# United States Patent [19]

**Long et al.**

[11] **3,820,169**

[45] **June 28, 1974**


[54] **LOWER LIMB PROSTHESIS**


[76] Inventors: **Ivan A. Long; Richard L. Long,** both of 1478 Birch St., Denver, Colo. 80220



[22] Filed: **June 2, 1972**

[21] Appl. No.: **258,949**

**Related U.S. Application Data**

[63] Continuation-in-part of Ser. No. 71,745, Sept. 14, 1970, abandoned.

[52] **U.S. Cl.** ..... **3/22,** 3/21, 3/7

[51] **Int. Cl.** ..... **A61f 1/04,** A61f 1/08

[58] **Field of Search** ..... 3/22–30, 2, 3/21, 6–8



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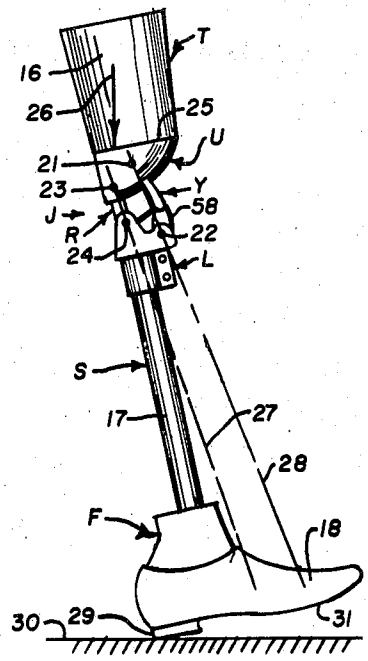
*Attorney, Agent, or Firm*—Horace B. Van Valkenburgh



[57] **ABSTRACT**

The lower limb prosthesis includes a knee joint connecting a thigh section to a shin section, to which a foot is attached, the knee joint including a rear link and a yoke-shaped front link pivotally connected between upper and lower bodies, and the rear link pivot points being so positioned that, with the lower limb in extended position, an extension of the centerline of the rear link pivot points will intersect the foot forwardly of the heel, while extensions of the centerlines of the rear link and front link will intersect above and rearwardly of the knee, to provide stability. A wedge-shaped abutment, engageable with the rear link, limits pivotal movement of the joint and is adjustable to change the point of release, i.e. the point at which the knee joint will begin to flex, when the body moves forwardly over the foot, during walking. An elastic strap interconnecting the forward and rear links resists extension after flexing and prevents terminal impact. A shin tube extends between clamps on the lower body of the knee joint and the foot, so that tubes of different lengths can be used to provide different lengths of the lower limb.


**10 Claims, 17 Drawing Figures**



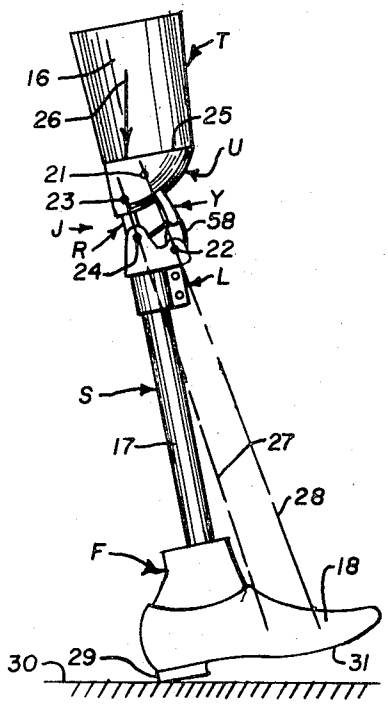



Fig. 1

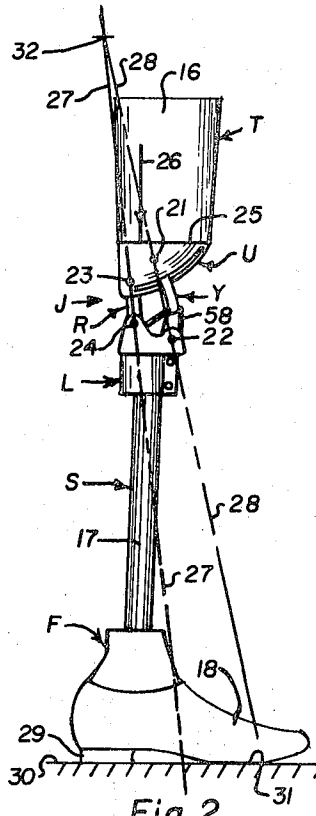



Fig. 2

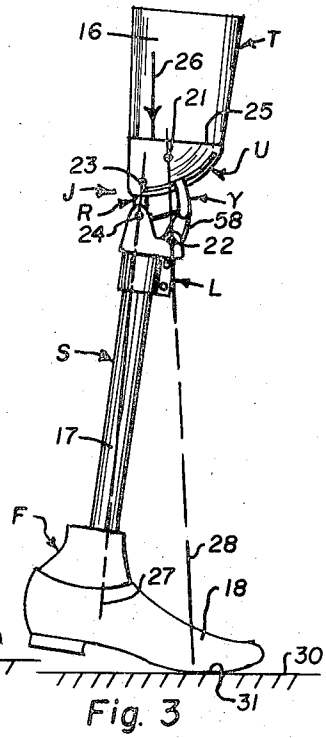



Fig. 3

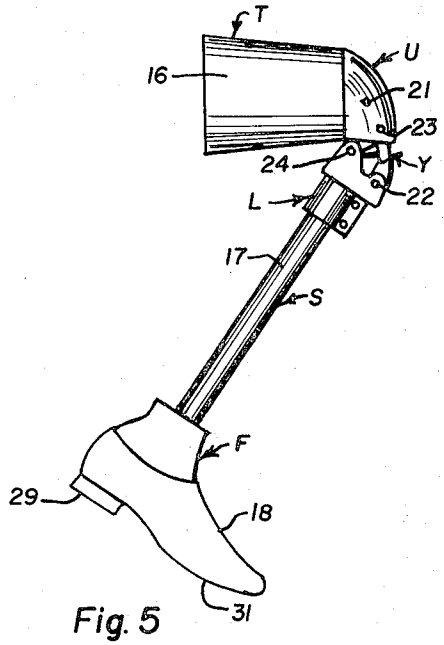



Fig. 5

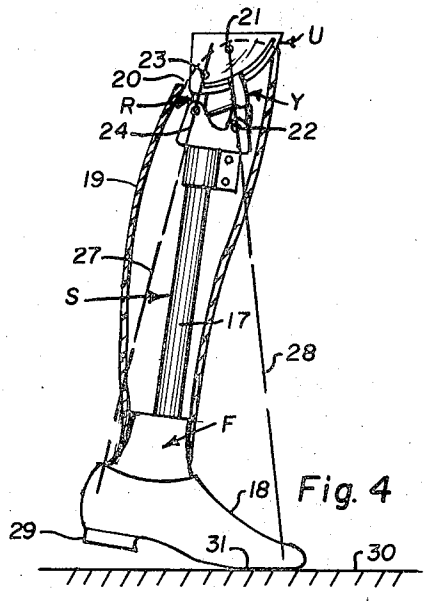



Fig. 4

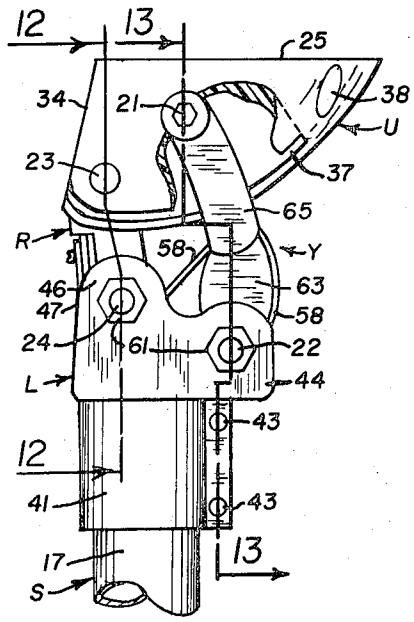



Fig. 6

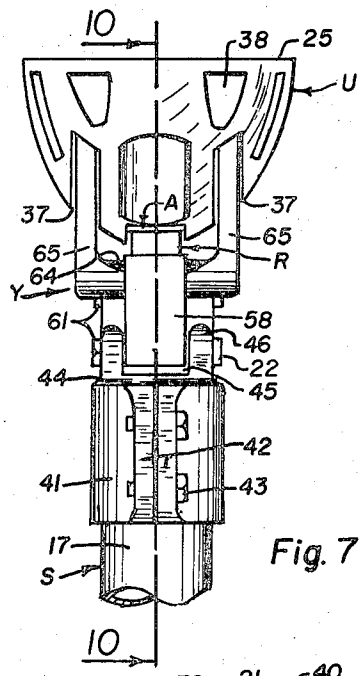



Fig. 7

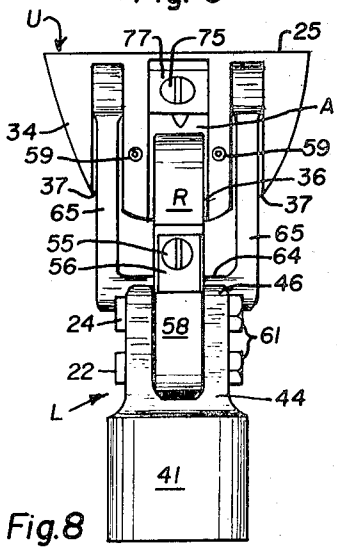



Fig.8

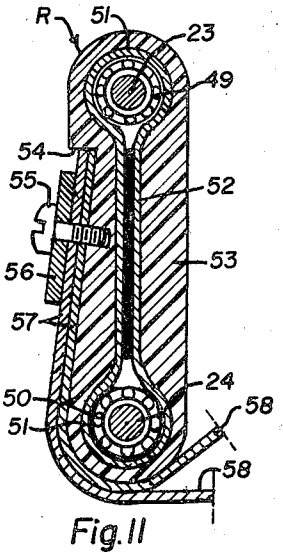



Fig.11

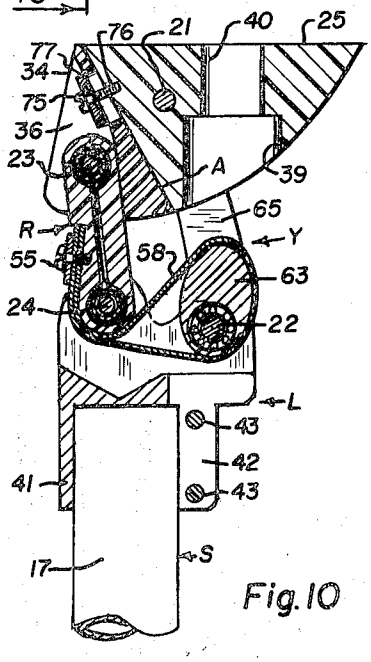



Fig.10

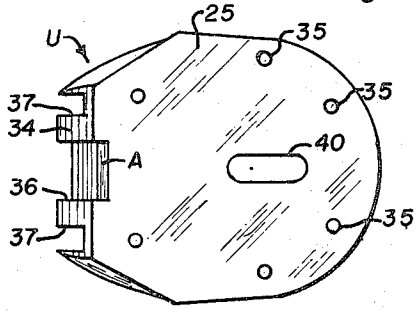



Fig. 9

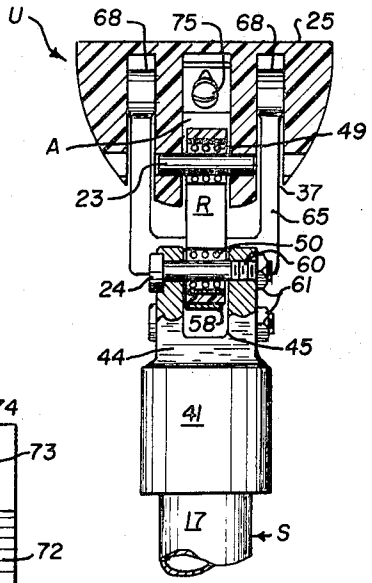



Fig. 12

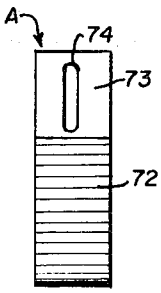



Fig. 15

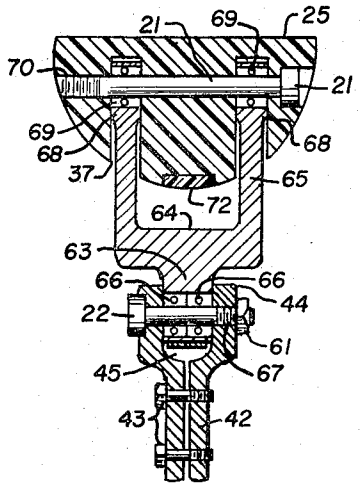



Fig. 13

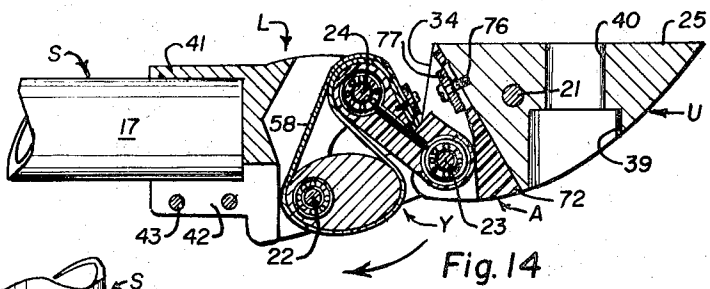



Fig. 14

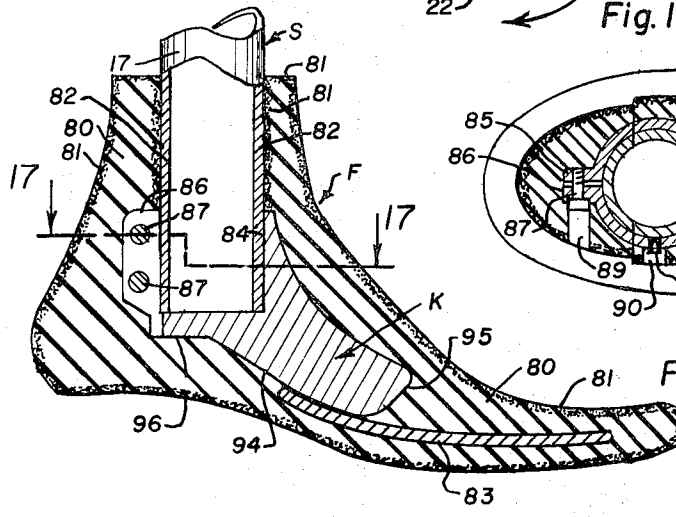



Fig. 16

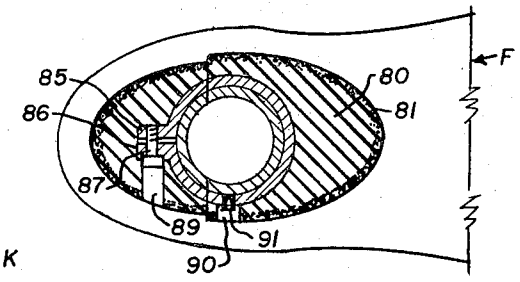



Fig. 17

# LOWER LIMB PROSTHESIS

This application is a continuation in part of our copending application Ser. No. 71,745, filed Sept. 14, 1970 (now abandoned).

The present invention relates to prosthetic appliances, and more particularly to artificial legs and articulated knee joints therefor.

Considerable study and effort have been directed to the improvement of artificial limbs and especially to the improvement of the knee joints in artificial legs. There is a need for an improved knee joint of an artificial leg to permit an amputee wearing the limb to walk in a manner which duplicates, insofar as possible, the walking movements of an ordinary person. It is necessary for an artificial leg to have stability so as to remain in a straight, locked position while the user is standing on it and during certain cycles of a walking step to prevent the limb from buckling under the weight of the amputee wearing such a limb. In other cycles of a walking step, however, a flexing of the knee is desirable. For example, after the amputee swings such an artificial limb, the limb must be straight and remain straight for a period thereafter, when the limb is supporting him. During subsequent cycles of the step, however, when the amputee shifts the weight of his body from the artificial leg to his other leg, the artificial leg shifts to a position rearwardly of the body and then is swung forwardly for another step. When the amputee shifts his weight from the artificial leg during these subsequent cycles of a step, it is desirable that the knee joint of the artificial leg flex, so the foot of the leg will clear the ground surface as the leg is swung forwardly. This problem is particularly acute for the double amputee, who must wear a pair of artificial legs with knee joints, as well as the single amputee who has a relatively short stump and therefore is unable to utilize as effectively muscles attached to the femur.

Associated with the need to improve the knee joint of an artificial leg is a further need to construct the artificial leg in as natural appearing a manner as possible, and especially to provide a foot for the artificial leg which appears substantially the same as a normal foot capable of being fitted into a shoe and which can also function in a manner which will assist the amputee in walking and standing. A number of foot structures may be used for this purpose, such as a type similar to the prosthetic foot disclosed in U.S. Pat. No. 3,098,239 issued July 23, 1963. Such a foot is a comparatively rigid member consisting of a rigid core covered with a tough, resilient foam material, such as a high density, closed pore, polyurethane foam. Such a foot may be rigidly secured to the shin section of the artificial leg. However, such a foot structure does not approximate the bending and resiliency of the human foot to produce more normally appearing walking movements. Thus, there is a further need for an artificial foot structure which will more clearly approximate normal walking movements.

It is also desirable to provide such a limb which will accommodate different distances between the knee and foot, in accordance with the user, and does not require substitution of expensive or complicated parts to achieve the same, as well as an artificial leg which can be used as either the left leg or right leg.

The present invention was conceived and developed to attain the most desirable position of the artificial leg, while walking, for the knee joint to release from the stiff, straight leg condition to a flexing condition, such being hereinafter referred to as the "point of release". The most desirable point of release is when the amputee's body moves forwardly of the artificial foot and the pressure of his weight upon the artificial foot shifts to the toe portion, or the ball of the artificial foot mounted upon the limb. The invention thus comprises, in essence, an artificial leg including a thigh section, an improved, flexible knee joint and a shin section. The shin section includes a naturally appearing foot, and the lower portion of, or the entire, artificial leg may be enclosed in a case having the appearance of a natural leg, if desired.

The flexible knee joint defines a compound linkage, referred to as a four-bar linkage. This linkage consists of an upper body portion of the thigh section, a lower body portion of the shin section and a pair of links between these body sections arranged to hold the limb straight, with the linkage in a locked position, whenever the weight of the user is upon the heel of the foot, or when the user is merely standing flatly upon the foot, and to provide a point of release to permit the knee joint to flex as soon as the user's weight is shifted to the ball of the foot.

The improved artificial foot, which is rigid where necessary but which permits bending and flexing at the ball of the foot, embodies a solid keel which extends to the ball portion of the foot and a relatively stiff but resilient pad which extends from beneath the front portion of the keel across the ball portion and into the toe portion of the foot. Both the keel and the pad are embedded in a relatively thick covering of resilient foam material.

It follows that an object of the invention is to provide a novel and improved artificial leg having a flexible knee joint which functions to permit an amputee to walk in a manner which closely simulates a natural walk.

Another object of the invention is to provide a novel and improved artificial leg having a flexible knee joint, which is released from a straight leg locked position to a flexing position by simple weight shifting movements of the amputee without requiring him to exert unnatural pressure or lifting movements against the artificial leg, as by his leg stump, and permits him to swing and flex the artificial limb in a manner closely akin to natural walking movements. This permits a greater degree of freedom in walking and also a greater feeling of reliability and safety by the amputee when using the leg, especially in difficult situations, as when walking down a ramp.

Another object of the invention is to provide a novel and improved artiflcial leg having a flexible knee joint which operates by simple weight shifting movements only and is thus especially desirable for an amputee having a short, weak leg stump and for a double amputee requiring two artificial legs.

Another object of the invention is to provide a novel and improved artificial leg having a flexible knee joint which is controlled to permit flexing to occur by the simple shifting of the amputee's weight to the ball of the foot on the artificial leg, and which includes further, a simplified but effective means for adjusting the precise point of release of the linkage to suit the requirements of the amputee wearing the limb.

Another object of the invention is to provide such an artificial leg which is stable or on which the user can

stand, with the leg in an upright position, without the knee flexing.

Another object of the invention is to provide such a leg in which the different distances between the knee and foot will be accommodated easily and inexpensively.

Another object of the invention is to provide such an artificial leg which can be used for either the left or right leg.

Another object of the invention is to provide an artificial leg having a flexible knee joint which permits the shin section to be pivoted under the thigh section to a greater extent than is normal for previous artificial legs.

Another object of the invention is to provide an artificial foot which more nearly approximates the bending of the human foot during walking.

Another object of the invention is to provide such a foot which is particularly adapted to be utilized as a part of the artificial leg of this invention.

A further object of the invention is to provide a novel and improved artificial leg having a flexible knee joint, each of which is a simple, economical, neat appearing, rugged, durable unit.

With the foregoing and other objects in view, our invention comprises certain constructions, combinations and arrangements of parts and elements as hereinafter described and illustrated in preferred embodiment in the accompanying drawings, in which:

FIGS. **1, 2, 3** and **4** are side elevations of the improved artificial leg at several positions during a walking step, FIG. **1** illustrating the commencement of a step where the limb is forwardly of the user's body and weight is being placed on the heel of the foot thereof,

FIG. **2** illustrating an upright standing position,

FIG. **3** illustrating the limb at the point of release of the knee linkage when the weight of the user is shifted to the ball of the foot, and

FIG. **4** illustrating the position just prior to transfer of weight to the opposite leg, after the knee linkage has shifted from a locking position to a flexing position, with a covering for the shin section being shown in FIG. **4** but omitted from FIGS. **1–3** for clarity of illustration.

FIG. **5** is a side elevation similar to FIG. **1**, but illustrating the knee as being substantially fully flexed, as when the amputee is sitting upon a chair, with the shin section moved underneath the thigh section.

FIG. **6** is a side elevation of the mechanism forming the knee joint of the artificial limb, partially broken away to show certain interior parts more clearly.

FIG. **7** is a front elevation of the mechanism shown in FIG. **6.**

FIG. **8** is a rear elevation of the mechanism shown in FIG. **6.**

FIG. **9** is a top plan view of an upper body of the mechanism of FIG. **6.**

FIG. **10** is a longitudinal vertical section, taken along line **10—10** of FIG. **7.**

FIG. **11** is a longitudinal vertical section, on an enlarged scale, of a rear link and portions of the elastic strap attached to the link, of the above mechanism.

FIG. **12** is a transverse vertical section, taken along line **12—12** of FIG. **6.**

FIG. **13** is a transverse vertical section, taken along line **13—13** of FIG. **6.**

FIG. **14** is a longitudinal section similar to FIG. **10** but illustrating the knee joint as being flexed, as in the direction of the indicated arrow, so the shin section of the limb is swung to a position 90° from the straight leg position shown in FIG. **6.**

FIG. **15** is a plan view, on an enlarged scale, of an adjustable abutment used in the above mechanism.

FIG. **16** is a longitudinal section of the foot and its connection to the bottom of the shin section.

FIG. **17** is a fragmentary plan view, taken partly in offset section along line **17—17** of FIG. **16.**

Referring more particularly to the drawings, FIGS. **1** through **5** illustrate in a somewhat diagrammatic manner certain operative positions which the artificial limb may assume in actual use, as will be further described. The components forming the artificial limb include a thigh section T, a knee joint J, a shin section S and a foot F. The knee joint J is a flexible member interconnecting the thigh section and shin section and can hold the leg in a straight, extended, locked position, or release to permit the lower or shin section S of the leg to swing and flex, and its structure will be hereinafter described in detail. The thigh section T includes a rigid cup-like member **16** which functions as a stump socket. As such, its form may be varied in length and diameter to properly fit the leg stump of an individual amputee and also it may include straps and other connective gear, not shown. The bottom of the stump socket **16** is flat and normal to the axis of the thigh section, while suitable tapped holes, not shown, are provided in this bottom, so that the knee joint J may be bolted to it. The shin section S includes a simple, rigid tube **17** or pylon having its upper end connected to the knee joint J and its lower end to the foot F. Foot F is formed of resilient material, with a rigid center piece or keel K of FIG. **16,** in the general shape of a human foot and sized to receive a conventional shoe **18,** as in FIGS. **1–5,** to provide a normal, ordinary appearance. To further simulate the appearance of a normal leg, the shin section and a portion of the knee joint J are encased within a resilient, smooth shell or cover **19,** shown in FIG. **4** and formed of sponge rubber or other suitable material. Cover **19** is hollow and simulates the contour of a leg, extending downwardly to enclose the upper portion of foot F and upwardly at the front to mate with the upper portion of the knee joint, with a cutout **20** at the rear to accommodate movement of the shin portion S to the position of FIG. **5.**

The knee joint J is symmetrical to the median plane of the leg and includes a rear link R or control link and a front yoke link Y or swing link, each of which is pivoted between an upper body U and a lower body L. Thus, the upper ends of the front yoke link Y are pivoted on a pin **21,** located as closely as possible to the stump socket, and the lower end on pin **22.** The upper edge of cover **19** preferably just covers the upper pivot pin **21.** The upper end of rear link R is pivoted on a pin **23** and the lower ends thereof on a pin **24.** The upper body U has a flat top **25** generally normal to the vertical leg axis of the member for attachment to the stump socket **16** thereto. The upper end of tube **17** or pylon is attached, as by clamping, to the lower body U and the lower end to foot F, in a manner described below, although this feature of the invention permits pylons of different lengths to be used to provide different lengths of the shin section S, which reduces considerably the expense of providing a different leg length.

It is essential that the knee joint lock when the leg is straight and the amputee's weight, a downward force represented by the arrow **26** of FIGS. **1–3**, is supported by the leg. Thus, when the leg is straight, the rear or control link R and the yoke or swing link Y are each inclined to a position where they are biased to urge the shin section S of the leg forwardly, responsive to the weight of the amputee. To prevent any forward swing of the shin section, control link R bears against an abutment A of FIG. **10**, the preferred construction and adjustment of which are described below. The respective locations of the pivot pins connecting the control link R and the swing link Y to the upper and lower body members, and the length of the links themselves, effect a combined shifting and rotation of the lower body member with respect to the upper body member, as in the median plane of the limb. Each rear or control link R is substantially shorter, as about one-half the length of the swing link Y; however, when the limb is in a straight position, the two links are in the general direction of the axis of the limb, with the axis or centerline between pivots of control link R represented by the link **27** and the axis or centerline between pivots of swing link Y represented by line **28** of FIGS. **1–4**. In general, whenever the shin section of the leg shifts rearwardly from the straight leg position, both links shift together in unison with the shin section moving rearwardly, and with a minimum degree of rotation of the shin section. Subsequently, the longer swing link Y will cause rotation of the shin section, and the swing link will cross the control link, to effect a maximum swinging action without significant translation of the leg section.

In the present invention, it was discovered that the most desirable action of an artificial leg was to permit this locked knee joint to attain a point of release as the weight of an amputee is shifted to the ball of the foot, a position of unstable but easily controllable equilibrium of the control link, with the link axis at the center of pressure, as indicated in FIG. **3**. This is in contrast with the common practice of adjusting artificial limbs of the type herein considered, so that pressure on the ball of the foot causes the knee joint to become stable. In such an arrangement, the amputee is required to manipulate the stump, by an unnatural forward movement, as the artificial limb commences to shift backwards. The present invention requires only a moderate natural shifting of weight to permit the knee to commence flexing. It was discovered that this comparatively quick release by a mere shift of weight would not create any falling hazard, and that even a double amputee could easily walk up or down an inclined ramp, a feat considered most difficult for such an amputee. Moreover, with the improved knee joint J, it was possible to make slight adjustments of the abutment A to change this alignment, first to accommodate the stump length of a particular individual, and, second, to accommodate the taste of an individual with respect to the "feel" of the action of the knee joint. With the user standing upright and the leg in straight or extended position, as in FIG. **2**, it was found that an angle of 6° between the rear link R and the vertical would normally provide the maximum locking action and that, for most users, the most desirable angle would be between 7° and 5°, obtained through adjustment of abutment A, as described later.

The above action may be explained by reference to FIGS. **1–4**, in which the artificial leg and particularly the knee joint are shown in a sequence of positions involved in taking a step with the leg shown. In FIG. **1**, the leg has been moved forward in the step, the heel **29** of shoe **18** being in engagement with the ground **30**, with the weight of the user, indicated by the arrow **26**, having been transferred to that leg. Due to the fact that centerline **27** of the rear link R, as well as the centerline **28** of the yoke link Y, extend downwardly to a position forwardly of the heel **29**, the links R and Y will remain locked, with the leg in fully extended position. In other words, the rear link is inclined rearwardly. It will be noted that the abutment A, which will be described in detail later, prevents counterclockwise pivotal movement of the knee joint.

When the body shifts forwardly until both the heel **29** and the portion **31** of the shoe corresponding to the ball of the foot receive the body weight, i.e. the ball portion **31** engages the ground surface **30**, as in FIG. **2**, the knee joint will still be locked in extended position because the centerline **27** of the pivot axes of link R is between ball and heel, i.e. the rear link is still inclined rearwardly. Additional stability is provided by the intersection, as at **32** of FIG. **2** of the axes or centerline extensions **27** and **28** of the rear link R and front link Y, particularly above the knee joint and slightly rearwardly thereof. Thus, in standing position, not only are both rear link R and front link Y inclined rearwardly, but are also inclined toward each other. As long as the weight on the heel is greater, or the weight is equally distributed, the knee joint will remain locked. In this connection, it will be noted that the knee joint is provided with means, described later, which resists unlocking and therefore slows the flexing of the knee joint. This device also prevents a flexing of the knee joint if a temporary unbalance of weight distribution, such as more on the ball of the foot than the heel, occurs. Thus, the user may stand without undue difficulty, in an upright position, on one or both feet without the knee joint flexing or, in the case of a double amputee, without either knee joint flexing.

However, during walking, as soon as the weight shifts to the ball of the foot, as shown in FIG. **3**, the centerline **27** of the rear link R, as extended, is behind the ball of the foot, so that the upper end of rear link R will no longer be urged rearwardly by the weight of the user and may begin to pivot to produce flexure of the knee joint. Such pivoting continues to the position of FIG. **4** and beyond, although the bending of the knee joint is such that the knee remains at its approximate elevation. At this time, the other leg is being swung forwardly in order to receive the weight as soon as the heel of that foot engages the ground. In the meantime, the body has moved forwardly with respect to the leg as shown in FIG. **4**, wherein the rear link R is inclined forwardly and the knee joint is easily flexed. As the opposite leg takes the weight, the first leg will be relieved of the weight and can be pulled forwardly. During this forward movement, until the first leg reaches the position of the second leg, the weight of the shank portion S and foot F and a rearward thrust of the stump will tend to cause the leg to straighten, assisted by the aforementioned means which resists flexing of the knee joint. Thus, by the time the first leg has moved past the second leg, it is in an extended position and prepared to take the weight to be thrust upon it, i.e. at the position of FIG. **1**.

It will be understood that, during walking, the knee joint may flex to a greater extent than shown in FIG. **4**, as to a position in which the axis of the shank S is at an angle of approximately 20° to 30° to the axis of the thigh portion T. Of course, the knee joint can be bent to a greater angle, as when the user is at rest or perhaps sitting down. Thus, the knee joint can be bent to the 90° angle shown in FIG. **14**, or even a greater angle, as in FIG. **5**, such as 135 ° from a straight position. When bent to the latter angle, the rear link R crosses over the yoke link Y, as shown, with the rear link extending into the opening of the yoke link. The ability to bend the knee joint to the angular position of FIG. **5** is of great advantage to the user. For instance, the user, while sitting down, may pull the shank and foot toward him, so as to be able to tie the shoestrings on the shoe **18**, a feat which has been difficult to accomplish with prior prostheses for the same purpose.

The upper body U is preferably formed from a structural plastic material with a low coefficient of friction, such as nylon, as by molding, although any suitably strong but lightweight material could be used. The upper body U, as in FIGS. **6–10** is cup-shaped with the front and sides being prow formed, having a rear wall **34** inclined outwardly and downwardly at a small angle from the leg axis, with the flat top **25** generally normal to the leg axis. The upper body is bolted to the underside of the stump socket **16**, as by bolts extending through holes **35**, shown in FIG. **9**. A central, median slot **36** in the rear wall and side slots **37** at each side of the central slot, but extending from front to rear on the underside of the body, provide openings for movement of the rear link R and yoke link Y, respectively, with the pivot pins therefor extending across the respective slots, as in FIGS. **12** and **13**. A notch **38**, below each bolt hole **35**, is provided in the inwardly tapered outer wall to provide a flat seat for the bolt heads and readier access thereto. The center of upper body U may be solid, but is preferably provided with a well **39**, formed, as in FIGS. **9** and **10**, with a slot **40** extending upwardly therefrom to the top **25**, to permit temporary attachment of the upper body U to a connector (not shown) which is installed during surgery and is attached to a temporary socket, so that the amputee may begin walking within a day or two of surgery. As shown in FIG. **10**, well **39** provides a flat seating face on the underside of slot **40** for the attachment screws. Adjustment of the position of this connector to the upper body U may be made by a slight loosening of the attachment screws in slot **40**. It is to be noted that temporary attachment of the artificial leg is normally done only when the amputee is fitted with such a connector, which is removed by the prosthetist when the leg is healed sufficiently to permit a thigh section T to be fitted.

The opposing, lower body member L, preferably cast of an aluminum alloy, includes a downwardly directed socket **41** to receive the upper end of tube **17** of shin section S, as in FIGS. **6–8** and **10**. Socket **41** is split between flanges **42**, at the front side thereof, while bolts **43** through the flanges compress the socket and hold the shin tube **17** tightly in place. The top of the body member is formed with two spaced, upstanding flanges **44**, as in FIGS. **7**, **8**, **12** and **13**, which extend from the front to the back of the body, with a slot **45** therebetween accommodating the lower ends of links Y and R and the pivot pins therefor extending across the slot. An upstanding ear **46** is provided adjacent the downwardly tapered rear edge **47** of each flange to elevate the lower end of link R with respect to the lower end of link Y.

As shown in FIGS. **8**, **10** and **11**, the rear link R is formed essentially as a rigid bar having parallel flat sides, rounded ends and a bearing hole perpendicularly through the sides at each end. A pair of shaft bearings **49** and **50**, in the respective holes, are preferably roller type bearings, as shown, engaging the respective pins **23** and **24**. As in FIG. **11**, the bearings **49** and **50** are held at each end of the link in circular ends **51** of a metal link or center reinforcement piece having flat center plates **52**. This center piece is conveniently formed from a section of metal tubing flattened in the middle and the center plates **52** brazed together. The center piece **51**, **52** is conveniently molded in a body **53** of the link when formed from a structural plastic material having a low coefficient of friction, such as nylon, as by a molding process. A sloped cutout **54** on the back side of the link is tapped to receive a machine screw **55** which clamps a metal plate **56** against the ends **57** of an elastic strap **58**, the function of which will be hereinafter described, to attach the band to the link.

The upper end of the link R is fitted into the central slot **36** at the rear of upper body U, while, as in FIG. **12**, transverse pivot pin **23** extends through bearing **49** of the link and into mounting holes in the upper body at each side of the central slot. The lower end of link R is fitted between the ears **46** of the lower body flanges **44**, while transverse pivot pin **24** extends through bearing **50** of the link and through mounting holes in the ears. The upper pin **23** is a simple, rod-like member and is held in place by set screws **59** in the upper body, as in FIG. **8**, while the lower pin **24** may be a bolt-like member having a threaded end screwed into a tapped hole **60** in one of the ears and held in place by a lock nut **61**, as in FIGS. **6**, **7** and **12**. Any moving contact of the sides of link R against the sides of central slot **36** or ears **46** as the link R is moved on its pivots is free and smooth because of the low friction characteristics of the plastic material of link R. The use of plastic materials in the knee joint allows for smooth, quiet movement of the moving parts without the need for lubrication, while at the same time providing a tough, durable and lightweight unit.

The swing or yoke link Y is formed, as from an aluminum alloy casting, to provide a central tongue **63** depending from a cross bar **64** and spaced arms **65** upstanding from the ends of the cross bar, as in FIGS. **7** and **13**. The yoke link Y is bowed or arcuate in a longitudinal direction, as in FIG. **6**, with the concave side facing the rear link R, to provide additional clearance on that side at the lower end. The central, depending tongue **63** of the yoke is fitted between the forward portion of the flanges **44** of the lower body L, its lower end having a bearing hole which receives a pair of roller type shaft bearings **66**, as in FIG. **13**. Pivot pin **22** extends through the bearings **66** and through aligned holes in the flanges, being essentially a bolt-like member having a threaded end screwed into place in a tapped hole **67** in one of the flanges and secured by a lock nut **61**. The arms **65** of the yoke are elongated to have a length sufficient and are spaced apart a distance sufficient to permit the rear link R to pass between them, whenever the knee joint is folded, as described. Arms **65** extend into the side slots **37** of the upper

body, the upper end **68** of each arm being thickened to provide a closer fit with the walls of the slot, to increase lateral stability but permit the remainder of the arm to move freely in the slot. Each upper end **68** of an arm is provided with a bearing hole which receives a roller type shaft bearing **69**, with transverse pivot pin **21** extending through mounting holes in the body and through the bearings. Pin **21** is essentially a bolt having a reduced threaded end **70** turned into a tapped hole in the body.

The abutment A of FIGS. **10, 14** and **15** limits the angular movement of the knee joint when pivoted to an extended position; that is, it engages rear link R to determine the extent of counterclockwise movement thereof. Abutment A is also adjustable along the inner wall of slot **36**, to locate more precisely the point at which rear link R will be stopped, which also locates the position from which the knee joint will begin to pivot when the weight of the leg is transferred onto the ball of the corresponding foot, as described previously in connection with FIGS. **3** and **4**. This adjustment is important, since the point at which such pivoting begins appears to vary with different users, in order to select a point which provides a natural "feel" of the prosthesis in walking, for the individual concerned. Abutment A comprises a triangular wedge-shaped block **72** formed of plastic and having an end tab **73** provided with an elongated slot **74** therein, through which extends a machine screw **75** which is threaded into a tapped hole **76** in the upper body U, for tightening a metal plate **77** against the tab, to hold the abutment in adjusted position. The abutment is placed so that block **72** is positioned between the central portion of the rear link R and the lower portion of the inside of slot **36**, to hold the link away from the inside of the slot. The abutment A may be shifted along the slot **36** to different positions. to adjustably change the spacing between the control or rear link R and the inside of slot **36** and thereby adjustably vary the alignment of the link R.

It is desirable to bias the shin section S of the leg to either the straight leg position or to a fully knee bended position, such biasing being accomplished by the means heretofore mentioned which resists unlocking and slows the flexing or extending of the knee joint. Such means, as in FIGS. **10** and **14**, includes the elastic strap **58** having ends **57**, referred to previously, and preferably an elastic cloth strap having an elastic core, as of rubber, with overlaying cloth layers, which extends from the clamped ends **57** on the rearward side of rear link R, around the curved lower end of link R, over the cross bar **64** of yoke link Y, around the lower end of tongue **63** of link Y, and back again to the rearward side of link R. Flexure of the knee joint J causes the length of elastic strap **58** to change as links R and Y pivot, with the straight leg position and the fully knee bended position of the knee joint corresponding to the shortest length of the strap. Thus, the elastic strap exerts a toggle action tending to urge the knee joint to either of the extreme positions mentioned above. It should be noted that, during flexure of the knee joint as the links R and Y pivot and the elastic strap **58** flexes, there is sliding contact of the cloth outer surfaces of the strap against the link, allowing the bias of the elastic strap to swing the joint to either of its extreme positions and to hold it there, but at the same time, providing a slight cushioning or braking action as the joint swings from one extreme position towards the other during walking. This tends to make movement of the knee joint smooth and quiet during walking on the prosthesis. There is not the sudden snapping of the knee joint to its extreme positions, which often accompanies use of earlier types of artificial legs having spring biased knee joints, particularly to the extended positions of FIGS. **1** and **2**.

For the artificial leg, an improved foot F having a central, rigid keel K, such as cast of aluminum, was developed, to provide flexibility of the toe and ball portions of the foot, so that the artificial foot would react in a manner similar to the human foot. Also, a special connection for the shin tube **17** was developed. The keel K, as in FIG. **16**, is molded within and covered by a comparatively thick, resilient layer or covering **80**, such as of polyurethane foam and having an outer skin **81** principally formed by chilling in the mold in which the polyurethane foam sets. The skin **81** is less flexible than the remainder of the covering **80** and has the special property of being substantially impervious to moisture, thereby avoiding the accumulation of moisture within the pores of the foam. The skin **81** also extends downwardly around the sides of a hole **82** through which the shin tube may be inserted, for connection to the keel K in a manner described below. The foot F further includes a relatively stiff but resilient pad **83**, which is conveniently a heavy, woven fabric impregnated with rubber or the like and rectangular in shape, extending from beneath the forward portion of keel K, past the ball portion and into the toe portion of the foot. The pad **83** permits flexing of the ball and toe portion of the foot F, thereby simulating, during use, a normal walking step. For attachment of the shin tube **17** to the foot F, the keel K is provided with a cylindrical socket **84** having a diameter essentially the same as that of shin tube **17** and extending downwardly into the keel at approximately the ankle position. The keel is also provided with a pair of rearwardly extending, opposed flanges **85** and **86**, with flange **85**, for instance, being provided with a pair of threaded holes, each for receiving a cap screw **87**, as in FIG. **17**. The opposite flange **86** is provided with a pair of smooth bores through which the corresponding cap screws extend. As will be evident, the cap screws **87** may be tightened to clamp the lower end of shin tube **17** in socket **84**. A slit as shown, extends between the flanges **85** and **86** to permit the above described clamping produced by the cap screws **87**. A pair of holes **89**, the upper hole being shown in FIG. **17**, is formed in the covering **80** during molding, for access to the head of each of the cap screws, in order to insert the cap screws after molding and also to tighten or loosen the cap screws. In order to retain the shin tube **17** in socket **84** against twisting after clamping, a hole **90**, as in FIG. **17**, is made in the covering **80**. The keel K is then drilled and tapped for insertion of a set screww **91**.

The keel K extends forwardly and downwardly from socket **84** to a position at approximately the rear of the ball **31** of the foot, indicated in FIGS. **1–5**. The keel includes an upright, central rib and a lower flange **94** which terminates at its front, lower end in an upturned, lateral rib **95**. Both the central rib **93** and the lower flange **94** merge at their upper ends with the wall of socket **84** and the upper edge of each slopes downwardly in an approximately parallel relation to the upper surface of the foot F. A base portion **96** of the keel, below the socket **84**, is general horizontal and

provides a cushioning effect at the heel, due to the thickness of the resilient set foam beneath, while the front portion of the lower flange **94** presses downwardly against the rear of pad **83.** During walking movement, the curved, upturned, lateral rib **95** compresses the set foam between it and the pad **83** to provide additional resiliency for the step. The pad **83** not only introduces resiliency into the step, but also returns the ball and toe portion of the foot F to its initial position, when pressure on the foot is released. The cost of the foot of this invention is decreased by the fact that only one size of shin tube **17** is necessary.

As will be evident, the present invention fulfills to a marked degree the requirements and objects hereinbefore set forth. Although a preferred embodiment of the invention has been illustrated and described, it will be understood that other embodiments may exist and various changes made therein, all without departing from the spirit and scope of the invention.

What is claimed is:

**1.** A knee joint, adaptable for use in a lower limb prosthesis which includes a thigh section and a shin section having a foot attached thereto, comprising:

front and rear link means pivotally connected at their upper ends to the thigh section and at their lower ends to the shin section and pivotal from a fully extended to a fully bent position of the prosthesis;

an upper body at the lower end of the thigh section, said link means being pivotally connected at their upper ends to said upper body;

a lower body at the upper end of the shin section, said link means being pivotally connected at their lower ends to said lower body;

said front link means comprising a yoke having a lower tongue, a cross bar and a pair of arms extending upwardly from the ends of said cross bar; and

said rear link means comprising a bar whose upper end is adapted to move between said arms of said yoke link.

**2.** In a knee joint, as defined in claim **1,** wherein:

said upper body is provided with slots for receiving the upper ends of said yoke link arms and said rear link bar and for accommodating movement thereof, said slots extending forwardly into said body from the rear.

**3.** In a knee joint as defined in claim **1,** including:

an abutment for limiting movement of said joint toward extended position and engageable with the front side of said rear link means;

said upper body having a rear wall on which said abutment is mounted; and

means for adjusting said abutment to change the position of said rear link when engaging said abutment.

**4.** In a knee joint, as defined in claim **3,** wherein:

said abutment comprises an elongated, longitudinally triangular block formed of resilient material.

**5.** In a knee joint, as defined in claim **4,** wherein:

a slot extends forwardly in said body from said rear surface, for receiving the upper end of said rear link means;

pivot means for the upper end of said rear link means extends across said rear slot;

said abutment being mounted in said rear link means slot; and

said adjusting means for said abutment is disposed in said rear slot above the upper end of said rear link means.

**6.** In a knee joint, as defined in claim **1,** wherein:

said upper body is flat on the top and has a prow-like front and an outwardly and downwardly inclined rear surface;

a slot extends forwardly in said body from said rear surface, for receiving the upper end of said rear link means; and

a pair of slots in the underside of said body extends from front to rear, for receiving said yoke arms of said front link means.

**7.** In a knee joint, as defined in claim **6,** wherein:

the front edge of said rear slot extends downwardly and forwardly;

an abutment for engaging said rear link means to limit movement toward extended position of said joint is mounted in said rear slot; and

including means for adjusting said abutment to change the position of said rear link when engaging said abutment.

**8.** In a knee joint, as defined in claim **1,** wherein:

said lower body is provided with a depending clamping socket, open at the bottom and split at the front, with flanges at each side of said split, said flanges having fastening devices for clamping the upper end of a shin tube in said socket; and

the upper end of said lower body has a slot therein extending from front to rear, with a flange at each side of said slot, and upwardly extending ears adjacent the rear of each said flange, whereby said front link means may be pivoted between said flanges at the front and said rear link means may be pivoted between said ears at the rear.

**9.** A knee joint, adaptable for use in a lower limb prosthesis which includes a thigh section and a shin section having a foot attached thereto, comprising:

front and rear link means pivotally connected at their upper ends to the thigh section and at their lower ends to the shin section and pivotal from a fully extended to a fully bent position of the prosthesis;

an upper body at the lower end of the thigh section, said link means being pivotally connected at their upper ends to said upper body;

a lower body at the upper end of the shin section, said link means being pivotally connected at their lower ends to said lower body;

said front link means comprising a yoke having a lower tongue, a cross bar and a pair of arms extending upwardly from the ends of said cross bar;

said rear link means comprising a bar whose upper end is adapted to move between said arms of said yoke link; and

resilient means comprising a resilient strap attached at its ends to the rear side of said rear link bar and encircling the tongue and cross bar of said front link means.

**10.** In a knee joint, as defined in claim **9,** wherein:

said resilient strap comprises rubber-like cords woven into cloth, with an essentially cloth outer surface, whereby said strap is slideable against the lower end of said rear link means and the tongue and cross bar of said front link means.

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