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THE UNIVERSITY OF CAPE TOWN ARTIFICIAL LIMB

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In the research and development of this limb the guiding principle has been to produce by mechanical means an apparatus which functions as closely as possible in the manner of a normal limb. While this principle has been carried to a useful practical stage, it is appreciated that its further perfection will open vast fields for future research. Hitherto lower limb prosthetics have relied upon a back-locking action at the knee by dorsiflexion, or its equivalent, of an equinus foot. As a result of this amputees have had to master special actions which deviate from normal gait and which necessitate extra work with consequent fatigue.

LOWER LIMB PROSTHETIC GAIT

A through-the-thigh amputee fitted with a standard-type prosthesis places the prosthetic heel on the ground ahead of him. He has to augment his forward momentum with additional muscle power in order to lift his body weight upwards. This lifting is considerably higher than is necessary on a normal limb because the prosthetic foot has to be limited as regards its ability to dorsiflex. When the prosthetic limb is in the vertical weight-bearing position with the weight taken essentially on the forefoot in order to produce adequate knee stability, the sound limb is swung forward into a position ready to commence taking body weight. At this stage, body weight has moved sufficiently far forward for the prosthetic knee to go into flexion. When weight is adequately placed on the sound limb, the amputee then swings his prosthetic leg past the sound leg, preparatory to recommencing the walking cycle. In so doing he once again has to elevate the pelvis on the prosthetic side and exert muscular action to swing the prosthesis through in such a manner as to clear the terrain and any obstacles thereon. This latter action is rendered the more difficult by the prosthetic foot being either somewhat in equinus, or at least limited as regards its dorsiflexion, and most amputees require to swing their artificial leg outwards in an ungainly arc. Often an additional forward-flinging motion has to be imparted from pelvis and thigh stump to the prosthesis to ensure that the knee is braced back in extension for the safe commencement of the next walking cycle. The path through space traced by a point on the pelvis above such a prosthesis compares most unfavourably with the similar tracings described by such authors as Arthur Steindler,[1] and Saunders, Inman and Eberhart,[2] for normal gait. Lateral swaying of the pelvis and body varies greatly with different amputees, but in all of them it is evident from a study of these motion curves that the amputee needs to expend an excessive amount of energy. The gait with a standard type prosthesis is shown in Fig. 1.

Other Disadvantages of the Modern Prosthesis

Existing prostheses are crudely shaped, roughly to resemble an average limb. They are hard and unpleasant to touch, rough on the clothes and difficult to control in public places with close-spaced seating. They become dangerous when walking downhill and few amputees are able to walk downstairs.

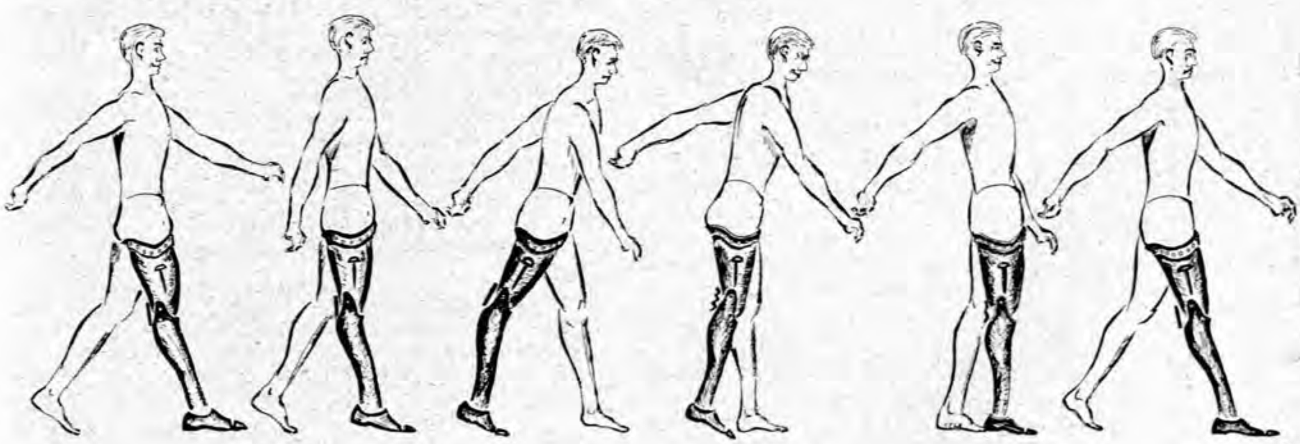
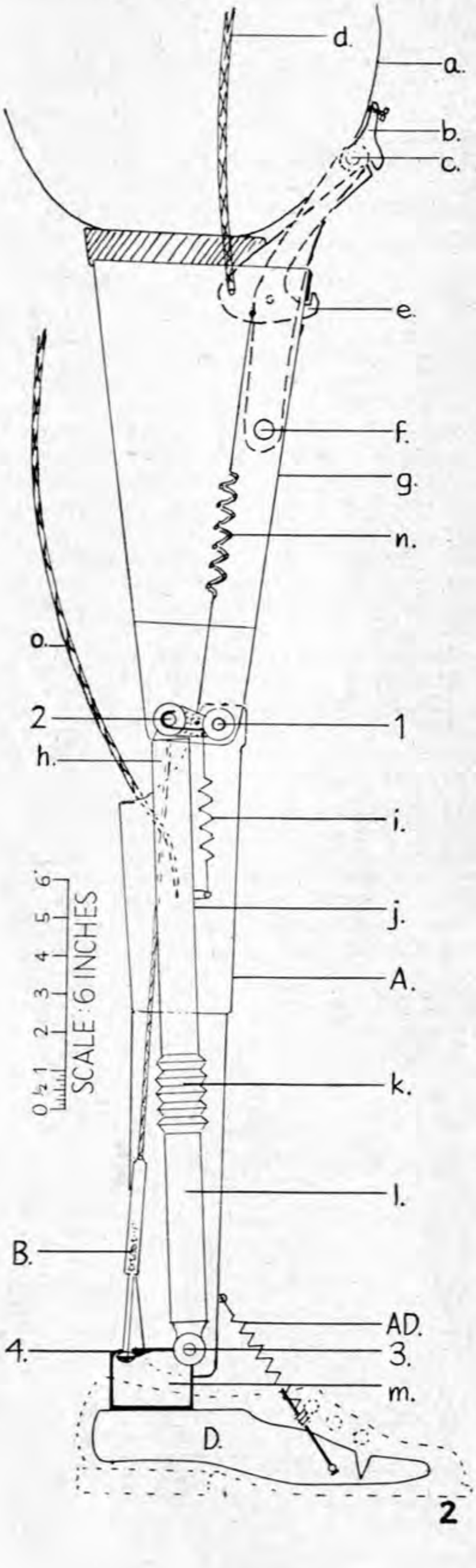


Fig. 1. Mediaeval in 1959—a gait as torturous of stump and Man must cease forthwith.



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THE PRINCIPLE OF ACTION OF THE NEW LIMB

The foot and knee are coupled together in such a manner that dorsiflexion of the foot produces flexion of the knee. This combined action is controlled simply by incorporation between knee and foot-action of a hydraulic and spring-bias system. The thigh, if there is a stump, is fitted to a standard-type bucket. If there is an amputation through the hip or pelvis, a thigh-piece is coupled to a suitable glass fibre pelvic-moulded bucket by means of a hinge working on the principle of the 'Canadian-type hinge'.

Walking Actions

The body weight is transmitted downward through the limb and the foot is pressed down into an equinus position. The knee is in extension. The forward momentum of the body is accompanied by increasing pressure under the fore-foot, gradual increasing dorsiflexion of the ankle, and flexion of the knee. The pelvis on the prosthetic side rises slightly at almost the same rate as a normal pelvis in walking would do. Shortly after the pelvis has reached its maximum height, the normal leg is swung through in the normal manner while forward momentum of the body continues to flex the foot and the knee. After body weight has been taken on the normal limb, the pelvis on the prosthetic side is again lifted as in normal gait and the prosthetic limb commences to swing forwards gravitationally. The ankle and knee being flexed, the prosthetic foot easily clears the ground as the distance between foot and pelvis is thereby shortened. The knee and ankle remain flexed until the prosthetic thigh commences to pass the normal thigh, after which the prosthetic leg increases its velocity and the knee and ankle extend, preparing the prosthetic limb for recommencement of the walking cycle.

At no stage during flexion of the prosthetic knee or ankle does the controlling bias system become disengaged, and these movements can therefore be carried out in safety and without danger of the amputee falling. A control cable is fitted to the hydraulic mechanism of the bias system whereby the amputee can regulate at will the pressure, and consequently the rate at

Fig. 2. (*a*) Glass fibre pelvic bucket.
(*b*) Adjustable stop to pace-length regulator.
(*c*) Canadian-hinge point.
(*d*) Pull-cable control for sitting down.
(*e*) Hinge lock coupled to pace-length regulator and knee-lock release.
(*f*) Lower bucket-hinge pivot.
(*g*) Thigh piece or bucket.
(*h*) Cap to bias extension.
(*i*) Knee-lock release spring.
(*j*) Bias-extension tube.
(*k*) Neoprene sealing bellows.
(*l*) Hydraulic and spring bias system.
(*m*) Ankle-pinion housing.
(*n*) Knee-lock retaining spring.
(*o*) Hydraulic needle-valve control cable.

1. Knee pinion; coupling leg to thigh piece.
2. Upper bias pinion; coupling bias extension and false tendo Achillis to thigh piece.
3. Ankle pinion; coupling bias system and leg housing to ankle-pinion housing.
4. False tendo Achillis attachment on to ankle-pinion housing.

A. Leg housing—can be set and riveted to patient's leg length.
B. False tendo Achillis.
D. Artificial foot.
AD. Special spring.

which combined flexion of knee and ankle occurs. For walking downhill the pressure would normally be raised and these movements thereby more resisted. Setting of this control by the amputee is a matter of personal choice and is very quickly learned in much the same way as the controls of a motor car. In actual practice the control is not very frequently altered. A separate control releases the mechanisms at the knee and enables the amputee to sit down. Standing up automatically re-sets the connections and prepares the leg once again for walking.

THE ADVANTAGES OF THE NEW LEG

The flexion of the ankle and the knee during the forward movement on the prosthetic leg lowers the height to which the body weight requires to be lifted, thereby decreasing considerably the expenditure of muscular energy. The shortening of the leg by flexion of knee and ankle enables the prosthetic limb to clear obstacles easily and reduces the need for the ungainly outward swing of the standard prosthesis. The constant control during bending of the knee makes for safety, comfort and more normal habits of walking while, at the same time, placing far less stress and strain on the bucket-to-thigh stump attachments. Standing is for practical purposes normal.

The mechanisms required to obtain these actions have been so simplified that it has become possible to enclose them in a light metal skeleton-like housing. Plastic foam and sorbo rubber are then built on to this skeleton appliance, covered in turn by skin-tinted material and stockings shaped to match with accuracy the normal leg. This gives a softer and more pleasant limb to live with, which does not harm the clothing and which, by attention to cosmesis, serves to offer additional psychological rehabilitation, especially to women.[3]

DESCRIPTION OF THE LIMB

The component parts of the limb are shown in Figs. 2, 3-7, and 9.

The Foot

This, for convenience, has been made of wood with a hind portion and a separate toe-piece. The toe-piece is fastened onto the hind portion by two plastic tubes, enabling it to flex easily within the shoe. The wooden foot is shaped to the amputee's shoe and it should be possible to fit any number of wooden shapes to fit different types of shoe, for example, high heels and flat heels. It should be prepared on its edges to receive the outer sorbo rubber shaped covering snugly. Attached to the hind portion of the wooden foot is a metal ankle-pinion housing.

The ankle-pinion housing should be attachable to the wooden foot-piece by a simple yet easily released method. Such attachment, however, requires to be very strong as the strains on it are great. The ankle-pinion housing itself is arranged to have a pivot of silver steel working in a teflon or nylon bearing antero-superiorally, and postero-superiorally an attachment for a cable which we will call the artificial tendo Achillis. In Fig. 2 the latter is labelled B and the point of attachment of the artificial tendo Achillis to the ankle-pinion housing is labelled 4. The ankle pinion to which the leg housing is attached is labelled 3.

The Leg Housing

The leg housing consists of two portions: (1) a lower 2-inch diameter drawn or extruded aluminium tubular portion, telescopic in (2) an upper shaped aluminium portion. It is made telescopic for adjustment to the specific leg length of the patient, and after this length has been determined the lower tube is cut off and riveted to the upper aluminium part. The leg housing is attached to the thigh housing by a pinion labelled 1.

The Thigh Housing

The thigh housing consists of a standard type of bucket which has to be fitted to the patient, and the bucket in turn is attached to a thicker gauge aluminium lower part which contains the knee mechanism. For patients with amputations of the thigh no special part other than the knee mechanism is contained in the thigh housing, but for persons with an amputation through the hipjoint or the pelvis, the thigh portion requires to be specially shaped, being fitted with a hinge and a pace-length control. These will be described separately.

The Tendo Achillis

The leg is fitted with a false tendo Achillis which, in practice, works in a similar way to the tendo Achillis in the live body. This is a cable which is attached with a screw length-control mechanism to the ankle-pinion housing at the point labelled 4 and, above, to the thigh housing at a pinion labelled 2. This pinion 2 is also the upper attachment of the bias-control mechanism.

The Bias-control Mechanism

The most important part of the limb is this bias-control mechanism. It is contained between the two pinions of attachment labelled 2 on the thigh-piece and 3 on the ankle-pinion housing. The lower portion of the bias-control mechanism is a hydraulic cylinder containing a piston, a special collar, and adjustment mechanism and springs. This will be described separately. The upper part of the bias-control mechanism is, for convenience, a tubular extension of the lower portion attached to the piston shaft.

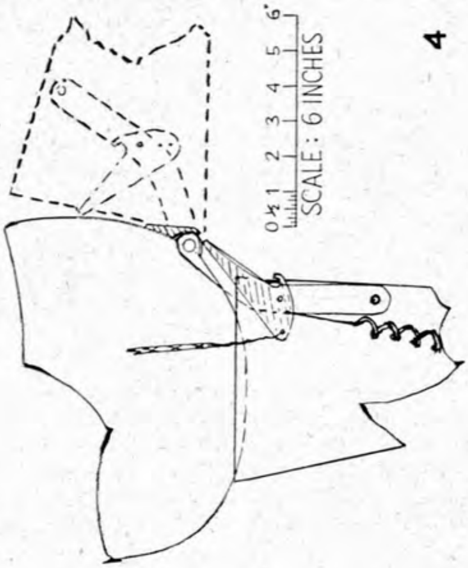
Special Spring

A special spring labelled AD is attached above to the leg housing and below to the front end of the posterior wooden foot portion. The tension on this spring is adjustable, and indirectly adjusts the behaviour of the main spring inside the hydraulic cylinder, as well as dorsiflexing the foot against the tendo Achillis.

The Hydraulic Cylinder

This consists of an outer casing and a piston to which a shaft is attached, the shaft passing through the centre of a special collar attached to the outer casing with precision-machined clearance. The shaft also passes through a guide ring and adjustment mechanism at the top of the hydraulic cylinder. Contained in the upper part of the cylinder is the main spring of special strength. The bias extension tube is indirectly attached to the shaft. Passing through the centre of the shaft is a needle valve which can control a small opening at the lower end of the centre part of the piston. A small neoprene sealing washer at the top of the shaft prevents oil leakage when the leg is turned upside down.

A sealing bellows made of oil-resistant neoprene is fastened to the bias extension tube above, and to the upper part of the cylinder of the hydraulic system below. This is to keep dirt out and to contain any possible leakage. Owing to the hydraulic cylinder design including a no-pressure chamber, leakage, for practical purposes, does not occur.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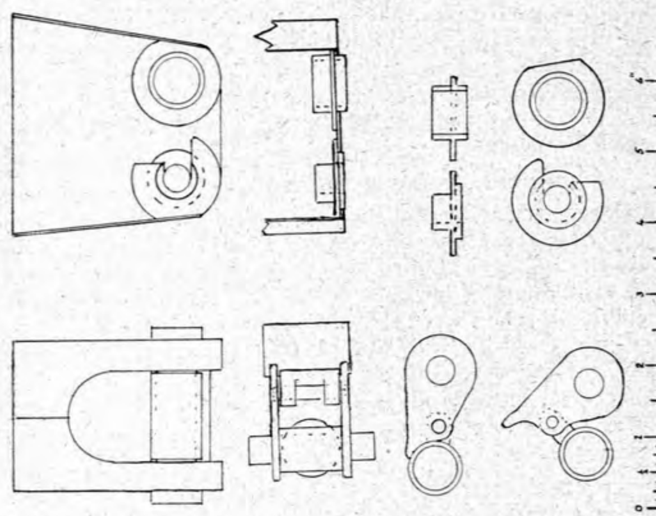
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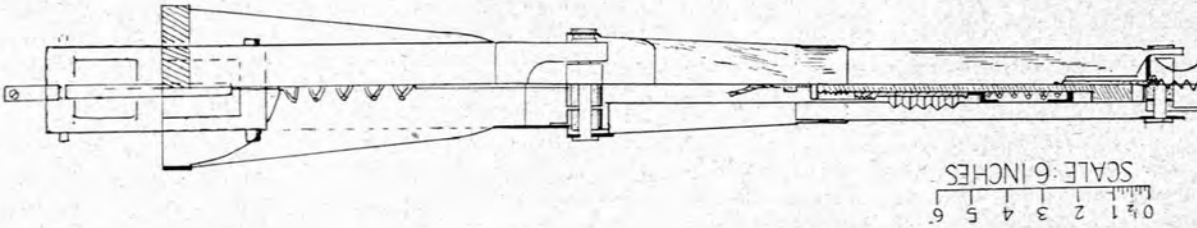
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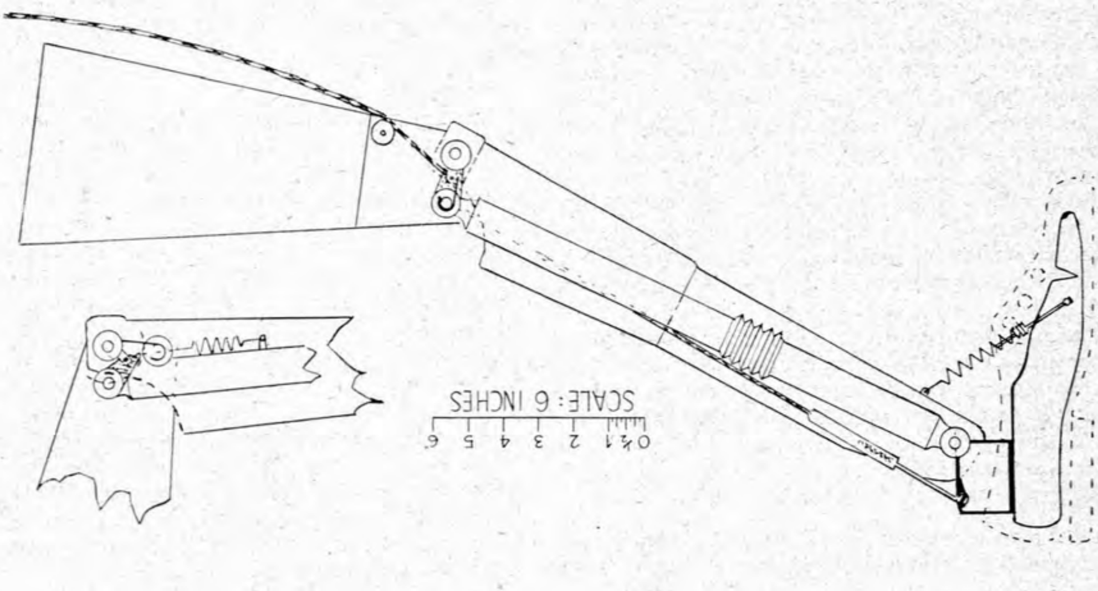
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The hydraulic system is divided into 3 chambers. The lowest is a chamber under high pressure when the piston is being pushed downwards carrying the weight of the amputee. This chamber is below the piston. The second chamber is the chamber formed between the upper part of the piston and the special collar through the centre of which the shaft moves. This chamber at times is also one in which oil is under considerable pressure. A third chamber exists between the special collar and the top of the hydraulic cylinder. This is the no-pressure chamber. It is in this third chamber that a special spring is placed to fit comfortably round the shaft. On insertion, it is compressed to give a pre-loading of between 30 and 40 lb.

The piston is designed to have sinuses through it in such a manner as to permit oil to flow in the proper way.

The Action of the Bias System

Piston downstroke. When the shaft is pressed downwards, oil is compressed in the lowest chamber, passes through a little central hole in the bottom of the piston where the rate of flow is controlled by the point of the needle valve. The needle valve is in turn controlled through an attached flexible cable by the amputee. This compressed oil flows through the piston into the middle chamber. The middle chamber is of smaller volume than the lower chamber because the shaft in this chamber displaces a certain volume of oil. Thus, oil being displaced through the piston will, in part, have to find a passage between the special collar and the shaft into the upper, or no-pressure, chamber. In this way the piston descends slowly at a rate determined, in the first place, by the setting of the needle valve.

The amputee's flexible cable control is brought up alongside the thigh piece to the person's clothing, where it can be worn either in a pocket, or as a button, or in any of a number of convenient ways. If he screws his needle valve down, he will allow less oil to pass through the piston and thus slow the rate at which the piston is pressed down.

While the shaft and piston are being pressed downwards, the special threaded adjustment apparatus at the top of the cylinder and attached to the shaft moves downwards compressing the main spring, and this loading of the spring determines the power with which the leg can be straightened again.

A convenient landing spring can be inserted at the bottom of the lowest chamber for the piston to compress as it gets near the bottom end of its stroke. Thus, at the end of the compression stroke, the spring in the upper chamber has become compressed and stores potential energy ready to push the piston upwards again.

The upward stroke of the piston. The shaft and piston in moving upwards are driven by the previously compressed spring in the upper chamber. Most of the oil will find its way back to the lowest chamber *via* the same channels as were used on the down stroke. Some oil, however, is sucked through a hole made just above the collar in the shaft, and this oil will pass down to the piston through the central shaft lumen. Thereafter it enters sinuses in the piston, lifting little ball valves and re-entering the lowest chamber. The piston will continue to rise in this manner until all except the pre-loaded potential energy stored in the spring in the upper chamber has been used. As described above, the bias-extension tube, being attached to the shaft, will rise and fall with the shaft and piston, compressing the sealing bellows on the down stroke, and elongating the bellows on the up stroke.

Knee-lock Release Mechanism

This mechanism has become very much simplified and consists of a means whereby the pinion labelled 2 can be dislodged from its position to enable the knee to hinge on the pinion labelled 1 for the purpose of sitting down. This knee-lock release control can have a small cable attached to it, or some such similar mechanism, conveniently arranged for the amputee to use at will. On standing up, the pinion 2 automatically reassumes its normal position in relation to 1.

The Pelvic Bucket and Hinge Mechanism

This bucket is constructed according to the description of the Canadian bucket. It is, of course, used only for persons who have an amputation through the hip joint, or a hind-quarter amputation. It is made at present of glass fibre and fitted to include the stump tissues and pelvis. Its under surface is carefully shaped so that the thigh portion can conveniently abut underneath the bucket in the upright position.

The thigh piece is attached to the pelvic bucket by a hinge which employs in principle the concept of the Canadian-hinge system. Incorporated in the hinge is a small adjustable pace-length regulator. Also for convenience the thigh piece is topped with a rubber edging to cushion it against the under surface of the bucket. In the University of Cape Town limb the hinge is especially arranged to permit the thigh piece to swing from its position underneath the bucket, as used in walking, to a similar position in front of the bucket for the purpose of sitting down. The knee release mechanism is coupled to a pelvic bucket hinge-release to permit this to occur.

By means of this special method of hinging it is possible to maintain the proper proportional relationships of leg and thigh lengths in both upright and sitting positions.

HOW THE PROSTHESIS WORKS DURING THE MOVEMENTS OF WALKING

The movements of walking with the new prosthesis are shown in Fig. 8.

In position 1, the amputee is preparing to take a pace. The heel of the prosthesis is being placed on the ground. The body weight of the patient is being thrust down the apparatus. The foot, hinging at pinion 3, is being depressed into a plantar flexed position, elongating the spring AD (Fig. 2).

The prosthetic knee is in a position of extension about the pinion labelled 1. The tendo Achillis, B, is slack. The piston in the cylinder is in the up position. The amputee's body weight is being thrust forward by the impetus of his walking action and by the good leg. As his pelvis rises towards the upright position on the prosthetic leg, the foot becomes slowly dorsiflexed and the tendo Achillis, B, becomes tight. As it tightens it tends to draw pinion 2 towards pinion 4 and

Fig. 3. The coupled action of dorsiflexion of ankle coordinated with flexion of the knee. In this figure the limb is represented as for a through-the-thigh amputation to demonstrate the alternative knee-lock release for such cases. *Above.* The knee as in sitting.

Fig. 4. The movement of upper thigh piece on pelvic bucket from standing to sitting positions.

Fig. 5. Front view. Half-section drawing.

Fig. 6. Sketches of the knee-release link and the knee fittings in their housing.

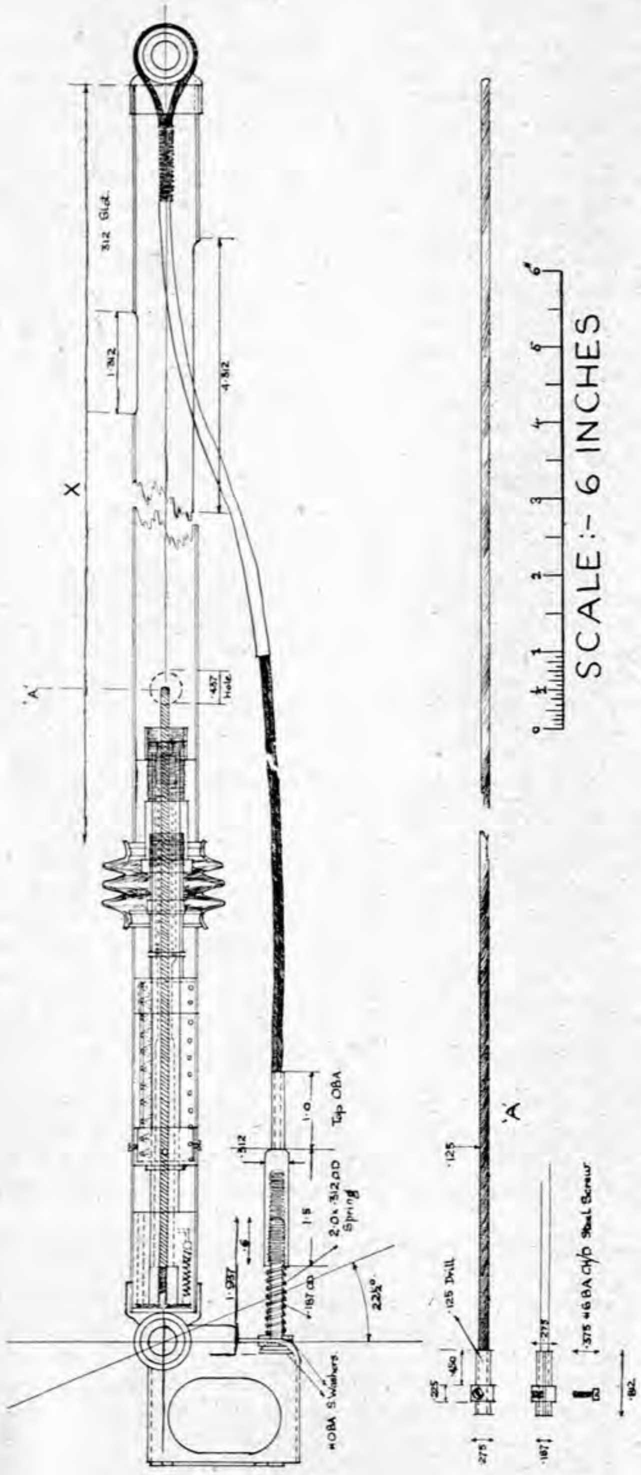

Fig. 7. The hydraulic-spring bias system. In this diagram no landing spring is inserted. Hydraulic-bias extension cap at the top of hydraulic-bias extension should have longer skirts. Length X adjusted as required for patient's leg length.

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this brings about a flexion of the knee. The rate of flexion of the knee is controlled by the compression which results from the downward movement of the piston in the hydraulic cylinder. Thus, in position 2 flexion is beginning to occur at the knee and dorsiflexion is occurring at the ankle. The patient is stable throughout all movements. He can take his full weight on the apparatus. The compression of oil in the lowest chamber by the piston has been regulated to the patient's body weight by himself by adjusting his needle valve through his cable.

In position 3, flexion of the ankle is continued and, with it, flexion of the knee. The piston has moved downwards, almost to the bottom of its stroke in the lowest chamber; it has displaced oil in so doing into the middle chamber, and some of this oil has passed through under the special collar into the no-pressure or upper chamber. At the same time, the spring in the the upper chamber has become steadily compressed. Stability increases, as does the flexion of the knee and ankle. The normal limb has been swung past the prosthetic limb in readiness to commence taking body weight.

In position 4 the normal limb has been placed upon the floor, the prosthetic limb is maximally flexed at the ankle and the knee, and the patient has commenced lifting the pelvis on the prosthetic side. The prosthetic limb can move forward ready for weight bearing, clear of the ground, because the leg length is shortened by the flexion of the knee and ankle.

In position 5 the prosthetic limb is being swung forwards. At this position, where the prosthetic thigh has not yet passed the normal thigh, the rate of oil flow in the cylinder has been so arranged as to prevent rapid extension of ankle or knee, i.e. the clearance between shaft and collar is minimal. The piston is returning by the action of the spring in the upper cylinder; the oil is passing back through two channels into the lowest chamber, in the first instance through the same sinuses that it fed upwards on the down stroke, and in the second instance by lifting the small ball valves in the piston and returning *via* its own special sinuses. Resistance to the return passage upwards of the piston enables the knee and ankle to be kept properly flexed for clearing the ground until the two thighs pass one another.

After the prosthetic thigh passes the normal thigh, however, the velocity of straightening of the knee and ankle is increased, and this has been achieved by locally tapering the shaft as it passes the collar, thus rapidly allowing a flow of oil to occur when desired. This local tapering of the shaft supplies mechanically the same action to the prosthesis as does the quadriceps muscle in a normal limb.

In position 5, then, we can see how the shortening brought about by flexion of the knee and ankle at the same time facilitates the clearance of the ground and mitigates undesirable outward-flinging actions.

In position 6 the amputee is still bearing his weight on his normal leg and, although the prosthetic leg is not yet in position to place its heel on the ground, it has already become straightened at the knee, and ankle and foot are ready for the next weight-bearing step.

Further Improvement

We have designed, but not yet adequately tested, a simple addition. The inclusion of a small cam-like link between the ankle-pinion housing and the ankle pinion is expected to cause still further temporary flexion at the knee when the body weight is taken off the prosthesis.

If successful, this will make an even more profound advance by further imitating natural gait and by increasing clearance ready for the swing past of the prosthetic leg.

MANUFACTURE OF THE LIMB

Parts Made by Factory

The hydraulics, the knee mechanism, and the hip hinge require to be precision made. Some of these parts need to be specially hardened. These should be constructed by engineers capable of normal precision work. The metal housings for thigh, leg and ankle pinion would best be made by experts in sheet-metal work. This sort of work is already being done by present-day manufacturers of artificial limbs. The shape of these components has been simplified in order to lower the manufacturer's costs. Cables with a good range of adjustment on their swagings should be supplied attached to their components. This applies also to springs.

The foot should be made by wood machinists who use a master foot and make any number by means of parallel spindling. It would be of advantage, if the manufacture of such foot pieces proved reasonably inexpensive, to supply different feet particularly to women who may wish to change shoes. The University of Cape Town foot is greatly simplified as compared with the foot of present-day prostheses, and factory production should be simple and cheap.

The Work of Technicians

As in modern lower-limb fitting, the technician's work would involve putting the pieces together and fitting them to the patient. There is no difference as regards bucket fitting which remains as it has always been. The work required in fitting shoes to the artificial foot should be rather less with the University of Cape Town foot and simple techniques can be evolved and improved upon with the passage of time.

The fitting of the completed leg to the patient should also be rather simpler than is the case with modern standard lower-limb prostheses, except in the patient with the through-the-hip, or hemipelvectomy type of amputation. In such cases the technique to be followed is virtually as laid down by the Prosthetics Research Board, Canadian Research Council for the Canadian Type of Hip Disarticulation Prosthesis.[4] Details of technical method will still require to be improved for obtaining the alignment of the components of the limb in the above-hip amputation cases.

Limb Length Adjustment

This will be the orthopaedic technician's province. The thigh-piece top will have to be cut and shaped so as to bring it into good contact underneath the pelvic bucket in trans-hip and hemipelvectomy amputees. This must be done with due regard to the proper thigh length from knee to anterior superior iliac spine. In trans-thigh amputees this is simpler, but nevertheless the weight-bearing distance from knee to anterior superior iliac spine must again be kept the same as on the normal side.

The leg length adjustment is then determined and set by sliding the drawn tube of the leg housing in its upper shaped piece and then cutting and riveting.

Having determined the leg length, the technician must then cut the top of the bias-control extension tube to its proper length and attach its pinion-carrying top piece. This is sweated on with soft solder. Final delicate adjustment of the bias-control length is then made before fastening the neoprene sealing bellows into place by screwing the bias-extension tube in or out as required.

These adjustments are all simple when understood. Special care has been devoted in design to accessibility of components, thus cutting down the technician's fitting time as far as possible.

The only additional duty the technician has, is the making of suitable rubber coverings to the shape of the limb which has been lost. This is done as follows:

The patient's normal limb is laid sideways on a piece of template paper and a pencil held vertically traces the anterior outline of the limb from the groin to the dorsum of the foot. At 2 or 3-inch intervals the hemicircumference of the normal leg is projected backwards from this anterior profile on the template. A faired line, joining these hemicircumferential loci, is then drawn and the template cut. This template is placed over two $\frac{1}{4}$-inch thick sheets of sorbo rubber and the rubber sheeting cut to the shape of the template. The front and back edges of the sorbo-rubber shapes are then joined together by a suitable adhesive. By this method a reasonably accurate limb shape can be obtained simply and quickly.

Conveniently shaped small pads of plastic foam are glued where desired on to the metal leg and thigh housing to make this sorbo-rubber covering conform more accurately to the leg shape in mirror image to the healthy limb. With a little

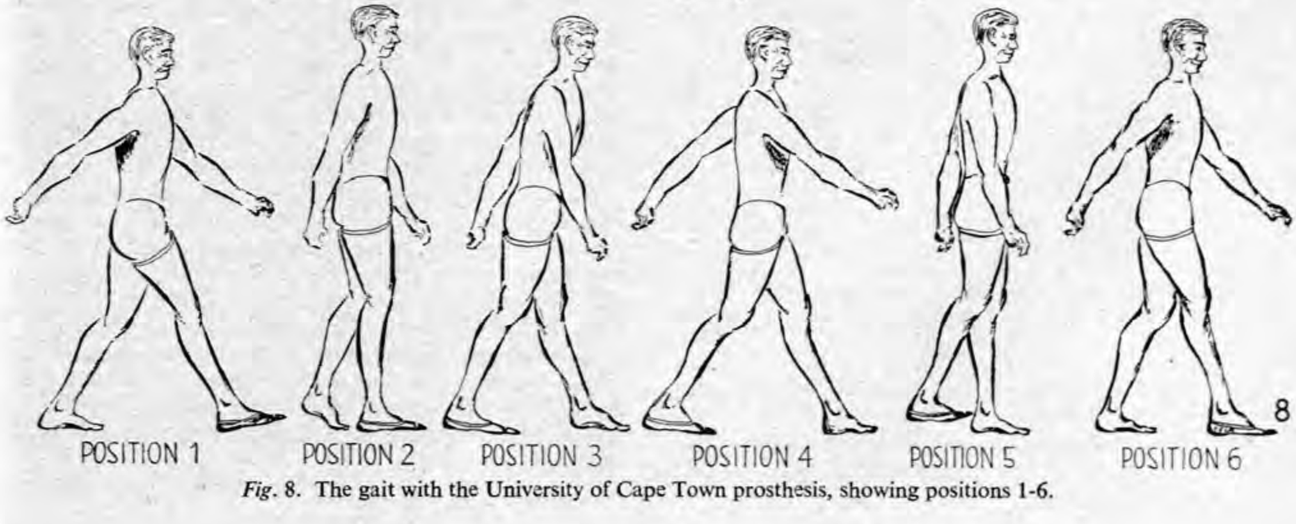

Fig. 8. The gait with the University of Cape Town prosthesis, showing positions 1-6.

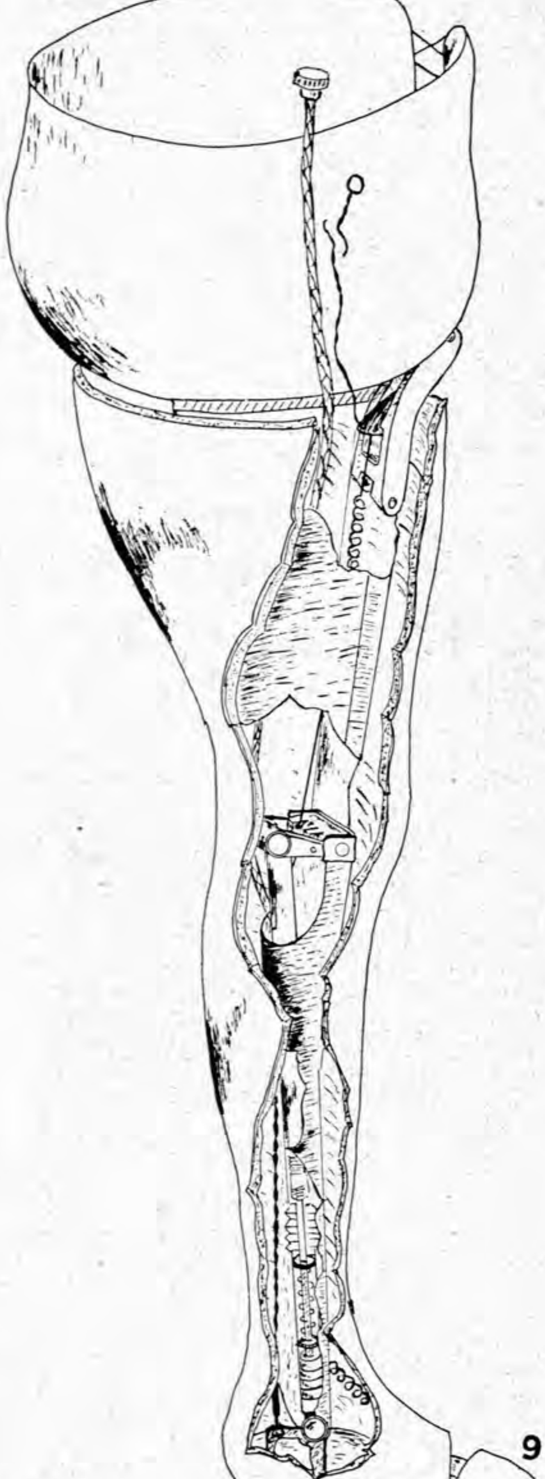

Fig. 9. Cut-away schematic drawing of the University of Cape Town prosthesis.

practice the technician will find this much simpler than it sounds. On our experimental limbs we are now rapidly able to obtain a shape which would deceive even an expert eye.

All this technique requires to be developed further. It is possible that rubber companies which manufacture sorbo rubber may one day make ready-made rubber sheaths which could easily be shaped to suit.

The rubber covering requires to be fastened to the wooden foot-piece and this can be done in a number of ways.

In turn, the rubber is covered by a suitable skin-tint material. We have found a pair of acrobatic tights suitable for this. One leg-piece is cut off and over-stitched to prevent running, and pulled over the sorbo-rubber cover. This, in turn, is covered by the patient's own socks or stockings.

General Technical Data

Sheet work generally. 16 s.w.g. $\frac{1}{2}$-hard aluminium. Rivets are $\frac{1}{8}$-inch diameter aluminium.

Pivots. Silver steel running in teflon bushes.

Release and locking devices. Mild steel, case-hardened and double quenched.

Wooden foot. Birch.

Hydraulic cylinder. Stainless steel honed; piston m.s. ground, and shaft silver steel. Needle valve is silver steel and return valves $\frac{1}{8}$-inch ball bearings.

Oil. Multigrade S.A.E. 10 W-20.

Sealing bellows. Neoprene.

False tendo Achillis. Bowden cable 20 strand, 30 s.w.g. per strand.

Coverings. Outer, $\frac{1}{4}$-inch thick foam rubber with smooth outer skin coloured appropriately for patient's skin colour. Fillings and padding are foam plastic.

PATENTING

The University of Cape Town Artificial Limb has been patented and the right to make it requires to be obtained under the patent from the National Council for the Care of Cripples in South Africa.*

The main purpose in patenting this principle and design of lower-limb prosthesis has been to ensure that the limb does not become unreasonably exploited commercially. The act of patenting the apparatus was only adopted after deep consideration, and finally provoked by the growing tendency for over-commercialization in the field of such medical apparatus. It is strongly felt that it is a wrong principle to make a handicapped minority pay for royalties. Nobody at any time may draw royalties from the invention, or the principles which are used in the invention of this limb. It is hoped that this principle will become observed, not only in respect of this particular limb, but also in respect of other apparatus which is needed for handicapped persons.

As regards the limb itself, it is our earnest plea that future improvements which may be made from time to time by persons in any part of the world will be carried out by those who appreciate the importance of this humanitarian principle and who will observe an altruistic viewpoint in regard to it without attempting to patent for personal gain.

Although the research unit in the Department of Orthopaedic Surgery is in dire need of funds, it has nevertheless spurned the opportunity of claiming royalties, even in the face of its not being able to further future research for this reason.

* This matter is still under discussion

WORKING DRAWINGS

The detailed working drawings will become obtainable through the National Council for the Care of Cripples in South Africa* by persons who agree to manufacture the limb under the simple conditions laid down by the patenting act, namely that no undue profit and no royalties be drawn from the patenting.

BELOW-KNEE PROSTHESIS

Throughout a day's walking on a standard below-knee prosthetic limb both stump and amputee suffer severely. By applying the University of Cape Town limb hydraulic cylinder, fixed above to the leg housing and below to the foot, the shock of the amputee's weight on the heel can be absorbed. The foot can go into dorsiflexion on the forward prosthetic weight-bearing pace and this dorsiflexion can be maintained for ground clearance, as for the above-knee prosthetic limb. Obviously the problems of below-knee prosthetics are simpler than those for above-knee.

CONCLUSIONS

1. The prevalent principle in above-knee prosthetic design of obtaining knee stability by knee back-bracing against a down-toed foot is a violation of good anatomic principles and must for ever be discarded.

2. The new principle to take its place is that mechanical devices must aim at action which is as near as possible to that used by the normal person.

3. Even the materials used should be so chosen and employed as to replace as reasonably as possible what has been lost.

4. If the above three principles are observed, much will be done towards far-sighted rehabilitation in its widest sense.

5. A renascence is required through which fundamental research should return to the control and direction by universities. There has been a dangerous drift of scientists and their work towards specific and commercialized research. Such a drift must ultimately result in sterility in all spheres. Although this trend is not discussed in this article, it should be mentioned because the work done in developing this limb and its principles of action has been in the face of such difficulties which have made this point abundantly clear.

6. The growing dangers of selfish monopolistic over-commercialization of apparatus and medical requirements of the needy are real. The world must become conscious of this and take rational action.

This has been done in this work by using the protective mechanism of patenting the principles and mechanical design of the University of Cape Town Artificial Limb.

SPECIAL RECOGNITION OF ASSISTANCE

Described in this article is the University of Cape Town Artificial Limb in its final and very simple state. This limb has taken many years to evolve; it has not become a fact by accident. However, even years of sound research and the knowledge of what was required was not enough to bring about its realization. An expert precisionist and designer had to be found, capable of translating a quasi-mechanical academic concept into mechanical reality. This expert was found in the person of Mr. L. V. Holmgren.

Mr. Holmgren, a principal mechanical assistant of the Trigonometrical Survey Department of Cape Town, voluntarily devoted most of his spare time over the first 2 years of the project. He constructed many special models, drawings and diagrams, and was mainly responsible for the evolution of the mechanical apparatus to its present simplified form. I therefore wish to thank him especially for the work he has done.

The Patient

The voluntary patient, Mrs. J. Tribelhorn, was selected partly because she presented the challenge resulting from a hip-disarticulation amputation, and largely for her courage and qualities as a factual observer. She has had to travel 300 miles each way for fitting with each new prototype, and to tolerate falls and frights similar to those experienced by an aeronautical test pilot. We are all grateful to her for the part she has played so admirably.

I wish to thank the University of Cape Town under whose auspices my Department has been enabled to do this work, and the Dean of the Faculty of Medicine, Prof. B. Bromilow-Downing, for his valuable guidance over relationships between Provincial Departments and the University.

I also wish to thank the National Council for the Care of Cripples in South Africa, which has made available funds for tools and apparatus and for the purpose of patenting the limb for its protection. Without this help the work could not have reached its present stage of success.

The Hospitals Department of the Cape Provincial Administration has given every assistance permitted by their regulations. The Provincial technicians under Mr. D. Louw, Mr. T. O. Davies and Mr. R. C. Vigus have earned my gratitude for their assistance; also Mr. A. H. Hodges, who helped to make the first pelvic bucket for Mrs. Tribelhorn.

I thank Mr. G. McManus of the Department of Surgery and Mr. R. C. Hampton for the time they have given us in mechanically assisting Mr. Holmgren.

Photography and cinematography were carried out by Mr. G. McManus, with the kind consent of Prof. J. H. Louw, Head of the Department of Surgery, and by Mr. B. T. A. Todt, by kind permission of the Medical Superintendent of Groote Schuur Hospital, Dr. J. Burger. I extend my special thanks to both these photographers, and also to Mr. J. Linney of Thornton Estate, for voluntarily coming to our aid in taking the last test cinematograph reels.

Finally, I wish to thank Mrs. J. Forsyth, my secretary, for the immense amount of correspondence work she has coped with and the time she has devoted to translations, and for many organizational matters which she has attended to.

Two donors, who wish to remain anonymous, have each contributed an amount of £1,000 to start a fund for future research in the Department of Orthopaedic Surgery, University of Cape Town.

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The British Commonwealth Ex-Services League have magnanimously offered to carry out the first 6 'guinea-pig' trials before manufacture can become possible. This is consistent with the spirit of BCESL members and is an outstanding offer.

A Government organization is giving consideration to making the first manufacturer's test run for their own employees as soon as the BCESL test has proved successful.

* This matter is still under discussion

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