, including those of the scapula, being atrophied and diminutive. The entire length of this arm was only a little over half that of its fellow one; still it terminated in a perfect but diminutive hand with which he could perform various actions such as dressing and feeding himself. Of course its lack of length and its puniness were drawbacks, but what pained him most was that the exhibition of this abortive member was constantly shocking those who saw it, there being something unpleasantly unnatural about it. He likewise wished to go into the Church, and came to me to know if anything could be done in the way of encasing this curious limb in an artificial one of natural form. To do this efficiently I found would be an impossibility, and I came to the conclusion that the only course for him to pursue would be to have it amputated, and I explained to him that some time previously one of the bishops had considered an artificial arm no bar to ordination in the case of an amputation through the forearm, because with the artificial arm all the rites of the Church were shown to be capable of unconspicuous and proper performance.

The course I proposed, however, was counter-advised, and for several months nothing was done. When, however his studies at the University were completed, he made up his mind to undergo the amputation, seeing no other course open to him if he wished to go into the Church. The arm was therefore amputated through the humerus, the part healed well, an artificial arm was applied, and shortly after he was ordained. Whenever I have seen him since he has always expressed himself extremely thankful that the course I proposed was adopted, having been enabled to do all the duties of his profession with ease and decorum.

In a case of this kind I consider amputation perfectly justifiable and other similar instances arise. It is not unusual after excision of the elbow-joint to find an extremely useless arm and hand left, and for the patient to be anxious to have amputation performed. And although at first sight this might seem a mistaken view, still if all the actions possible with the injured arm are carefully and fully ascertained, and are weighed with those that can be performed by an artificial limb, and if the preponderance of advantage is largely on the side of the latter, I see no reason why amputation should not be considered perfectly justifiable, provided of course that it is the patient's earnest wish to have it done. I have recently seen a case at Netley Hospital of this kind where an excision of the elbow-joint had first been performed, and where Surgeon-Major Codrington afterwards amputated at the man's earnest desire, and the results answered his anticipations.

CHAPTER V.

ARTIFICIAL APPLIANCES FOR THE UPPER LIMB.

There are crucial **differences between the upper and lower limb** which affect the possibilities of imitation. I have shown that the natural *lower limb* can be artificially imitated with an accuracy of form and action that is as nearly as possible perfect. The minimum of difficulty is presented in copying it. The natural one is an automatic mechanism; the artificial one is readily constructed on similar lines.

With the *upper limb* it is quite different, and at the very outset many obstacles to perfect imitation present themselves. The upper limb is not an automatic piece of mechanism; down to its extremest detail, it is under compulsory voluntary control, it is ordered in every action, it is governed in every movement. The leg is a hidden part covered by boot and trowser or petticoat; the arm, and more especially the hand, are subject to constant critical inspection. The foot is one simple mechanical lever, the hand and arm are a mass of refined and complicated machinery.

The foot is not used as an organ of feeling, the hand possesses the most refined sensibility of any part of the body and how can this be reproduced?

The leg and foot are only rarely subjected to the criticism of touch by one's fellows, and whether flesh or wood can pass without question; the very first thing a hand is submitted to is to be shaken; it is held, it is felt, it is handled.

There can be actual language in the pressure of a hand, the foot does not speak, it walks, and its formation is walking alone. But how many things are done with the hand! With the hand one feeds, with the hand one dresses, with the hand one writes, and one performs a multitude of the actions of everyday life with the hand.

It can be readily conceived then what a problem it is to produce an efficient artificial arm and hand with anything like an approximate representation of nature whether it be in form, in action, or in substance. Before going therefore into a description of the special appliances used after the various amputations to which the upper limb is submitted, I will discuss generally what can be done towards reproducing artificially tho parts of the upper limb, and how far up to the present time the difficulties have been overcome.

Tho simple reproduction of **form** alone is not so insuperable a matter. The efforts of the sculptor and carver have from time immemorial been directed towards this point, and inanimate form can, as everyone knows and sees, be very admirably imitated. And yet it is no such vulgar task to reproduce the exact and beautiful shape of the human hand. The sculptor who successfully does so receives the encomiums of admiring critics; they profess to see and feel touches of genius in his modelling of the human form. The artificial handmaker (and I speak of tho aproned workman) turns out his work with the expectation of nothing beyond his week's wages and his master's expression of satisfaction, and yet often he does not fall very far short of the artist in his modelling. Notwithstanding this, to reproduce the simple form is the least portion of the task that is set him in attempting artificially to imitate the natural arm and hand. He has to go a great deal further; not only must perfect form be gained but **joint movements** also. He must, in imitation of naturo, put a joint and give mobility wherever it should exist. Flexion of the fingers, wrist, and elbow, rotation of the humerus, pronation, and supination of the hand, all these must have their respective imitations at the same time that exact shape is secured. The methods of doing this I will not enter into now, but will describo them later on when I go methodically through the appliances used after the various amputations to which the upper limb is subjected.

Granted, however, that form has been reproduced and that joints have been put so as to exactly simulate the joint movoments that exist in nature, how are these joints to be endowed with **voluntary movement?** This is the great problem that exists at this moment in the perfect construction of artificial hands and arms, and as yet it must be admitted that it has only beon partially solved, although many attempts have been made in this direction.

The hand and arm perform, as has been said, a large number of movements through the modium of the joint motions just montioned, and in nature all these movements are under the control of definite regulated voluntary power. To gain one single power governable by will has been all that the efforts of mechanical ingenuity have been able hitherto to attempt, and it is evident that even if one satisfactory voluntary power could be obtained, it would of course be dedicated to movement of the fingers, the other motions of the hand and arm being quite subordinate to the one paramount prehensile power of the fingers and thumb. All efforts, therefore, towards gaining volition over an artificial hand and arm have, up to the present, been directed towards getting control over the thumb and fingers, not only because they are the most important portions of the whole upper limb, but also because amputation is more frequent lower down at or near the hand than higher up, and therefore there is a greater call to supply the finger power than any other power.

Now, in the attempt to gain voluntary finger power the most efficient up to the present has been that plan devised by my father, and used so successfully in the case of Mrs. Robertson (*qua vide* p. 98). In this case a catgut tendon was fastened to the thumb, and this tendon when drawn on pulled the thumb open and away from the fixed first and second fingers, while on relaxing the tension of the tendon a spring brought the thumb again into apposition to the fingers and any object intermediate between the thumb and fingers was firmly grasped. These arms, now in the Royal College of Surgeons Museum, can be seen by anyone interested in the subject, and may be taken to represent the most perfect mechanical artificial hands of the time at which they were constructed. With them Mrs. Robertson managed to maintain herself by needlework, and to gain a livelihood up to the time of her death last year.

There still seemed to me, however, that much was yet to be done in the direction of getting some voluntary power to control the fingers. For even with the arms and hands just quoted the spring of the thumb was a constant prehensile force, and was incapable of being modified in strength so that prehension might be either gentle or firm at will. Then the tendon which opened the thumb had to be drawn on by the motion of one of the other joints, either elbow or shoulder, and so the position of the hand when about to grasp any object was deranged by such motions. I therefore experimented with a view, first, of getting a voluntarily variable force for the thumb, and next, of gaining one that could be brought into play by some set of muscles that did not disturb the position of the hand when directed to grasp an object.

The plan that I hit upon and have been in process of perfecting is a simple one and may be termed the hydraulic method. It is as follows: an india-rubber ball filled with water is suspended in the armpit of the wearer, and from this ball a fine india-rubber wire-bound tube passes along the arm to the artificial hand. When the armpit muscles compress the water-filled ball it is obvious that a hydraulic force is generated and can be carried along the tube to any mechanism that may be devised to convert this force into definite action. The mechanism, which merely consists of a piston working in a water chamber, is placed within the palm of the artificial hand and connected with the thumb by a proper tendinous arrangement. The tendinous power thus obtained can be used either to open the thumb against a spring or to close it against a spring, and being worked by the muscles at the armpit can be varied in power at will, so as to be either gentle or forcible. Anyone can see on their own body that compression of an object placed in the armpit can be gained by the adductors of the humerus in nearly all positions of the arm, and therefore the problem of voluntary control, with voluntarily variable power is solved satisfactorily by this plan.

There may be other plans by which this could be done, and although it is taking rather a wild glance into the future, I do not see why with the advance of electrical or other powers, voluntary connection will not be able to be made directly with the nervous system; for the present, however, the utilization of an existing set of muscles to gain power, and the transmission of such power to the hand and its conversion into use at that part, seems to be an appreciable advance on the older method.

The last and only remaining point in the problem of imitating the natural hand and arm, namely, that of **deceiving the sense of touch** of other persons when the hand is grasped or shaken by them, I think I can claim satisfactorily to have solved, seeing that I have carried it out in three cases with perfect success.

The best artificial hands that could be made have been constructed of wood. This could be carved, as I have said, to perfectly represent form, it could be jointed to represent movement, and even prehensile power could be given to the thumb and forefinger, but when touched by a neighbour the sham was at once detected. Sight could be deceived, but touch could not be.

A case arose, however, in my work which led to this last factor of my problem being satisfactorily solved. A young lady, daughter of a distinguished nobleman, had through congenital malformation a hand which was minus all its fingers and a great part of its palm; the thumb, however, remained; she had had the deficiency made up since her childhood by a wooden piece of mechanism which presented every visible appearance of the natural hand, and with which, having a perfect thumb, she could perform naturally all the duties of an ordinary hand. When, however, she reached the age at which she was to be presented, and was to take that position in society for which her rank fitted her, it became obvious that at dances and elsewhere, whenever she gave her hand to anyone, its artificiality would be detected, not only by its woodeny hardness, but also by a point which is equally perceptible, its lowness of temperature (for artificial hands are always cold and below the bodily temperature, and feel, to use a popular expression, as the "hand of death"). Having thought the matter over I tried the following plan: I procured the skeleton of a hand the same size. I then, by a very carefully and beautifully made system of jointing, articulated the various bones quite accurately and naturally. I had them fitted on to a leathern glove-sheath that exactly enclosed the malformed part and then caused a special kind of felted material to be so modelled over the bones that the actual shape of the malformation plus the glove was that of the natural hand, and was a fellow to the one of the opposite side. Nothing remained but to have the contained bones precisely copied in ivory, because there was naturally an irresistible objection to wearing the actual bones of a defunct human being; and when this was done the hand was complete.

The result was perfectly successful. The felt had the exact feel of flesh, it took the temperature of the body, and the bones could be felt through just as they are in the natural hand. When we grasp anyone's hand we do not analyse nor appreciate the various discriminating sensations we experience in doing so. We feel its warmth, we feel its softness, we feel the bones through the flesh, we feel that when grasped and squeezed from its shape, no matter how gently, it instantly resumes it again on relaxation of the grasp. All this we feel ordinarily, and all this was felt with the artificial hand just described. It seemed to the touch to be flesh and bone, it took the temperature of the body and was warm; it had a springy disposition always to resume its shape, was compressible, was elastic; in short, on shutting one's eyes and holding it, it was impossible by touch to distinguish it from a perfectly natural hand. Of course in this case the thumb existed and prehension was easily gained by apposing it to the artificial forefinger. It was, however, so entirely satisfactory that twice subsequently I constructed the same form of hand in two other cases, and each time with complete success.

There is left one other obstacle in imitating an artificial hand, and that is that by no known process can the **texture or colour** of the human skin be reproduced, and therefore the artificial hand has always to be worn under a glove. And even if the attempts that have been made by careful painting and enamelling to gain an appearance identical with that of the human skin had been absolutely satisfactory, there would still have remained the difficulty of effecting a natural-looking line of junction between the artificial skin and the real skin. Anyone who has had any experience in theatricals will know the method of joining a bald-fronted wig to the skin of the forehead, and the manner in which the line of junction is covered with thick greasy paste and the artificial and natural skins are smeared and painted over till a false surface covers both of them alike, and hides their meeting-point. It will instantly be appreciated that this plan of junction would be wholly inapplicable to the hand in everyday life, and if the advanced perfection which stage imitations and deceptions have reached have failed to find any more cleanly and perfect method, it is much to be doubted whether those who design artificial hands will be able to surmount this obstacle. So for the present an artificial hand must always be worn gloved if sight is to be deceived.

I will now enter on the description of the particular appliances suitable after the various amputations on the upper limb. At the very outset there is a distinct peculiarity in their mode of adaptation to the stumps that are left. With the lower limb the weight was transmitted through the appliance, and the first consideration to be thought of was the point of bearing through which the bodily weight passed to tho appliance. The appliances for tho upper limb do not have to transmit weight, on the contrary they have to hang on to the remnant of tho natural limb, and therefore the most important consideration in this case is to secure the point of hold. If I may so put it, the artificial leg is made to bo pushed upon, the artificial arm to be pulled upon, hence the distinction in their modes of adaptation. In taking, therefore, any stump of the upper limb, a proper point of cling for the appliance to take to the body has first to be sought, and this having been secured, the artificial appliance can be built on to it.

Again, since the most conservative of conservative rules should govern operations on the upper limb, and since every portion of the actual natural limb that can be preserved is of service, the stumps that are left are liable to be of every conceivable kind, whereas in the lower limb, as I have shown, an attempt should be made always to gain definite stumps to suit certain prescribed appliances. Or, to put it in other words, *with the lower limb operation should always be made subservient to reconstruction, while in the upper limb reconstruction has nearly always to be subservient to operation.*

In amputation of **one or more phalanges** of the fingers it is frequently necessary to add some artificial part, not so much for utility's as for appearance's sake. This is done by gaining the hold on the stump that is left by means of a leathern or silver sheath on to which a carved representation of the missing part is fixed. The appliance simply fits on to the stump end as a thimble would, and in the glove completely restores the appearance and remedies the defect of the lost phalanx or phalanges.

When an **entire finger** is lost, if the operation has been skilfully performed, there is rarely any necessity to restore the part either for use or for show, as the other fingers usually soon rearrange themselves in such a manner that it is less conspicuous to leave matters as they are than to attempt to apply an artificial finger. With men a gun accident is frequently the cause of a lost finger, and it is common enough to meet with hands that are not at all unshapely after operation, and in which the casual observation of the general world would fail to notice any defect. Still if such a gap is left that the deficiency is noticeable, it is very easy to artificially restore one or more fingers, as far as appearance is concerned.

Loss of parts or of the whole of the **thumb** are more conspicuous, and likewise more serious in their incapacitating effects on the hand, and it is always advisable therefore to attempt to artificially restore what is lost. If the distal phalanx is lost then an artificial one worn thimble-wise on the remaining phalanx will very easily and perfectly restore use and appearance. If both phalanges are gone, a more extended appliance is needed, which is thus constructed. A gutta-percha mould having been taken of the stump left by the metacarpal bone with its thenar muscular covering, a plaster cast is run, and a thin leathern sheath produced which exactly fits the aforesaid stump. A carved wooden representation of the missing phalanges is then modelled on to the leathern sheath, and the whole appliance so formed is held *in sitú* either by a glove or by an extension of its leathern sheath round the wrist. With such an appliance it will be found that owing to the muscular control under which the stump remains, it is easy enough to appose the artificial thumb to the forefinger, and a very useful and shapely substitute is the result.

Great perfection of movement and sensibility can be gained with such a false thumb. Some few years ago a gentleman who was very accomplished at playing the violoncello came to me, having recently lost his thumb through an accident. After several experimental attempts I found it perfectly possible to restore to him not only the power of properly holding his bow, but also of giving all that refinement of feeling and motion that performance on such a musical instrument required.

Loss of all the fingers, the thumb alone remaining, is a very common result of frostbite, explosion, or other accident. Absence of all the fingers congenitally with a similar appearance, is also one of the most common malformations of the hand that one meets with, a good palm being present on which either diminutive, abortive fingers exist, or perhaps only finger-nails indicative of their position (Fig. 23).

The appliance in such cases consists of an accurately moulded leathern sheath (made as usual by means of a gutta-percha mould, and subsequent plaster cast), and on to this sheath the fingers are attached and built up so as to represent in size and position those that are missing. The sheath itself is laced on to the remnants of the hand, and if the palm is bulbous with its big extremity most distal, then the sheath will hold extremely well even if only carried as far as the wrist-joint. If, however, the palm is not of the shape that is capable of being held to by a short sheath then the latter has to be carried up above the wrist-joint and over the prominent lower extremities of the ulna and radius, and the grip or hold is obtained beyond these prominences. The fingers are constructed, as will presently be described in considering the entire artificial hand. The natural thumb becomes the means of prehension, and knife, fork, pen, or indeed anything can be held with perfect power and ease. As I have before mentioned, it was in three cases of this kind that I applied the hand which was really a felt-covered skeleton, and the marvellous success of these three cases was doubtless due to the fact that the thumb existed.

A hand of this kind need not be used in the house, or when the wearer is not being seen, and this remark particularly applies to cases of congenital malformation, in which it is wonderful to see what can be done by the thumb and palm alone, the life-long necessity for using them having trained the parts into most masterful manipulative power.

Loss of all the fingers together with the thumb is not uncommon, and in such a condition there is entire absence of natural prehensile power, and therefore it becomes not only a question of restoring shape, but also of arranging some plan by which the various commoner implements with which the duties of everyday life are performed, can be fixed on to the artificial part, I mean such implements as knife, fork, spoon, button-hook, paper-clip, &c. The description of these implements and their attachment I reserve till a little later (p. 86). The actual artificial substitute itself is constructed on an identical principle with that previously described, namely, there is a thin leathern sheath embracing

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FIG. 23 represents a malformation case in which all the digits except the thumb are absent, and is similar to a case of amputation of the fingers. Fig. 22 represents an appliance adaptable to such a case, being the one described p. 76. Fig. 24 is another malformation case, in which both thumb and fingers are missing, and is similar to a case of amputation of thumb and fingers. Fig. 25 is the appliance used in such a case, and is described p. 80. Fig. 21 is a sketch of the appliance used for amputation through the wrist-joint, and is sketched from the one worn by William Edwards, described p. 83.

Fig. 21.

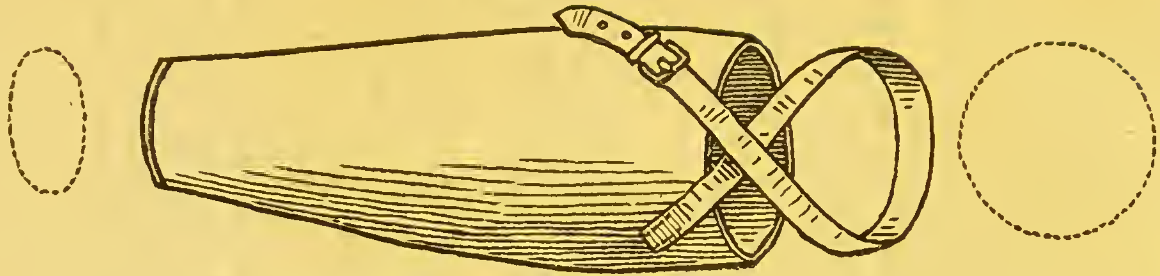

Fig. 22.

Fig. 23.

Fig. 24.

Fig. 25.

the stump, and on this tho missing parts are mado up *secundum artem.* Of courso if there be the metacarpal bone of the thumb left or an abortive thumb, and either of these be capable of giving a positive power to any false thumb to which they may bo attached, then prehension is preserved; but the majority of cases of injury to all tho fingers and thumb entail the loss of everything beyond the palm, and in such a caso of course prehension is gone, and proper arrangements have to be made for affixing when needed the various implements necessary for the common everyday actions of feeding, reading, writing, &c.

Loss of the hand at, or very near, the wrist-joint entails an entire artificial hand. Natural joint movement of course is gone, but sometimes, even with cases of amputation, a slight way above the wrist pronation and supination may be preserved, and I will therefore describo the appliance (Fig. 21) arranged for retaining this power, which is a very important one. This appliance is applicablo to all cases of amputation at or near the wrist, whether it be between the first and second row of the carpus, at the wrist, or just above the wrist. Of course the existence of the pronating and supinating power in the stump is easily determinable by trial, and if it remains the appliance for the case will be as follows:

The forearm is encased in a stiff leathern sheath fitting very accurately except just at its two ends. At its upper end (next the elbow) it is not too tight, as it would then hold to the flesh just below the elbow and prevent the sheath sliding round in pronation and supination. At its lower end it is not too closely fitting as the flap coverings to the ends of the radius and ulna aro generally very thin and intolerant of pressure. Just above the operative ends of the bones, however, it fits accurately, and the section of the forearm at this point being oval, the sheath is carried round by the contained forearm as the radius works round the ulna.

This sheath is attached at its upper end to a leathern band encircling the arm just above the condyles of the humerus, tho attachment between sheath and band being effected by the light lateral straps whoso tension is sufficient to hold the sheath in position but does not check its movements with the bones of the forearm in pronation and supination. Another plan of attachment is that shown in Fig. 21, whero a simple figure of 8 strap suffices to give a perfect hold on the upper arm.

The lower end of the sheath is continuous with the artificial hand, either directly, or with the intermediation of a wrist-plate; that is, the artificial hand is either made a fixity with the sheath, or is removeable at will.

In the lighter class of cases the artificial hand is made continuous with the sheath and is not removeable, and the various instruments for "everyday" actions are fitted into the palm of the artificial hand, and as pronation and supination are left, these instruments are readily guided into the direction that their use necessitates.

In some cases, however, a wrist-plate by which the hand is disconnected from the sheath is desirable, especially where form is not so much thought of as great strength, in which instances the instruments for "everyday" use are inserted directly into the metal wrist-plate that terminates the sheath, instead of into the palm of the artificial hand.

For example, in a case that recently came under my care, amputation had been performed at the wrist-joint of a commander in the royal navy.

For some time after the accident which led to the loss of his hand, he held an official position in which form and shape were of more importance than anything else, and he wore a hand of the kind just described, affixed to a leathern sheath, so arranged as to allow the movements of pronation and supination which remained in the stump of the forearm. Later on he received a commission again to the command of a vessel, and then utility became of greater consequence than appearance, and the substitute he adopted was so arranged that the leathern sheath that encased the forearm terminated below in a very strong wrist-plate, into which he could either insert his artificial hand when appearances were paramount, or could on the other hand affix a very strong hook, when utility was the main essential. On board ship, where his injured hand was required to be utilised in holding to rigging, &c., he used his hook, which was of such strength that he could hang bodily by it although a very stalwart and heavy man. His quadrant and other nautical instruments were also arranged to fit into the wrist-plate at will. And I quote this case to show that a substitute can be arranged so that it may at one time subserve one object, and at another time another.

Another equally interesting and instructive case is that of William Edwards, at present in employment in the Royal Arsenal at Woolwich. He, while planing in the carriage department in March, 1875, had his hand caught between the tool of the machine and the lug of a gun trunnion on which he was at work. The hand was completely cut off across the palm by the accident. Dr. Maunsell amputated the remains of the shattered carpus and with such neatness that not only was the stump ready for an artificial limb within two months, but a good firm pad was left covering the bone ends. Within three months he was at work again with the appliance shown Fig. 21, into the wrist-plate of which an artificial hand fits for show, and this he scarcely ever uses; while the various implements he employs at his work also fit the same wrist-plate, and enable him to continue making his living just as he did prior to the accident. At present (October, 1885) he is engaged on one of the largest planing machines in the arsenal.

Amputation through the forearm entails a further appliance than that just described. There being no voluntary wrist movement, and no pronation nor supination of the forearm, the great point with this appliance is to gain as perfect and as powerful elbow movement as possible. With a long or medium forearm stump this is easy enough, but the shorter the stump the more difficult it becomes to cause it to govern the elbow-joint of the artificial arm with any great degree of strength. Still, as the biceps and triceps are both inserted very near the elbow-joint, even the shortest stump to which these muscles can be left connected is of some value, and should be if possible preserved in operation. The appliance is shown Fig. 26. It consists of a broad leathern band laced or buckled round the upper arm a little above the elbow-joint. To this band are attached two very light lateral rods of tempered steel, their substance and weight being quite insignificant compared with the steel work used in the artificial lower limb, seeing that the arm has not to transmit weight at all in ordinary everyday life. These steel rods terminate in joints whose axes correspond to the axis of the natural elbow-joint, and from these joints proceed two other lateral rods which are continuous with the artificial forearm. This artificial forearm consists of a hollow leathern sheath, accurately

FIG. 26 is a sketch of the artificial arm for amputation through the forearm, consisting of a laced band above the condyles of the humerus, lateral joints connecting this band with a forearm sheath, at the lower extremity of which is a wrist-plate, into which the artificial hand fits by means of the catch shown, Fig. 27. The various instruments are either fitted into the artificial hand, Figs. 28 and 29, or else directly into the wrist-plate, as shown Figs. 44, 45, 46, 47.

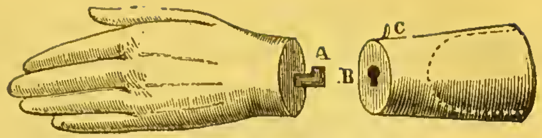

Fig. 27.

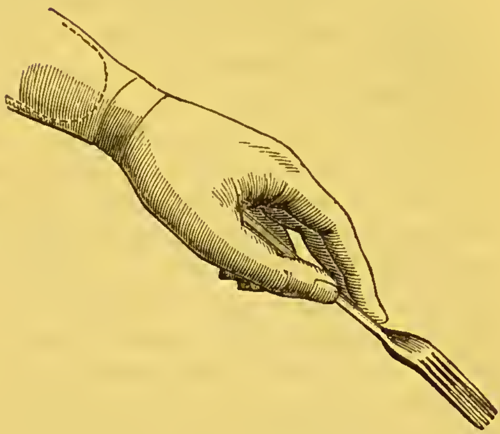

Fig. 28.

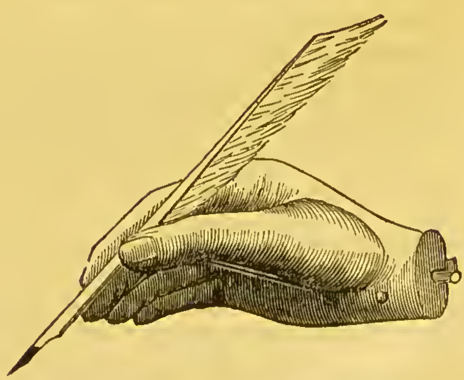

Fig. 29.

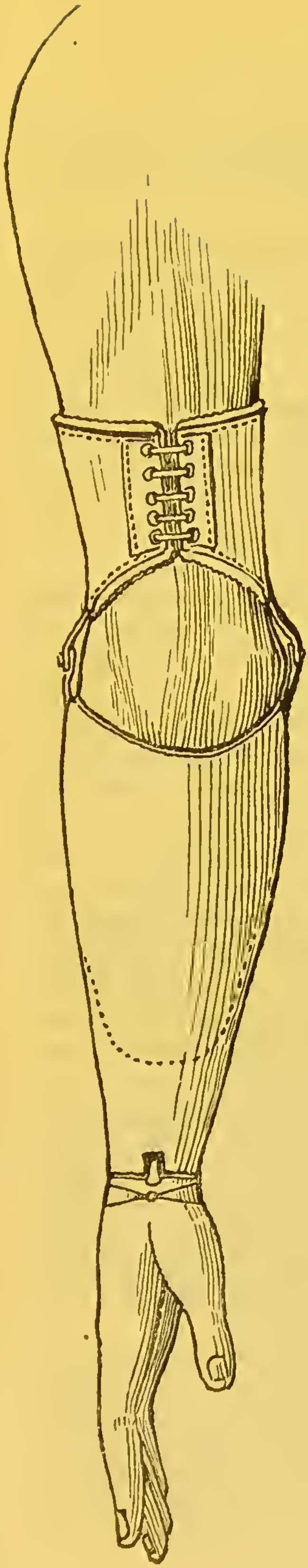

Fig. 26.

moulded by its inner surface to the remnant of the natural forearm, and by its outer surface representing in shape and bulk the fellow sound forearm, and being lightly padded up to do this if necessary.

The forearm sheath terminates in a thin steel wrist-plate, and there is a corresponding plate on the artificial hand, the two plates coming into apposition when the hand is attached to the sheath of the forearm. The method of attachment is simple, as will be seen at Fig. 27, there being a "key-hole plug" (A) on the plate of the hand, and an aperture (B) for the reception of the plug on the plate of the forearm. When the hand is affixed it can be rotated round into any position in imitation of natural pronation and supination, and further there is a small spring pin (C) which fixes it at any particular point that may be desired.

The artificial hand is constructed ordinarily of carved wood, and has wrist- and finger-joints as in nature. The wrist-joint is made to work stiffly so that the inclination of the hand to the forearm can be fixed at any particular angle that may be required for feeding, writing, playing billiards, or other occupations. The thumb of the hand works with a light spring, and comes thereby into apposition with the index finger with an amount of power sufficient to hold light objects, such as a pen, paper, or other things. This hold would, however, be insufficient for many purposes, and there is consequently a provision for affixing to the palm of the hand a **variety of instruments*** according to the hand, whether left or right. Thus there are knife and fork for feeding, penholders, paper-clip, vice, hooks of various kinds, simple hooks for holding or lifting, riding hooks for the reins, billiard implements, either a cue-rest for the one

* The following list extracted from a pamphlet entitled 'Enchiridion,' written in 1822 by Captain G. W. Derenzy, 82nd Regt., who lost his right arm at the battle of Vittoria, shows comprehensively what he found to be of daily service: 1, wash-hand tray; 2, ivory vice with ball-and-socket; 3, shaving box; 4, lead cushion; 5, syringe; 6, nail-file; 7, file-holder; 8, boot-hooks; 9, silver egg-cup; 10, steel egg holder; 11, penknife; 12, quill-holder; 13, pen nibber; 14, ruler; 15, steel vice; 16, hat stick; 17, knife and fork; 18, nutcrackers; 19, card-holder.

On the utility of all of these he dilates with the enthusiasm of an inventor; some of them, however, are superfluous in the present day, while there are others now of service which he failed to think of.

FIGS. 30, 31, 32, 33, 34, 35.—These figures represent the regulation instruments adaptable to Government artificial arms: they are —knife, Fig. 30; fork, Fig. 31; hook, Fig. 32; penholder, Fig. 33; vice, Fig. 34; and paper-clip, fig. 35.

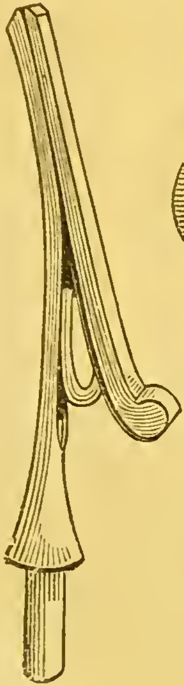
FIG. 35.

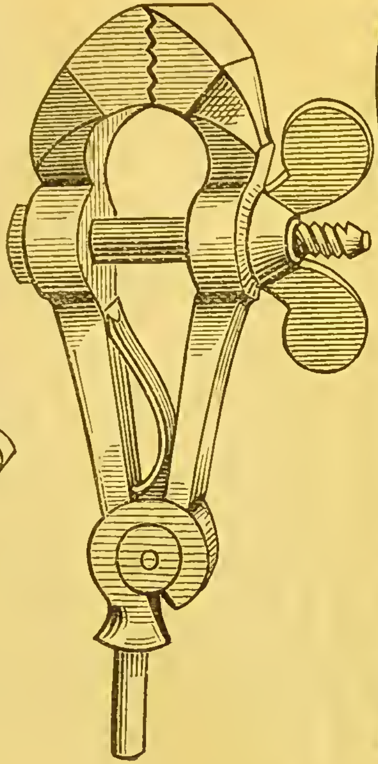
FIG. 34.


FIG. 33.


FIG. 32.

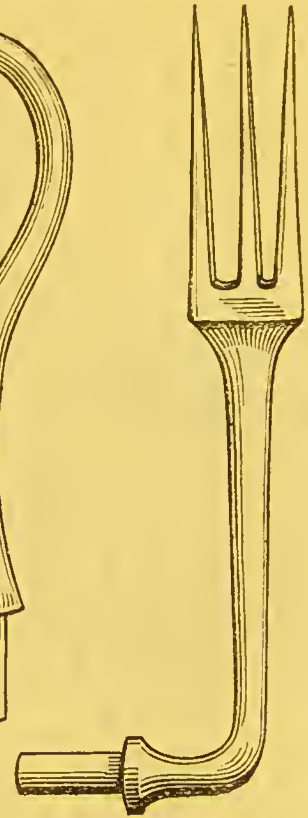
FIG. 31.

FIG. 30.

hand, or a cue-hold for the other, and various other instruments of such a kind as the occupation or calling of the wearer may necessitate. Indeed, at different times during the century various one-armed men have recorded their experience of the implements that they have personally found most useful and advocated similar arrangements being tried by others.

Whatever instruments are attached to the hand, are fixed by one simple contrivance; into the centre of the palm is inserted a small steel "socket," and into this in turn fits a snap plug with which every instrument is provided, and by which each instrument is firmly fixed to the hand in such a position that it may have the appearance as far as possible of being naturally held by the fingers.

Some persons prefer the instruments fitted into the wrist-plate direct without the intermediation of the artificial hand at all; as I have explained before (p. 83), this depends on whether utility or strength is most to be considered.

To this general outline of the artificial arm for amputation through the forearm must be added the details of the more particular parts.

Ordinarily the steel elbow-joints are, if the forearm stump is a good one, left quite free, and their motion or their fixity determined solely by the muscles of the natural elbow-joint; indeed, in such a case the lateral jointed rods, in conjunction with the leathern band round the upper arm, may be regarded merely as the light attachments of the forearm sheath to the forearm stump, holding these two in structural apposition.

Many cases, however, arise in which the forearm stump, although long enough and powerful enough to control the artificial forearm and to raise light things such as a knife or fork, can neither raise nor sustain anything heavier, and yet it may be of paramount importance in the profession or occupation of the wearer that some weight can be borne by the forearm.

For instance, some years since an old Rugby schoolfellow of mine, when on the point of being ordained, met with an accident which necessitated amputation through

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FIG. 36.—This figure shows the artificial arm for amputation above elbow, consisting of a leathern sheath embracing the stump, a rotatory point above the elbow-joint, a hinged elbow-joint, which can be locked at will by mechanism not shown in the drawing. The forearm and hand are of the same kind as that used for amputation lower down.

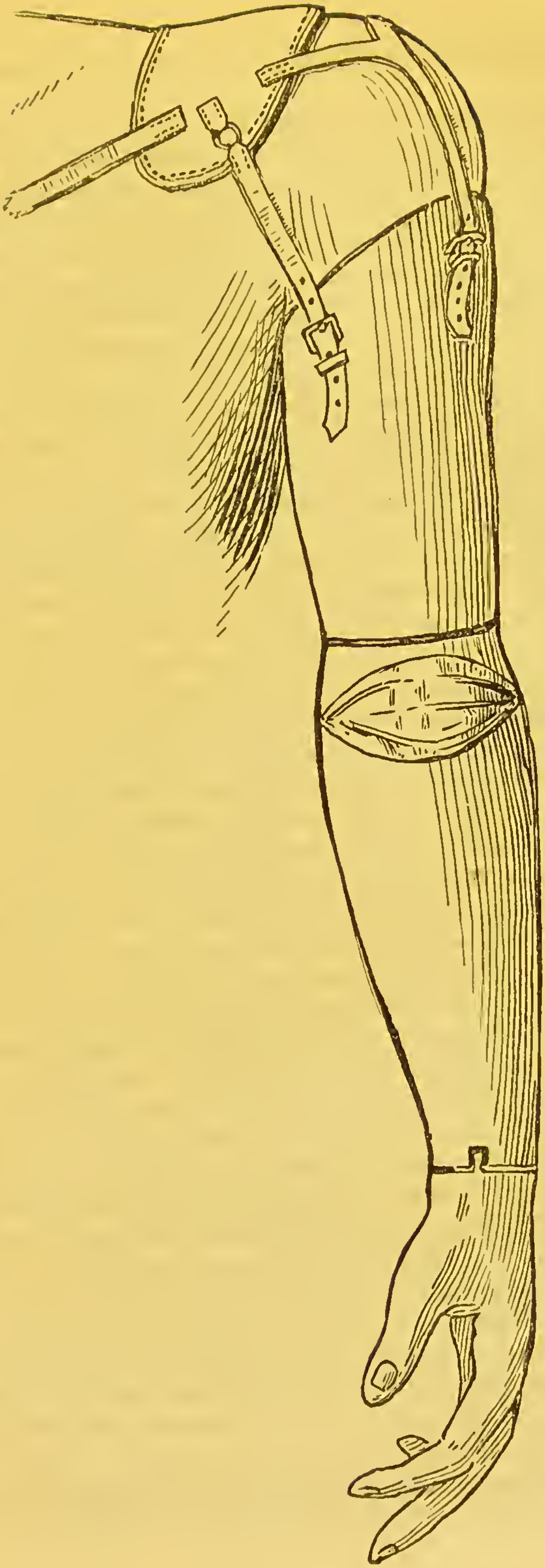

Fig. 36.

the forearm with a very short stump. Having determined what was his vocation, and having pursued all his studies with that view, he found himself cut off apparently from all hopes of following this sacred profession to which he was so attached, because it would have been impossible for him to efficiently perform certain of the rites of the Church, and also because it was contrary to long-established rule and custom that anyone should be ordained who was not bodily perfect.

In this dilemma he applied to several bishops, and at last found one who, with broadly-enlightened views, consented to ordain him provided that he could have natural shape completely restored and could satisfactorily perform various religious rites, among others, hold an infant securely in baptism. To accomplish these points successfully he applied to me, and I had constructed for him an artificial arm which perfectly restored shape, and the forearm of which he had the power of locking by means of a catch at the elbow, so that perfect fixity was attained, and the infant could be safely held in baptism. Further, the hand had such arrangements for prehension that a book or plate or anything else could be naturally and firmly held.

I mention this case primarily to show that the elbow-joints of the artificial arm may require accessory mechanism if the forearm stump is short, but also to show that a misfortune, like the loss of an arm, can be mechanically remedied with, at all events, a perfection that will satisfy the barrier that formerly existed in the way of a man's following a sacred calling, in which perfection of mind rather than perfection of body might naturally be deemed to be the most necessary requirement. And while on this latter point I may allude again to that somewhat similar case (which is described p. 70) where the same bishop did not consider loss of the entire arm a barrier, provided that form and function were satisfactorily reproduced artificially.

The appliance for amputation through the elbow-joint is identical with the one just described, but as there is no possibility of voluntary power over the elbow-joint, the locking mechanism at the elbow becomes a constant necessity. Further, a deeper band is used to secure the hold on the upper arm (humerus); indeed, this appliance intermediates between the previous and the next one, but requires no special description.

The appliance for amputation through the upper arm (Fig. 36) consists of a sheath to receive the stump, of a joint to allow rotation in imitation of rotation of the humerus, and of a special elbow-joint. From the elbow-joint downwards it is nearly identical with the appliance for amputation through the forearm, and this latter part will not therefore require redescription.

The sheath is a leathern one accurately fitting the stump, except just at its lower extremity if this be tender. As the stump itself is often very wasted there, in comparison with the fellow arm, it has frequently to be padded out externally with light felt, in order to proportionately fill the sleeve of the coat. In other respects it presents no peculiarity.

At the lower part of the sheath and an inch or so above the elbow-joint is the arrangement for allowing that rotation which simulates rotation of the humerus. Its construction is similar to that described at the wrist-joint, namely, two very thin metal plates work one against the other on an axis through their centres.

The advantage of such a motion is obvious; for when the elbow is flexed and the hand and forearm raised, the latter can be brought round till close to the body, and a shawl or coat carried over the arm quite naturally.

The elbow-joint, since the natural joint is away, is constructed right across the artificial limb, and is made of wood, this being lighter than metal. It is of the same type as the joints seen in artists' lay figures, and has amply sufficient strength for all the purposes to which artificial arms are ordinarily put. It has also, as a rule, a small spring catch by which it can be locked at any particular angle.

The parts below the elbow are, as I have said, similar to those previously described (*quâ vide* p. 86). There remains only to describe the plan by which the artificial arm is attached to the body, and this is done as follows: a thin leathern pad is placed on the shoulder and held in this position by a leathern strap, which passes from its front edge across the chest under the opposite axilla and across the back to its posterior edge. From this shouder-pad three suspensory straps pass to the sheath of the artificial arm, one being in front of the arm, one behind, and one outside. The hold thus gained is an excellent one, and at the same time allows perfect freedom of shoulder movement.

The **appliance for amputation through the shoulder-joint** is arranged thus. An accurately moulded leathern shield (it can barely be called sheath) is fixed in position by a broad strap passing from its front to its back edge under the opposite axilla. To this sheath is attached the artificial arm, which has a shoulder-joint of the monaxial type, and is continued below into upper arm, forearm, and hand of the construction previously described. Form is perfectly reproduced, and, what is also of importance, a balance is given to the upper part of the body. The utility of such an arm cannot be claimed to be as great as that of those in which there is any portion of the natural limb left.

The **method of taking the measurement** for an artificial arm is analogous to that for an artificial leg, namely, a tracing must be taken of the injured limb to give the shape of the stump, and of the sound limb to give the lengths of the missing parts. On the sound side the elbow is bent nearly to a right angle, the whole limb placed palm downwards flat on the paper, and a vertical pencil run carefully round so as to give its outline. The most convenient position for doing this, after the arm has been bared, is for the patient to kneel on the floor by the side of a table on which the paper for the tracing has been evenly spread out, and then the entire arm is easily placed in position for tracing. While so placed the circumferences are taken and written down on the paper at the spot where the measuring tape is used. The circumferences in order from below upwards are the wrist (*a*), centre of forearm (*b*), just below elbow (*c*), at elbow (*d*), just above elbow (*e*), centre of upper arm (*f*). The lengths are indicated by the tracing. (Fig. 37, *B*.)

With the injured limb the same procedure holds good, only that the circumferences of the stump should be taken at every inch from its end upwards, and likewise any tender spots noted and marked on the tracing paper. Further, a cast of the stump, though not always imperative, is generally necessary, and it may be noted that a mould taken in gutta percha by a medical man is generally more reliable than the cast taken by a professional modeller, unless the latter abstains entirely from "touching up" the cast to give it a good appearance. Such "touched up" casts look very smooth and nice, but having been scraped, cleaned, and consequently altered, are generally useless guides for obvious reasons. (Fig. 37, *A*.)

A glove, the fellow to that worn on the sound hand, is also necessary as a guide where an artificial hand has to be constructed. (Fig. 37, *C*.)

FIG. 37.—This figure is a diagram explanatory of the measurements needed for an artificial arm, and is fully described in the text.

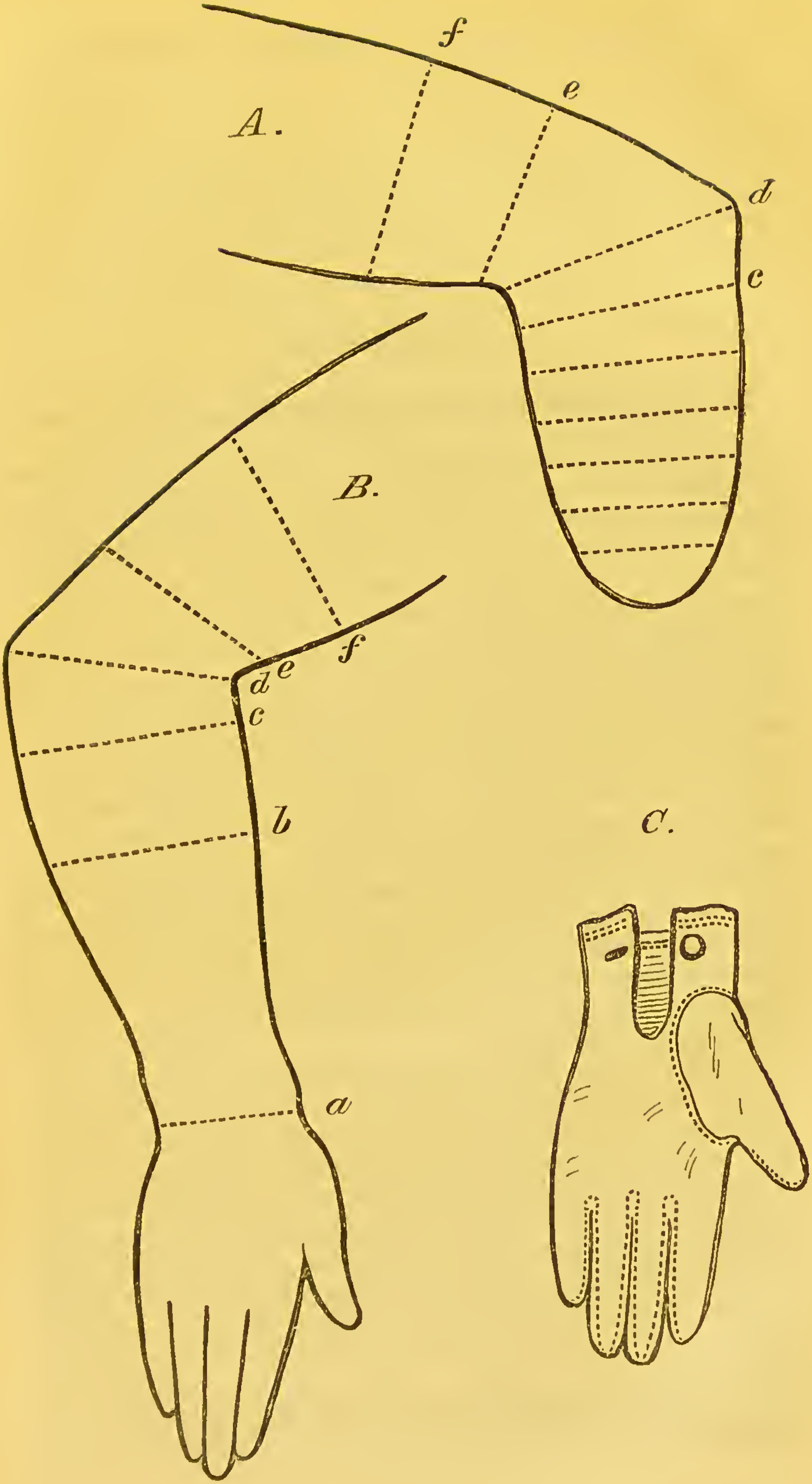

Fig 37.

CHAPTER VI.

DOUBLE, TRIPLE, AND QUADRUPLE AMPUTATIONS.

Cases of double amputation are by no means rare and are generally the result of machinery or railway accidents; the proportion of such cases is greater therefore in civil than in military life. Cases of triple amputation occasionally are met with but are very rare. Of quadruple amputations there is, as far as I know, only one case on record, and it is to this case that I devote the ensuing short chapter, not only because it is unique but because it is in every way instructive. It may be premised that in adapting artificial limbs after multiple amputations precisely the same lines are followed and the same laws kept to as in cases of single amputation; the distinction only lying in the fact that as each separate limb may be considered an element in the helpfulness and activity of the body, so the greater the number of limbs lost the more helpless will the patient become, until it would seem that if every limb was lost it would be impossible for the trunk that was left to be other than a useless mass. That such is not so will be found exemplified in the unparalleled instance of Mrs. Robertson, of Dundee.

A brief *résumé* of her case is as follows:—In 1869, when twenty-one years of age, she was attacked with idiopathic gangrene; her four limbs were amputated; when the stumps had healed she came to London, and my father had constructed for her four artificial limbs. With these she walked and made a living by needlework, and continued to do so until the time of her death last year (1884). I purchased these artificial limbs back again from her friends, and presented them to the Royal College of Surgeons, in whose Museum in Lincoln's Inn Fields they can now be seen.

To give fuller details I cannot do better than quote the notes made on the case at the time. Mr. John R. Begg, of

Dundee, who performed the amputations, gives the following account :*

"Mrs. Elizabeth R—, aged twenty-one, was admitted into the Dundee Royal Infirmary on the 25th May, 1869. She had been delivered of a healthy male child on the 24th March previous. She stated that the labour was a protracted one; that afterwards she did not partake of nourishment proper to one in her condition, and that she therefore remained in a weakly state for some time. She had, however, quite recovered from her confinement, and was following her household duties, when, one day, a little over a fortnight previous to her admission to the Infirmary, she was seized with an itchy sensation in both her hands; this was followed by slight pain, and at the same time she noticed the tips of the small and ring fingers of the left hand become of a blue colour. Previous to this, however, there had appeared a blue spot on the tip of the nose; and shortly after the left hand had been attacked with the blueness, the left foot exhibited a similar appearance; then the right hand, the right foot, and finally the lobules of the ears; the blueness always commencing at the tips of the fingers and toes, and gradually ascending. She then experienced a feeling of numbness in the parts, and latterly pain whenever she made any movement.

"Previous to this illness the patient had always enjoyed the best of health. Her medical attendant stated that her labour, although lingering, was a natural one; that she got about sixty-five grains of ergot in infusion in two doses; and that she made a fair recovery. Mrs. R— stated that for years she had suffered from coldness of her extremities, more especially her hands, and that even in the hottest days of summer. Her husband remarked the extreme coldness of her fingers, hands, and feet, and often applied remedies to warm them."

"On admission, the diseased parts were found, on careful examination, to be in the following condition :—1st. On the tip of the nose there was an irregularly-shaped black patch, of about the size of a fourpenny-piece, hard and dry. 2nd. The fingers of the right hand were flexed, black, withered, and devoid of feeling as far as the middle joints. On the dorsal or posterior aspect of the hand, and

* This account appeared in the 'Lancet' of September 17th, 1870, and also in a pamphlet entitled "Idiopathic Gangrene of the Four Extremities, Nose, and Ear; Amputation of the Extremities; Recovery." By John R. Begg, L.R.C.S. Ed.

extending for about two and a half inches above the wrist, the integuments were of a purple colour, mottled here and there with shades of a darker hue; the forearm above the wrist was of smoky colour; the corresponding part on the palmar surface of the forearm, where it extended for the same distance, was of a reddish tint. 3rd. The left hand was dark in colour, the fingers flexed and withered, and devoid of sensibility up to the middle joints. The blackness in this hand extended from an inch and a half to two inches above the metacarpo-phalangeal articulation, where there appeared to be an irregular line of demarcation forming; and towards that point it was of a lighter or reddish colour. 4th. The left foot was for the most part of a light red hue, with a slight intermixture on the dorsum of a darker colour. It reached from about three to three and a half inches above the ankle-joint on the anterior surface of the leg, where the line of demarcation was forming. Some large bullæ had formed. The toes were black, withered, and devoid of feeling up to the middle joints. The integument on the plantar aspect of the foot was of a dark colour. 5th. The right foot was of a dark red hue, mingled here and there with shades of a darker cast. The toes were black, and withered up to the middle joints. The discolouration of the skin extended about three and a half inches above the ankle-joint, where a line of demarcation was forming. Some bullæ had formed near the line of demarcation. The sole of the foot was of a dark colour. The whole of the extremities were cold to the feel as far as the discolouration extended.

"The patient was ordered a liberal diet, with wine, brandy, and beer; a morphia draught and a dose of castor-oil when necessary.

"June 14th.—Up to this date little change has taken place in the patient's condition. The pulse kept at about 120. The line of demarcation is now well formed; suppuration has commenced in the lower extremities; tendo Achillis slightly exposed in left leg. The gangrene in the lower extremities is of the moist or humid kind; in the upper, the dry or mummified. Urine normal. Has been taking her food tolerably well; relishes her wine, brandy, and beer.

"17th.—This morning, at 10.30, the patient was placed under the influence of chloroform, and amputation performed in both her legs, about their middle. In either case short anterior and long posterior flaps were made. The usual number of arteries required to be ligatured. Very little blood was lost during the operations. The anterior tibial arteries in both amputated extremities were found to be pervious as far as they could be traced.

"July 2nd.—Up to this date the patient has progressed favorably, with scarcely a bad symptom. The tip of the nose was removed yesterday, and, some days before, portions of the lobules of the ears. Pulse normal; tongue clean; appetite good; sleeps well; very cheerful; stumps looking well, nearly whole. The left hand is much the same; in the right the line of demarcation is well defined, and suppuration has taken place between the dead and living parts.

"9th.—At 10.30 a.m. the patient was chloroformed, and both upper extremities were amputated; the right about three inches above the wrist; the left at the wrist, removing the articular ends of the radius and ulna. No blood was lost beyond what it was impossible to prevent. Patient stood the operations well.

"Oct. 1st.—Since the upper extremities were amputated patient has never had a bad symptom; her health and spirits are now all that could be desired. The stumps of both upper and lower extremities are perfectly sound, and able to bear a great amount of pressure. She has been out of bed daily for some time, and has been amusing herself by writing with a pen and holder secured to her right arm stump. She began by writing on slips of paper a few proper names, but she is now able by this means to keep up a correspondence with her friends. Her writing is marvellous.

"16th.—The patient left the Infirmary to day for London, to be under the charge of Mr. Heather Bigg."

The further account given in 'Orthopraxy' is as follows.*

The state of the patient at this time, as shown in the accompanying woodcut (Fig. 38) drawn from a photograph, was as follows:

"The stumps were in excellent condition, firm, without any tenderness on pressure, with good cushions of integument over their ends. Each leg stump had a length of five and a half inches from the centre of the knee; the right arm stump measured five inches from the elbow to its extremity, the left arm stump seven inches. The different

* Extracted from 'Orthopraxy,' by H. Heather Bigg, 3rd ed., p. 607. An account of mechanical construction of the appliances was also in the 'Lancet' of February 15th, 1870.

stumps were well fitted for the adaptation of artificial limbs, although the leg stumps were somewhat short. The stumps would, indeed, have presented comparatively little difficulty in the adaptation of artificial adjuncts to them, if it had not been that, having regard to the circumstances which had made amputation necessary, it was held necessary to avoid as far as practicable all pressure upon tho stump which might interfere with the circulation. This difficulty, and the general requirements of the case, I met in tho following manner:

To each *thigh* I fitted a strong but yielding leather sheath, which surrounded it and was designed to receive the weight of the patient when standing. From this sheath two lateral steel rods were carried downwards, having a moveable joint at the knee, the axis of the joint being so fixed as to carry the centre of motion well behind the natural axis of the articulation, and thus give stability to the carriage when the patient stood erect or walked, but not interfering with the natural movement of the knee. To the stumps were carefully fitted troughs, lined with soft leather, and having shapely ankles and feet attached, the ankle being formed on the ball-and-socket principle, which admits of the patient maintaining an easy equilibrium upon the feet and gives great facility in walking.

The artificial hands I constructed upon a modification I have made of Count de Beaufort's plan. In his plan the thumb alone is moved, the movement being regulated by a catgut cord carried to the opposite shoulder. In the modification I have devised this awkward arrangement is dispensed with, the cord being affixed to a stud forming part of the elbow-joint. Two of the fingers, moreover, the index and middle fingers, in addition to the thumb, are given movement.

The success which followed upon the adaptation of the several limbs far exceeded my anticipations, and took me, as well as the numerous professional men who had the opportunity of examing the case while the patient stayed in town, by surprise. I had previously had no means of judging as to the extent to which artificial limbs might be

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Fig. 38 shows the case of Mrs. Robertson (which is, as far as I know, a unique case of quadruple amputation) before the artificial limbs were applied. Fig. 39 represents her after the limbs were applied. This case is described in the text. The figures are from photographs, and appeared in 'Orthopraxy,' 3rd ed., 1877. London J. and A. Churchill.

Fig. 38.

Fig. 39.

made available for practical uses in cases where *all* the limbs were artificial, and an artificial substitute had not to perform the ordinary function for which it is designed of supplementing undamaged members, but had to perform the whole duty of a natural member. It happily proved, however, that I had under-estimated the resources of my own craft. After short practice, aided at first by a go-cart, the patient became able to stand erect and to move from place to place with but slight support, walking, in fact, with a certain degree of facility and comfort. She rapidly acquired such control over and readiness of practice with her hands as to feed herself and carry vessels with liquids to her lips and drink from them easily; to use with freedom a pocket handkerchief in wiping her lips and brow; to crochet with great facility and precision; to pick up articles even so small as a pin; and finally to write with most perfect legibility."

From the time that the appliances were put on down to her death, that is, during a period of fifteen years, she maintained herself by crochet work, having a large sale for her work, not only on account of the excellence with which it was done, but also because it was accounted a great curiosity. Her Majesty the Queen graciously interested herself in the case, and presented Mrs. Robertson several times with donations, besides frequently purchasing articles that she had worked.

CHAPTER VII.

MILITARY AMPUTATIONS AND GOVERNMENT APPLIANCES.

In the previous section I have endeavoured to describe the best and most perfect kinds of artificial limbs that can be constructed irrespective of expense or any other restrictions, as well also as those appropriate operations by which in these present days of sure and deliberative surgery the most suitable stumps can be obtained.

I now come to a subject which is equally as important, namely, that of *military amputations and Government appliances*, and one which really requires the more careful consideration, because there are a variety of necessary restrictions under which both the amputations are performed and the appliances constructed.*

Its importance needs no comment, seeing that it affects the responsibilities of the nation to its soldiers and sailors; to those on whom it relies for defence, protection, and safety in time of war. Of recent years the greatest strides have been made towards maintaining the health of soldiers on active service and in the field, the more so because the numerical strength and the fighting capacity of armies are known to depend enormously on the medical care and hygienic comforts bestowed upon them, and therefore it becomes a point of self-evident national utility and advantage to see that the latter are fully conferred.

It is none the less a national debt which is acknowledged by every civilised country, to see that those who have been wounded or maimed in service and rendered unfit for further military employment should after their discharge from the hospital and from the service, receive every possible assist-

* And this chapter applies also to what might be termed pauper surgery, that is to operations in cases of those who, having only very slight means at their disposal, could never afford more than a few shillings with which to repair the loss of a limb. There are many such to whom the more improved and perfect artificial limbs are pecuniarily debarred, and to these persons the remarks now made will apply, as much as to those who, being in Government employ, are supplied with the substitute which the country provides.

ance towards enabling them to re-enter the civil class from which they were drawn, and to supplement their pension by their own efforts in undertaking any general work or trade for which they may be suited. The more perfect, therefore, the artificial appliances with which a Government supplies its pensioners, the more faithfully will its obligation be carried out, and the better chance will the man himself have of getting a tolerably lucrative living after his army service and of becoming again useful to his country as tradesman or employé.

And the number of men that actually have to return maimed from military into civil life is not a small one. England is really pretty constantly involved in wars, and even if some of them are quite minor compared with the recent gigantic campaigns of continental countries, still after each a good number of men are invalided home who have lost some portion of one of their limbs through injury and amputation, and to whom it is necessary to apply some kind of artificial substitute. After the larger campaigns, such as the Peninsular or Crimean ones, the number of such maimed men has been enormously increased.

Every well-meaning provision has always been made by the Government to send these disabled men back into civil life with all the advantage their cases admit. Apart from their pension they are supplied with such artificial appliances as are deemed likely to be most useful to them in the every-day life of their class, and further they are granted fresh ones to the end of their life at such intervals as reasonable wear and tear may justify.

For this purpose a careful schedule was drawn up after the Crimean war of those particular forms of appliances which were then thought to most accord with the requirements of the Government grant, and models of these were lodged by the contractors with the Commissioners of Chelsea Hospital.

These are the appliances which for the last thirty years have been issued to pensioners. Some of them are excellent, and for their purpose could not be improved upon. *Others are not of the service that was erroneously imagined* when the original schedule was drawn; in what respect they are deficient or useless I shall show later on.

This faultiness in some of the appliances, together with the misunderstanding that exists of the precise **relationship between amputation and the appliance** to be afterwards worn, has really led to many old soldiers not being given the best means of locomotion or handiness that they really should have had, and which, without any extra expense or trouble, might at the outset have been afforded them.

I propose, therefore, to review the appliances that are most proper for soldiery, under the existing provisions of the Government grant, as well also as the amputations that should be insisted on as best in the field or the military hospital, provided always that they are feasible and not contraindicated by potent surgical considerations. And I will do this generally first, and particularly afterwards.

The main point to be held in view in considering military amputations and the subsequent appliances is that there should be a properly understood relationship between the two. **The object should be to remove what is useless, in order to replace it by what is useful.** When a limb is wounded and amputation is needed, not only should the exact operation be determined and recognised as proper by the surgeon, but also at the same time the subsequent appliance should be held in view. He should operate for that appliance. As the list of appliances allowed by Government is a small and simple one, so the precise operations should be equally simple and small in number.

It cannot be too strongly insisted that as Government allows certain definite regulation appliances to be requisitioned after cases of amputation, so these ought to be fully known to every military surgeon, as well also as the definite operations which serve to secure stumps most appropriate to their use. This does not seem at present to be the case. The military surgeon has no regulations to guide him as to the exact appliances that will be afterwards granted. He operates according to general surgical rules, and the soldier is invalided home to be supplied with an appliance about which it is not the duty of the original operator to be cognisant. His duty is complete when he has satisfactorily removed what is useless,—he is not supposed to look any further. The result is that many a soldier comes home with what is surgically a splendid stump, but a most inappropriate one mechanically, and to my knowledge it has frequently been found advisable by medical officers attached to the military hospitals at home to re-operate (p. 116) in order to get better ones. If the relationship between stumps and appliances were better understood this would not be the case. As I have shown in the previous part of this work it is necessary to suit the stump to the appliance even where the latter is constructed without any restriction as to mechanism and expense; how much more therefore ought this to be the case in military surgery, where for each limb there are only three or four standard Government appliances to select from, and these of the very simplest kind?

Now as to the Government appliances. **Simplicity** is essential, as are also **economy, strength,** and **durability**; and the appliances have to be constructed to meet all these points.

The Government appliances are made as a rule without the constructor seeing or fitting the patient. It is important therefore that they should be worked to some easily understood measures which can be taken by the patient himself. Of course this method cannot be expected to lead to such accuracy and comfort of fit as would be the case if the constructor took the measures and saw the stump; still notwithstanding this drawback, the results are generally pretty fairly good.

With respect to strength and durability the terms of the contract specify that the appliances should last without repair being needed for four or five years; new ones are then granted if it is necessary. The amount of wear naturally depends on the activity of the wearer, but the average number of years laid down in the specification seems by experience to prove a fairly just one.

Economy has also to be regarded as a great point, and that this has been considered even to an ultimate degree may be gathered from the statement that, taking all the simpler artificial appliances as a whole, the average cost for each pensioner is about half a guinea for four years, or about three shillings a year, so that the maimed soldiers of England walk about at a cost to the country of about threepence a month apiece, as far as the appliances are concerned. Still, notwithstanding this apparently trivial expense it cannot be denied that some of the simple appliances with which they are supplied answer their purpose excellently, for though no attempt is made to represent the form of the lost parts, still use and function are fairly well restored.

In exceptional cases special appliances are granted which are much more expensive than the simple ones ordinarily allowed.

To sum up, then, I have explained generally the basis upon which military amputations should be performed, as well as the conditions under which the military appliances have to be made. The operations should be conducted with a view to yielding stumps most suitable to the appliances, while the appliances themselves have to be of such a kind as are durable, strong, economical, and worked to simple self-taken measurements.

I will now go over the appliances themselves in particular, show in what way some of those in the existing Government list are faulty or useless, suggest an improved list, and at the same time indicate the operations which will be found to yield the most suitable stumps.

Regulation appliances after amputation in the Lower Limb.—There are three kinds of regulation appliances for the lower limb specified in the schedule of the contract, namely, the "soldier's leg above knee, or bucket," the "soldier's leg below knee, or box," and the "socket leg giving the use of knee-joint." To these a fourth must be added, for although it is not specified yet it is often specially requisitioned, and that is the so-called "Chopart" appliance, which is supposed to be used indiscriminately after any of the numerous operations through the foot or at or about the ankle-joint; this, like the others, is made in strict accordance with a pattern long ago deposited with the authorities. Of these four appliances the bucket and the box legs are excellent, as far as they can be, while the "socket" and the "Chopart" are in my opinion exactly the reverse, because in exceptional instances they undoubtedly enable a wearer to walk well, and these exceptions lead to the presumption that they are invariably serviceable, whereas it is only exceptionally that they are so. Hence to operate with the view of suiting a stump to these appliances generally leads to disappointment (p. 116).

I would therefore suggest always holding in view the idea that operations should be performed (as far as is surgically advisable and possible) for prospective appliances, that the "socket" and "Chopart" legs should be set aside, and that an appliance which I may call the "Pirogoff" for want of another name, should be substituted in their place. The reasons for this I will explain further on.

The "Bucket" Leg is the Government leg for amputation at or above the knee, and is pretty well known to nearly everyone. It consists of a rightly shaped wooden bucket (hence its name) which receives the remnant of the thigh, and into the lower end of this is fitted a "pin" on which the patient walks, or, to use a more correct expression, stumps along.

The bearing in the bucket leg is taken by the top circumference of the bucket reaching up to and receiving the fit of the firm parts of the thigh at the level of the fork and ischial tuberosity. No bearing is taken on the end of the stump, but the entire stump rests with an easy fit inside the bucket. Is is the upper edge of the bucket that receives the weight of tho body, and particularly so through the ischial tuberosity or sitting-bone, as the Germans aptly term it. The bearing, in fact, is identical with that one taken by the top ring of a Thomas's leg splint. As has been mentioned here, this circle of bearing is the most important one that exists for the adaptation of artificial limbs, for, as previously shown, it is utilised in nearly every case except where amputation has been performed through or lower than the ankle-joint.

Tho shape of the interior of the bucket must be correctly that of a natural thigh, the section of which is triangular, and not round, as is often imagined.

The bucket is held to the body in a correct position by a leather body strap which passes through a loop at the top of the outside aspect of tho bucket, and this encircling the hips is in ordinary cases sufficient hold to keep the leg in position.

Where the stump is very short a more secure hold to the body is gained by circling the hips with a metal pelvic band, with a short jointed rod attaching the pelvic band to the bucket of the leg; the axis of the joint is of course identical with the axis of the natural hip-joint. By this method the bucket is always held, whether in sitting or standing, close up to the stump.

Another modification sometimes adopted is to construct the bucket of leather in lieu of wood; it is somewhat lighter and seems to take a better cling to the fleshy surface of the stump.

The pin (which is the same also in the box leg) requires a little careful description both as regards its construction and also the direction in which it is set on to the lower end of the bucket.

FIG. 40.—This figure is a sketch of Sergeant Willian Hussey, formerly of the 68th Light Infantry, at present an in-pensioner of Chelsea Hospital. His limb was amputated by Dr. O'Leary, of the 68th Regt., in 1858, and he has since worn the regulation bucket leg shown in the figure, and described p. 106. I had the opportunity of taking this sketch by kind permission of the P. M. O. of Chelsea Hospital.

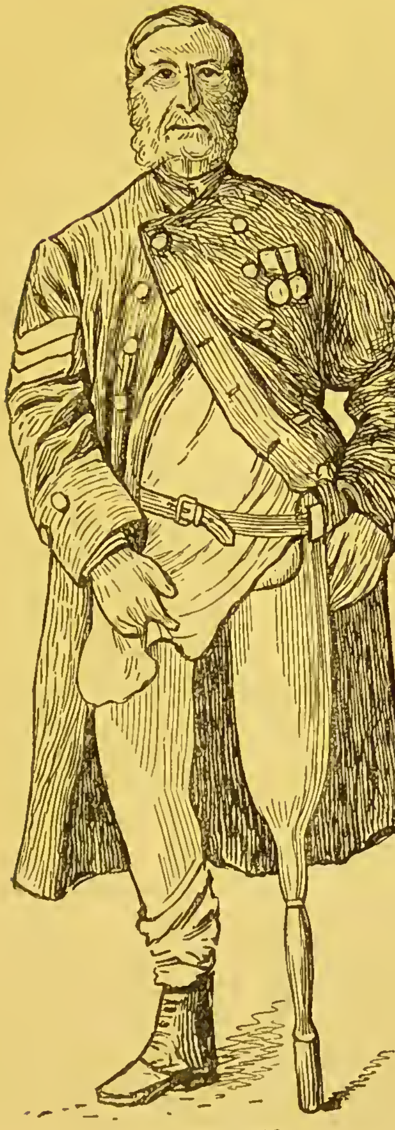

Fig. 40.

It fixes into the lower end of the bucket, and to avoid the jar which would be experienced at each step it is made of two parts, one sliding within the other, and between these parts are inserted two india-rubber washers, which act as buffers, and which give at each step when the weight of the body comes to be borne on the leg. The "pitch" of the pin on the bucket is also a matter of importance; it has been found by experience that if the pin projects in a perfectly straight and true line downwards walking is not as good as if it is pitched in direction a little outwards and a little backwards, and this latter direction should always be given to it, as it much increases the facility of progression.

The measures requisite to construct a bucket leg are as follows: (1) The circumference of the thigh at ischium, this giving the size of the top edge of the bucket or circle of bearing. (2) The circumference of the end of the stump in order that the bucket may be made large enough for it. As the stump is presumed to taper from the fork downwards no more circumferences are needed, but if any abnormal shape of stump occurred it would have to be noted and the size and situation of any swelling given. (3) The length of the stump that the bucket may be made long enough. (4) The length from fork to ground when the patient is standing that the entire artificial leg may correspond in length to the sound limb. (5) Finally, the side the leg is, for it must be stated whether left or right. It may be added, also, that with this, as with all other artificial appliances, a tracing of the sound and injured limb, taken in the way previously described, is of service though by no means imperative.

A leg of this type is exceedingly strong and durable, and is suitable for working men and for those who are compelled to be careful of their pockets and careless of appearance. As I said before, the wearer does not walk, but stumps along, as with all pin legs is the case. Its method of use is quite different to that of a proper artificial limb, because it cannot clear the ground in taking a step if carried directly and truly forward; it is therefore in walking swung away from the fellow-leg with a kind of characteristic sweep, and when once this habit of walking is acquired it is very difficult to break. It sometimes happens that a poor person who has been using a pin leg, and who is presented by charity or subscription with a perfect artificial leg, will not take the trouble to learn to walk as he should with the latter, but goes on with the same curious swing characteristic of a pin leg, and cannot or will not break himself of it. So that when it is stated, as it sometimes is, that a patient should learn first with a pin leg and be subsequently fitted with a perfect artificial one, the statement is based on a mistake.

There is one great disadvantage that the bucket leg has and that is, that when the wearer sits down it projects straight away in front of him, the whole limb from hip-joint to the end of the pin being rigid and straight. The inconvenience of this in travelling by omnibus or railway, where passengers have to pass one another, can be easily imagined, and this convenience is to a greater or less extent felt whenever the person is seated.

An obvious improvement, therefore, on the bucket leg is to add a knee-joint with a spring catch to it, so that on sitting down flexion of the pin can take place, while when the knee is in use for walking the knee is extended and firmly notched by the knee catch.

The mechanism of such a knee-joint is very simple, the joint being placed just below the bucket and being extremely strongly and solidly made. If the country could afford it it would be a great advantage for old soldiers to be granted this modified form, at all events in such cases as those in which the occupation of the man after he has left the service rendered it of importance for him to be able to bend the artificial limb at the knee.

The bucket leg is suitable for amputation anywhere through the femur, or even at the knee-joint. The bearing is not taken on the stump, and therefore all that is required is a well-covered but not over-covered stump. The longer it is the better, because the longer the stump the more complete will be the control over the substitute. The rule, therefore, would be to amputate as low down the femur as possible, and to leave as neat a stump as occasion permits.

The "Box" Leg.—This leg might have been more appropriately named the kneeling leg, and is applicable, broadly speaking, for all amputations below the knee-joint. It is for this leg that the rule of amputating a few inches below the knee in the case of soldiers or the poorer classes was laid down, as any greater length of stump left by operation lower down only proved inconvenient.

The leg itself is shaped, roughly speaking, like a tuning-fork, and it is on the bottom of the recess between the two arms or prongs of the fork that the patient kneels. The one of these prongs or arms that is on the outer side of the thigh is about two feet long, extending up beyond the hip-joint, while the inner one is only half that length. The handle of the tuning fork is represented by the "pin," and this pin is of the same construction as that previously described in the bucket leg (p. 108).

The bearing, of course, is gained on the knee as it kneels, that is, on the lower end of the femur, the patella, and the remnant of the tibia, and although at first this method of taking the bearing is somewhat taxing and irksome, still after a very little time it becomes quite tolerable. There is one change, however, that gradually takes place, and that is, that the knee contracts, and the tibia being constantly flexed, finally becomes permanently so to a greater or less degree. Hence, if after wearing a "box" leg for some time a perfect artificial leg is required to be adapted, a certain difficulty is presented by this contraction of the stump, because it cannot be extended and therefore cannot be used to voluntarily govern the lower portion of the perfect artificial leg. Still, if the contraction is neither very great nor very firm, mechanical extension can be undertaken with good results, and control over the lower part of the more perfect form of the artificial leg can be ultimately recovered.

The "box" leg is held to the body by two straps, one attached to the long arm of the box and encircling the hips, called the body strap, and the other a very broad strap, passing round both arms of the "box" and the contained natural thigh. It is this latter strap that steadies the thigh and secures it in its position. It may be mentioned also that in the box leg the knee rests on a very full pad, otherwise it would soon become tender and incapable of transmitting the weight of the body to the artificial appliance.

There is one important modification in the "box" leg which is worthy of notice, and that is, the addition to it, when it is used for cases where the length of stump below the knee is very great, of a leg rest. It can easily be appreciated that where the rule of amputating a hand's breadth below the knee has not been followed, and where the greater part of the tibia, or even part of the foot, has been left, the weight of the stump beyond the knee would

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FIG. 41.—This figure is a sketch of a present in-pensioner of Chelsea Hospital, formerly of the 2nd Bat. 7th Royal Fusiliers. His left leg is amputated through the tibia, and on this he wears the regulation "box" leg, while his right leg was amputated by a Syme's operation, and on this he wears a regulation "boot." I had the opportunity of taking this sketch by kind permission of the P. M. O. of Chelsea Hospital.

FIG. 41.

have to be borne by the flexors of that joint, unless some provision was made to relieve them of such a strain. The addition of a steel trough to the box leg allows the long stump to repose comfortably and without muscular effort; at the same time it must be remembered that the projection of such a long stump and tibial rest is a matter of great inconvenience, because they stick away behind the body and are liable to accidental injury from their prominence in an unprotected position, and also in sitting down they are greatly and clumsily in the way. Notwithstanding these drawbacks the box leg with a rest has by experience been really proved to form the best cheap substitute for amputations below the knee, where a long tibial stump is left. Still, in amputating with a view to the adaptation of a box leg it is better not to leave any great length of stump, but to adhere to the old rule of amputating about a hand's breadth below the knee.

Another modification of the box leg is to put a joint in the pin as high up as possible, so as to enable the wearer to sit down without the clumsy projection of the leg into every-one's way.

The measures required for this form of artificial leg are as follows: (1) the breadth of the knee to give the distance between the two arms of the appliance; (2) the length from knee to ground when the patient is standing on the sound leg and the knee of the injured one is flexed. If great accuracy is required a tracing is of great service, but ordinarily there is no necessity for it.

The box leg is used after amputations through the tibia, as well as sometimes for those through the knee-joint, although there can be no doubt that for the latter a leather bucket leg is the best appliance. The point of election in amputating for a box leg is four inches below the knee-joint, or, as it is generally put, a hand's breadth below. I believe that in military surgery, operation at this spot may justifiably be performed in preference to that at any other spot between this and the ankle-joint. Indeed, this was an old-fashioned and old-established rule, and in upholding its continuance in the present day I know I am differing (with the greatest deference and respect) from our highest surgical authority, Mr. Erichsen. In the chapter devoted to special amputations in his classical work on Surgery, he says, "Surgeons used formerly, even where the disease or injury was limited to the foot, to amputate immediately below the knee, in all those cases in which the patient would be obliged to wear a common wooden pin, the long leg-stump being highly inconvenient when the patient rested on his bent knee . . . . But this difficulty has been removed by the introduction of a short wooden pin in the socket of which the stump may be fixed in an extended position; and amputation in all admissible cases should consequently, even among the poorer classes, be done just below the calf at the junction of the lower and middle third of the limb."

The socket leg referred to in the above quotation as the "short wooden pin in the socket of which the stump may be fixed in an extended position" is as I have said in some cases successful with careful fitting, and the above statement is without doubt based on such luckily happy results. But as a rule even with careful fitting the issues are not satisfactory; much less then must they be regarded as so in military surgery as no arrangement is made by Government for the constructor actually fitting the substitute; it is, as I have stated, simply sent to the wearer made to his own self-taken measures. I therefore maintain that it is unwise to operate with the view of adapting a stump for the socket leg, and this view has been fully confirmed by eminent military surgeons, who after the late campaigns had had free opportunities of practically testing the point (p. 116), and I believe, therefore, that the box leg is the appropriate appliance for amputations through the tibia, and that the point of election should be a hand's breadth below the knee-joint. In order to go more comparatively into this point I will describe the socket leg and show its shortcomings.

The "Socket" Leg.—The socket leg is practically a diminutive bucket leg. It is composed of a wooden bucket, sheath, or socket receiving the lower or tibial portion of the leg, or in other words the stump below the knee-joint, and it terminates below in a "pin" which is proportionately short, seeing that it has a very little distance to make up to bring the injured leg to the length of the sound one (Fig. 42).

Nothing at first sight seems simpler than this or more likely to answer, but the reason why it fails unmistakeably in nearly every case is that no satisfactory bearing can be gained by this plan. Bearing cannot be taken on the end of the stump because (as a general rule) it is impossible to gain any bearing on a bony operative surface. This being so an attempt is made to take the bearing on the tibia just below its tuberosities, where it swells out and is wider above than below, becoming wedge like. This part of the tibia is therefore wedged into the top circumference of the socket or sheath by the weight of the body, and the result always is, even if most careful padding of the socket is arranged, that the prossure is intolerable and that the skin gives way with the friction of use. And not only does the skin give way at the part where the top of the socket actually bears on it and nips it, but also tho lower end of the stump yields, because the skin is pulled up over it as a stocking is on to a leg and the lower operative end of tho tibia tends to force its way through it. Hence, as a rule the socket leg even if carefully made is generally a failure, and will not therefore do as an accepted pattern of an artificial limb for general use among soldiers and Government pensioners.

That there are rare exceptions to this I have admitted. A man came to mo once who was an engineer and had lost both his legs about the middle of the tibia in a machinery accident. He came into my room on two excellently made socket legs of his own construction, but his object in coming was to get something else, as even with all the care that a man will bestow on himself, and with all the skill that as an operative engineer he had at his command, he found it impossible to do any satisfactory walking with them. And I have seen numerous similar instances.

My father, in his work on 'Artificial Limbs,' 1845, and also in his later work 'Orthopraxy,' briefly alludes to the socket leg, without, however, giving any decided opinion on its value. It is true that after the Crimean War he constructed some for certain soldiers at the Queen's special command, and that Her Majesty personally inspected them and expressed herself well pleased with the results, but it must be remembered that these cases cannot be accepted as test cases, since every effort was used to overcome the difficulties they presented; and further, that they were all personally and carefully fitted by the constructor, a thing which (under existing regulations) could not be done in the majority of cases. I therefore unreservedly condemn the socket leg, and any operations that are performed with a view to its adaptation in military and pauper surgery.

FIG. 42 represents the regulation socket leg, the whole bearing of which is taken below the tuberosities of the tibia, at the spot indicated by the arrow; its shortcomings are detailed in the text. Fig. 43 is the so-called regulation "Chopart" appliance, used indiscriminately for all operations about the foot and ankle, and having the bearing taken on the stump end. Fig. 43A represents a regulation "boot" for amputation at or near the ankle: its application is obvious.

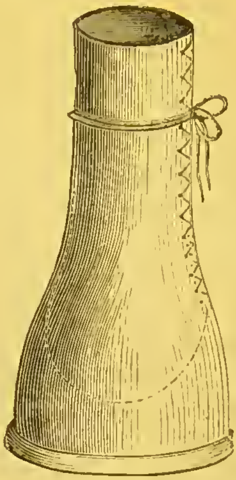

FIG. 43A.

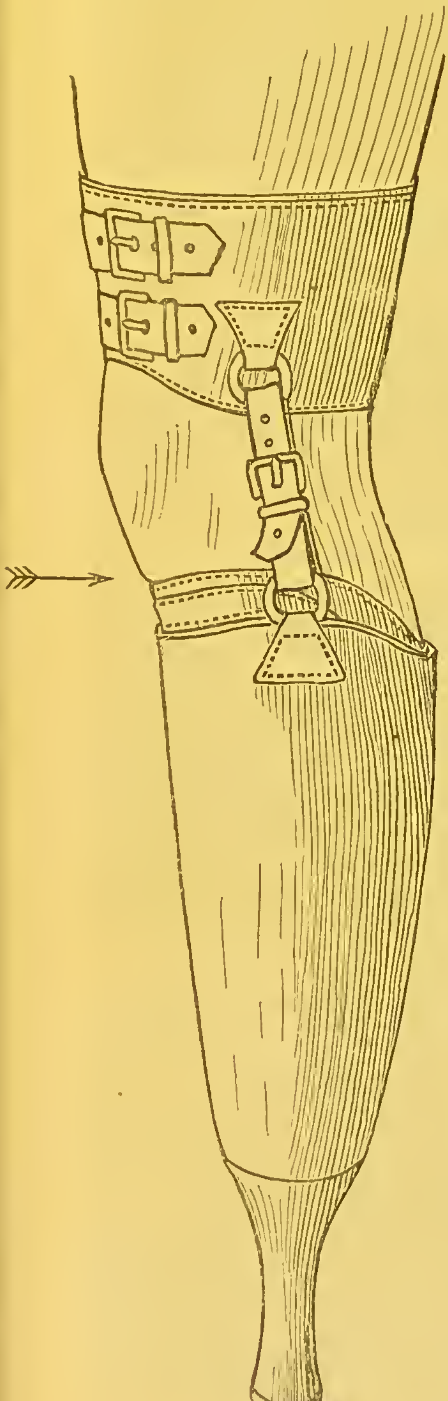

FIG. 42.

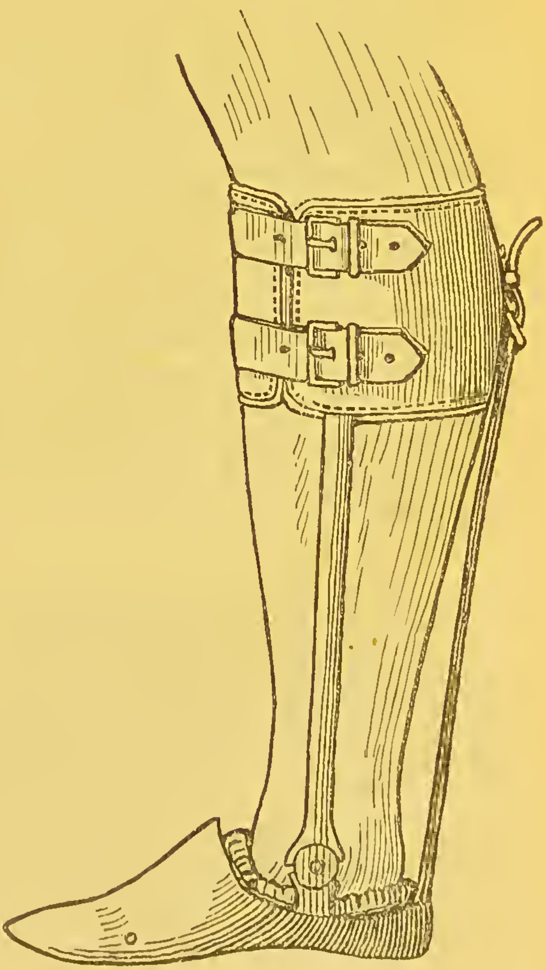

FIG. 43.

It has, however, been strongly asserted that if a long tibial stump were left, a so-called "socket leg" could be constructed on the same simple and economical principles as the "bucket" and "box" legs, and that therefore among soldiers and the poorer classes it should be a rule to amputate as low down the tibia as the lower third when possible; and this law is laid down as good in most of the standard works on surgery.

It is, however, directly contrary to all practical experience, even among soldiers, who, being of a picked and healthy class, can always be looked to give the best crucial results in any attempt to settle a point of this kind by experiment. I am prepared to admit that in a few exceptional cases the socket leg may yield successful results, but as the limbs at present under consideration are those which are suitable for Government patients, and as in this country the artificial substitutes supplied to soldiers are restricted by economy to the simpler sorts, I maintain that it must be held in military and pauper surgery that the old rule of amputation a hand's breadth below the knee-joint still holds good, and I venture to fortify this assertion by the following communications which have passed between myself and Surgeon-Major Tobin (now Brigade Surgeon) on the subject, while he was in charge of the surgical wards at Netley, and had under his care the soldiers who were coming home wounded after the Arabi Pasha campaign. Dr. Tobin gave these matters of operation in their relationship to appliances a greater amount of attention than is usually bestowed to them, and I think his letter may be considered as satisfactorily and practically settling a very important point.

NETLEY; March 25th, 1882.

MY DEAR SIR,—I have this day forwarded "for sanction" an artificial leg for Private P. Keefe, 2nd Northampton Regiment, whose leg was amputated in South Africa in the *lower third*, and for whom you had made an appliance of the kind laid down as suitable to such cases. He tried for some months to get about with that appliance, but as he was unable to do so with any comfort I, at his own urgent request, amputated his leg a hand's breadth below the knee.

I now write to ask you to kindly give me your experience of the practicability of fitting artificial legs to stumps (amputated in the lower third) of men in the position of a soldier, who have to do hard work and cannot afford costly appliances. It will help me and others in deciding what operation to undertake in future. Of three men who arrived in this hospital last year with legs amputated in the lower third, not one was able to get about comfortably with the appliance furnished to him. In two of the cases I operated a second time at the old point of election, and they went away much pleased with the old-fashioned appliance, "a box leg." The third case went away with the appliance which you had constructed for him, and I enclose a letter which my ward-master received from him lately reporting on his condition.

I hope you will understand that I do not write to find fault with the appliances furnished—which seemed to fit extremely well—but to elicit your opinion on this important point. All *modern* text-books advise you to operate as low down as possible in the leg, and say that *an appliance taking its bearing on the prominences of knee can be fitted* (*vide* Erichsen, last edition, Bryant, &c.). Is this so? Pray take into account the importance of the subject and excuse the trouble I am giving you. Yours faithfully,

R. F. TOBIN, Surgeon-Major,
Assistant Professor of Military Surgery.

To HEATHER BIGG, Esq.

P.S.—I have, of course, referred to your work on 'Orthopraxy,' 1865, but your remarks seem to me to apply to the "wealthier classes," and therefore I inquire as to the practicability of fitting cheap or moderately cheap appliances to the legs of the poor —R. F. TOBIN.

(*Enclosure in previous letter.*)

13, ALBERT STREET, LONDONDERRY;
15th February, 1882.

SERJEANT BALL,—In reply to your letter I am sorry to state that my artificial leg does very badly. In the first place it feels too long on account of the bottom of my stump having to be kept from touching. To do this I have to pad it below the knee so tight that it causes the bottom of the stump to swell, consequently it has to be taken off for a day, and the strap round the thigh works down over the knee and makes it uncomfortable. When I get it to work a little easy I might walk about half a mile a day very slowly, insufficient for my health, and as for employment I do not think I will ever be able to do any. I cannot apply for a situation when I am like this. The bottom of my stump is still so tender about the nerves that I cannot bear it to be touched. I made a great mistake in leaving until I got a properly-fitted appliance. It was all my own fault, and no one is to blame. Another fault in this leg is that it feels rather heavy. I would have it altered but there is no one in this city can do the like.

Yours faithfully,
H. LOGAN.

56, WIMPOLE STREET, W.;
21st April, 1882.

MY DEAR SIR,—I have only just returned from a holiday which, contrary to usual custom, I have this year taken at Easter, hence your note which was written nearly a month since has remained unanswered till now, having been reserved by my secretary for a personal answer.

In amputating the lower limb with a view to leaving an efficient stump for the adaptation of an artificial substitute a distinction has to be made between rich and poor.

In poorer cases, and pensioners would come in this class, the best spots for amputation are four inches below head of tibia and a little below middle of femur, these points leaving the best stumps for "box" and "bucket" legs respectively.

All the more conservative operations about the foot, namely, Hey's, Lisfranc's, and Chopart's have the disadvantage of generally yielding tender and unreliable stumps, and in my opinion should be eschewed in military surgery, but Pirogoff's yields excellent stumps, and so does Syme's as a general rule.

With the rich, on the contrary, the proper points are slightly below the middle of the tibia and of the femur, these being best for true artificial legs. The operations about the ankle, as Syme's and Pirogoff's, may be performed, and yield very good stumps.

The advantage of the tibial operation is shown, however, by the case of Lieutenant Davidson, of the Engineers, who performs all his duties, and can run upstairs two at a time (a very crucial test) with ease. His amputation is midway along the tibia.

I trust this has clearly answered your questions, but if there be any point on which I can give you further information I shall be most delighted to render it.

Yours faithfully,

HEATHER BIGG.

P.S.—The case of Serjeant Logan in the letter I return to you shows the impossibility of taking bearing *on the end* of the stump. *If the end of the stump were sound* then the appliance might perhaps be serviceable, but the end very rarely is sound, therefore the amputation four inches below the head of tibia is best.—H. B.

NETLEY; 11th May, 1882.

MY DEAR SIR,—I must apologise for delay in answering your letter of 21st April owing to its being mislaid.

I am much obliged to you for giving me the information contained therein. Your experience coincides altogether with mine. Still, it is stated by most teachers of surgery in the metropolis that a cheap and serviceable appliance can be fitted to legs amputated in the middle and lower third, leaving them the use of the knee-joint, and that hence the point of election for the working class is no longer a hand's breadth below the knee. I wonder on what facts is this advice founded, advice which, if not sound, must give rise to much suffering.

Yours faithfully,

HEATHER BIGG, Esq. R. F. TOBIN.

In my letter to Brig. Surg. Tobin, in addition to answering his question about the point of election for military operation through the tibia, I also referred to the operations about the foot and ankle, because these are often performed, and because also there is a regulation appliance, the so-called "Chopart," which is supposed to be used after them; this appliance I will now describe.

"Chopart" Appliance.—Mechanically speaking, this is a somewhat faulty appliance, and if successful is so, not so much through its own intrinsic merits and construction, as through the operation after which it is used. It may be stated at once that after a Pirogoff it answers excellently, and after a Syme's it answers usually well, but after any of the other operations below the ankle-joint its success is unlikely and cannot be counted on. Its construction is as follows (Fig. 43):

A composite band of metal and leather encircles the leg at the level of the calf and gains a hold by being buckled in front of the leg. To the metal portion of the band so formed two steel rods are attached, and running down the sides of the leg, terminate below in a strong wooden foot which is hollowed out to the shape of the terminal end of the stump. These steel rods are jointed at the position of the ankle-joint. The wooden foot has nothing peculiar about it, except that there is a mortice-joint at the tread, for the purpose of simulating the motions of the natural foot, and this it somewhat imperfectly does.

The bearing is taken **on the end of the stump**, which end fits into and rests in a recess that is hollowed out in the wooden foot to receive it. The band round the calf and the lateral rods constitute the hold that is taken on the leg, so that this "Chopart" apparatus is really nothing more or less than a wooden foot fitted on to the stump end, jointed and secured in this position by the hold gained on the leg through the medium of the calf band and lateral rods.

It is this fact of the bearing having to be taken on the stump end that leads to the non-success of the "Chopart" when used indiscriminately for the operations about the ankle and foot. If the matter is looked at mechanically the reason is quite clear. The appliance is only a block foot fitted in apposition to the end of the stump. When walking is attempted the stump end has to pivot on the block foot at each step, so that not only has the stump end to bear the entire weight of the body, but it has to do this under persistent rubbing and movement. Now, as anyone experienced in the matter knows, only the most hardened and tolerant stumps will stand this. After a Pirogoff the end being both firm and likewise of a shape that is suitable for pivoting allows excellent walking. After a Syme's a stump may be found to be sufficiently tolerant, with the aid of careful padding, to also admit of use with the "Chopart" appliance. Quite as often as not this fails. With the other operations failure is the rule and not the exception. Walking may be just possible with it, but it is quite likely and more than probable that if the patient happens to be in a military hospital at the close of a campaign, and has daily evidence of the "box" leg used after the higher operation, he will beg the surgeon to remove a further portion of the limb, as in the instance of the three cases mentioned in Dr. Tobin's letter.

Another minor disadvantage of the "Chopart," even when successful, is that all the mechanism has to be placed outside and around the remnants of the natural leg, instead of, as should ordinarily be the case, occupying the actual space which the removed parts of the natural limb would ordinarily occupy. Hence an amount of clumsiness of appearance is entailed, which is all the greater because Government appliances have to be stronger, more durable, and therefore more substantial and bulky than those appliances that are used by persons in well-to-do positions in life. I have referred to this point in the previous chapter.

The Chopart really is an attempt to get a sort of universal appliance which will suit all the operations, Hey's, Lisfranc's, Chopart's, Pirogoff's, Syme's, and their modifications, and further, an appliance that will accord with the present arrangement of being constructed without the patient being seen or fitted by the constructor. The attempt is a signal failure.

The question arises then what remedy is there? It seems a pity, and it may often be surgically unadvisable to follow the old rule and amputate just below the knee when an injury has been received only just sufficient to destroy the tread of the foot. Under these circumstances I should say that the rules I attempted to define in describing the more perfect limbs ought to be followed, namely, always to perform a Pirogoff if possible as the best operation, a Syme's if it is more convenient as a tolerable operation, and to discard the three other operations (Hey's, Lisfranc's, and Chopart's) altogether.

As regards the actual appliance itself, it would be better by far to substitute for it where it was possible one of the kind described at p. 45, where the whole stump is ensheathed in a closely fitting leathern sheath, which extends to the tuberosities of the tibia, and allows the bearing to be diffusedly taken not only by the stump end, but also in part by the swell of the calf as well as by the swell of the tibial tuberosities. This could be done from a careful measurement and a gutta-percha mould, even without the constructor fitting or seeing the patient.

The measures required for a Chopart or for the improved appliance I suggest are as follows:

First, a tracing of both the sound and injured limb should be taken as described at p. 63. Next, the circumferences of the stump at the swell of the calf, and every interval of two inches downwards, should be indicated. Lastly, when the patient is sitting with the sound foot resting on the ground, the knees together evenly and flexed to right angles, the distance from the stump end to the ground should be taken, or, in other words, the amount of length that has been lost by operation; a boot for the injured limb should also be sent to the constructor.

There is no special Government appliance for cases in which only small portions of the foot have been removed, but in which the tread of the foot has been functionally destroyed. Sometimes only a slight operation destroys the tread, but when once this has been done the foot may be considered useless for walking purposes and might just as well be off. I have had one or two cases of the kind, and the appliances that have to be used are very cumbrous and clumsy. They need not, however, be described here as they are rare in Government work, and have been alluded to in detail in the previous chapter.

Rules for amputation in Lower Limb.—To sum up then, the connection between the military operations and appliances for the lower limb may be regulated as follows:

If the injury renders it impossible to save the tread of the foot then perform a Pirogoff by preference, or, failing this, a Syme's, with a view to suiting the stump to either the Government "Chopart" appliance, or, better still, the improved appliance I have suggested (and disregard altogether such operations as Hey's, Lisfranc's, and Chopart's).

If the injury is higher and fails to admit of a Pirogoff or Syme's, amputate a hand's breath below the knee to adapt a stump to the "box" leg (and disregard the socket leg altogether).

If an operation higher than this has to be performed, then amputate through or above the knee. If amputation is performed through the knee and the patella is left, then a "box" leg will be the suitable appliance; if this bone is not left a "bucket" leg will be found better. In amputation through the femur the longer the stump the better, and a bucket leg will be subsequently applied.

Regulation Appliances after amputation in the Upper Limb.—The "regulation" appliances for the upper limb aim only at giving some sort of prehensile utility to that remnant of the natural arm to which they are adapted, and make no attempt to restore form nor appearance. As might therefore be expected they are of a somewhat crude kind, useful as far as they go, but only reproducing natural powers to the most limited extent. I explained in the previous chapter the almost insuperable difficulties that exist in imitating the upper limb even when no expense is spared; with the economical forms of substitutes difficulties become impossibilities.

The Government contracts specify two distinct kinds of substitutes for amputation through the upper limb. The simpler are known as the "stump arms;" the other and more complete are known as Major Little's "improved arms." In neither of these is any attempt made to reproduce the hand; indeed, these appliances constitute nothing more than methods of appending certain instruments to the stump left at such a convenient distance from the stump end as to be of service to the wearer.

The common "stump arms" consist of a leathern sheath fitting the stump and terminating below in a metal plate into which is screwed the particular instrument the wearer wishes to use. The instruments allowed for this kind of arm are knife, fork, and hook. Whether the stump arm is for amputation above or below the elbow, the construction is absolutely the same, only that if made for above elbow the sheath is longer than if worn below the elbow, and the mode of attachment varies in these two cases.

The "stump arm elbow below" consists of a stout leathern sheath embracing what is left of the forearm. To the distal end of this sheath is attached a metal plate with a central aperture into which is screwed the particular instrument in use. At the proximal end of the sheath are sewn on two leathern loops of sufficient length to reach above the elbow-joint, and through these loops passes a strap which is buckled firmly round the upper arm above the condyles of the humerus, and thereby a very excellent hold is obtained. The instruments allowed are knife, fork, and hook.

The use of this appliance depends on the length of the forearm stump. If sufficiently long to gain a secure hold in the sheath, then it is a serviceable appliance; with a

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FIG. 44 is the regulation common stump arm for amputation below the elbow; Fig. 45 is the regulation stump arm for amputation above the elbow, to which is added, in accordance with the extra authority usually granted at Netley, a shoulder-pad and suspensory straps. Fig. 46 is the regulation improved arm (Major Little's) for amputation below elbow, and Fig. 47 is the regulation improved arm (Major Little's) for amputation above elbow. These patterns date from the Crimean campaign. These figures are all fully described in the text.

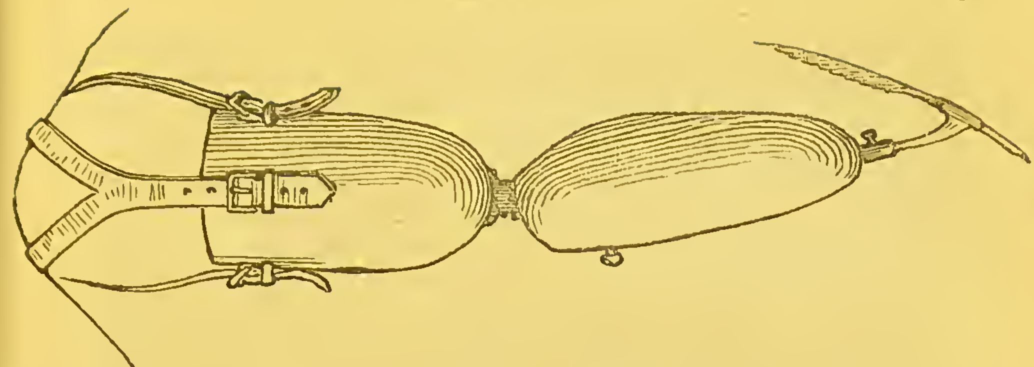

Fig. 47.

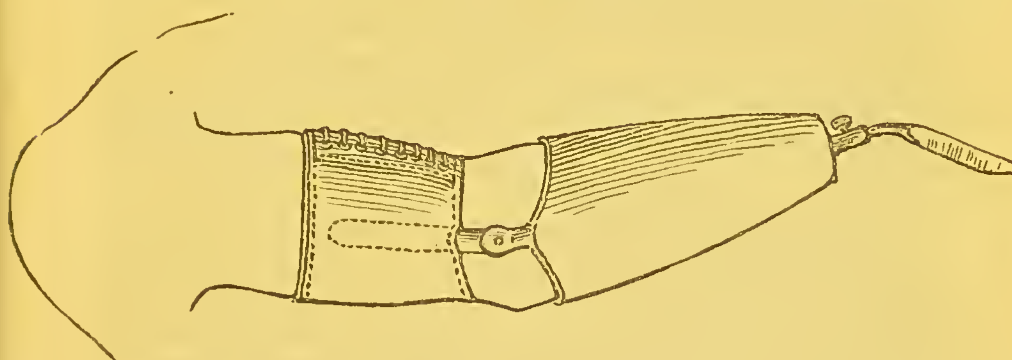

Fig. 46.

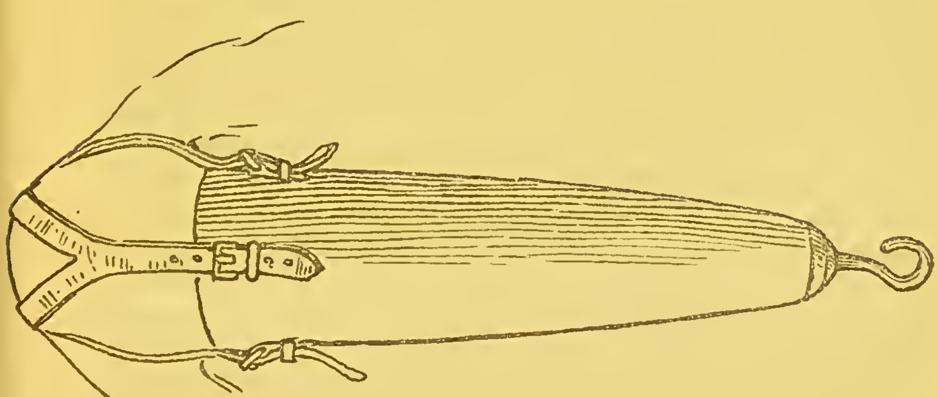

Fig. 45.

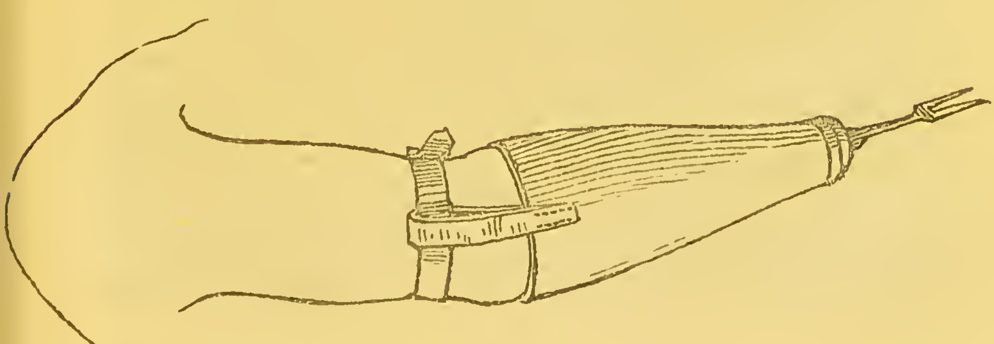

Fig. 44.

short stump, on the other hand, the hold taken on the arm is insuffieient and the appliance is not of much service.

And this insuffieiency of hold on the forearm in such cases is one of the most patent faults of this applianee, while another fault is that there is no axis of movement at the plate into which the instruments fit, and eonsequently the knife and fork eannot bo given tho angle best suited for its use, the angle I mean that in nature is given by the wrist-joint. Thero ean, I think, bo no doubt that a new Government model ineluding these improvements should be authorised, first beeause the existing applianee is in a very large number of eases useless on aeeount of these defeets, next, these defects are very easily remediable at a little extra cost, and that I do not think should stand in the way, seeing that the expense to which the conntry is now put for the supply of the present arm to its old soldiers is exaetly twopenee a month for eaeh ease.

The "stump arm above elbow" eonsists, exactly as in the previous applianee, of a leathern sheath receiving the remnant of tho upper arm, but the sheath is mueh longer, and only its uppermost portion is filled by the stump. To this upper end are attaehed two leathern loops, just as with the previous appliance, while the lower end has the same plate for the reeeption of instruments. The attaehment is supposed to be taken by a "body strap" passing through the loops at the lovel of the shoulder, under the opposite axilla. Practically, however, this mode of attaehment is useless, and tho medieal offieers at Netley, who really do give these matters eareful thought, aro in the habit of authorising the supply of a speeial attaehment, whieh eonsists in a shoulder-pad held in its plaee on the shoulder of the injured side by a body strap passing through the sound axilla; while from the shoulder-pad three small straps pass on the three aspects of the stump and are buekled to the leathern sheath. This mode of attaehment is a very good one, being an approximate imitation of nature, and it is the one adopted in the better artifieial limbs (fig. 45).

However, no matter how well this applianee may be attached to the body, it is about the most senseless and useless applianee that ean possibly be coneeived. It is really a long stiff projeetion swinging from the shoulder with no axis of movement at the position of the elbow-joint. With it are supplied a knife and fork, which ean never be used, as it would be an absolute impossibility to bring them to the plate; for if the artificial arm were raised on to a table it would reach half way across it. I would therefore unhesitatingly say that this arm ought to be excluded from the Government patterns, and one with an elbow movement introduced. The cost of this stump arm to the nation is under threepence a month for each soldier supplied with it.

The **improved Government arms** known as Major Little's are very strong though somewhat cumbersome affairs, and have this advantage over the stump arms, that an attempt is made in them to get elbow- and wrist-joint motions, there being axes at these points capable of allowing flexion of the parts of the arm to certain angles whereby a much greater facility in their use for many general purposes is attained.

The **improved arm for amputation above elbow** is constructed as follows. A leathern sheath receives and fits the stump, and gives attachment below to a central rod which terminates at the position of the elbow in a rule-joint. From this joint a second central rod is continued through the position of the forearm and terminates in a wrist hinge or joint which in its turn carries a socket for the reception of whatever instruments are used. The substance of the forearm is made up of cork disposed around the central rod The instruments granted consist of a selection made from the following list: knife, fork, hook, paper-clip, vice, and penholder. The great point in this kind of arm is the existence of the joints, which are provided with stops so as to be able to be fixed at any angle. It is obvious how much this must facilitate such actions as cutting food, writing, &c. The attachment of this kind of arm to the body, as laid down in Major Little's plan, is somewhat curious and extremely inefficient. It is effected by a stout canvas jacket or shirt being made to fit the body with a sleeve for the sound arm, and the artificial arm attached as a sleeve to the sleevehole of its side. A much better attachment is obtained by the shoulder-pad plan previously described, and this is well known to certain army surgeons who authorise it therefore by preference (Fig. 47).

The **improved arm below elbow** is a curtailment of the preceding. A leathern sheath receives the forearm, and gives attachment below to a short rod which terminates in a wrist-joint and socket for instruments similar to that for above elbow. Attachment is gained by means of a band laced round the upper arm, and connected to the sheath by two light lateral rods jointed in the axis of the elbow. This really constitutes a very serviceable appliance, as a fork or knife can be adapted at the wrist-joint to the angle requisite for use, and further, the natural elbow-joint being left, a good command of the forearm is obtained if anything like a reasonable stump is left (Fig. 46).

Rules for amputations in the Upper Limb.—In describing these Government arms I have said nothing about amputations, for this reason, that the rule laid down with the better class of arms holds good, namely, to be as conservative as possible, and not to over remove more than is absolutely necessary. Nothing that I know of comment can be added to this. Under these circumstances the army surgeon operating need not consider at all what appliance will be afterwards adapted, since he has not to adapt his stump specially to any form of appliance with the precision I showed was so important with the lower limb.

Measurements for an artificial arm, no matter how crude it may be, should be accurate, and it is always best to take a tracing of both sound and injured limb in the way I previously described (p. 92), written on the paper on which the tracing is taken should be the circumferences at every two inches from the elbow upwards and downwards, as well as any peculiarities and tender points that exist in the stump.

Suggested improvements in Government Arms.—Now, it must be remembered that the common or stump arms are the ones ordinarily authorised and supplied, the improved ones only being granted in exceptional cases; it is therefore very important that the common arms should be as perfect as possible. The "stump arm below" with two modifications would be a good arm; first, it should have a better attachment to the upper arm, and one that would not impede elbow movement, and next, there ought to be a joint of movement at the position of the wrist, in order that such instruments as the knife or fork could be inclined to a proper angle for the purpose of cutting and lifting food.

The attachment to the upper arm would vary according to the length of the stump. If long, and admitting of pronation and supination, then leathern loops running

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FIG. 49 is a "Nelson knife," combining knife and fork. This instrument ought to be made a regulation one, and should be granted to every soldier who has lost the use of one arm. It is a most serviceable implement, was always used by Lord Nelson, and is highly spoken of by that distinguished general, Sir Samuel Brown, on the faith of whose original recommendation Surg.-Gen. J. T. C. Ross grants one to all the one-armed soldiers assisted by the National Aid Society.

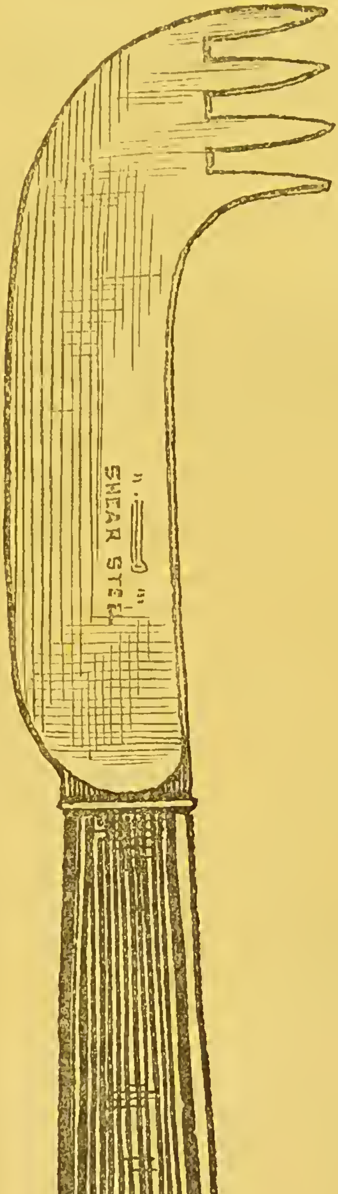

FIG. 49.

through metal rings would suffice and not impede these actions. If the stump is short, then lateral steel rods should be the method of attachment as described and figured with the improved arms.

The "stump arm above" ought to be done away with altogether, and an arm on the type of the improved arm granted, as although the stump arm costs so little, still it is useless to waste even that little in what cannot be of any service. For it is impossible for this arm to be of any service at all, seeing that it has no elbow movement, and that it projects stiffly and lengthily away from the body to such a distance that the instruments with which it is fitted cannot be put to any service. The "stump arm above" ought therefore to be replaced by an arm with elbow movement, and with wrist movement also, by which means a plate at table can be easily reached, and the food commanded and cut with the aid of the fellow hand.

In fact if a compromise were struck between the common and the improved arms, the results would be that only two appliances would be required for the upper limb, the one for amputations which left a practicable forearm stump, and the other for amputations higher up. It would, I think, also be wise to grant ordinarily the right of selection of three out of a list of six or eight instruments which could be inserted into the arm, the more so as these instruments, being metal, are very durable and would not require renewal with each new arm that was granted to the soldier.

The Nelson Knife.—Lastly, there is one instrument which certainly ought to be granted to every one-handed man who has been maimed in service, and that is the "Nelson knife." The knife which was habitually used by Lord Nelson consists of a handle like that of a simple table knife, while the blade, instead of terminating in the ordinary rounded extremity, turns up in the direction of the back of the knife, and is cut into four fork prongs. The instrument is therefore a combined knife and fork; the one side cuts the food, the other side picks it up and conveys it to the mouth. This very useful instrument is not granted by Government at all, but its importance and utility is obvious, and Surgeon-General Ross, at whose request I saw a large number of men at Netley Hospital, where he was acting for the Princess of Wales's branch of the National Aid Society, makes a special point of giving every one-handed man that comes within his power one of these very excellent instruments.

PRINTED BY J. E. ADLARD, BARTHOLOMEW CLOSE.