Nov. 2, 1954 E. R. SCHAEFER 2,692,990

ANKLE JOINT

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Fig.4.

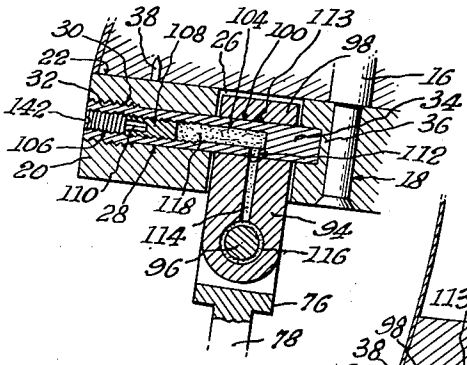


Fig.5.

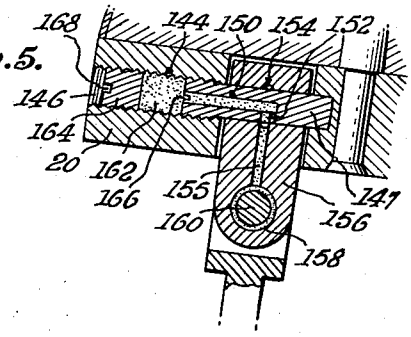
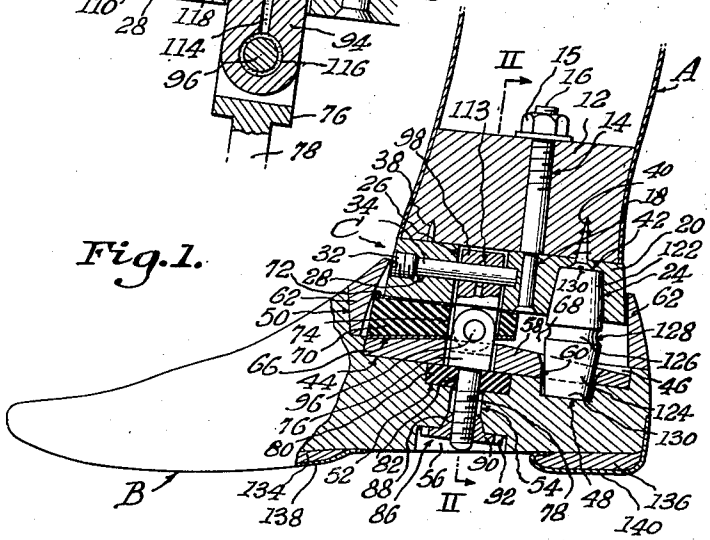


Fig.1.



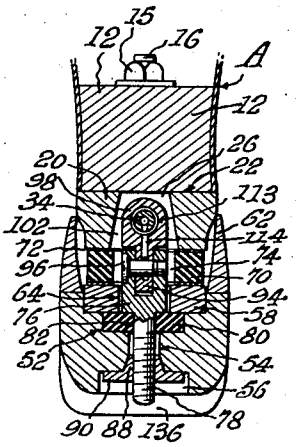


Fig.2.

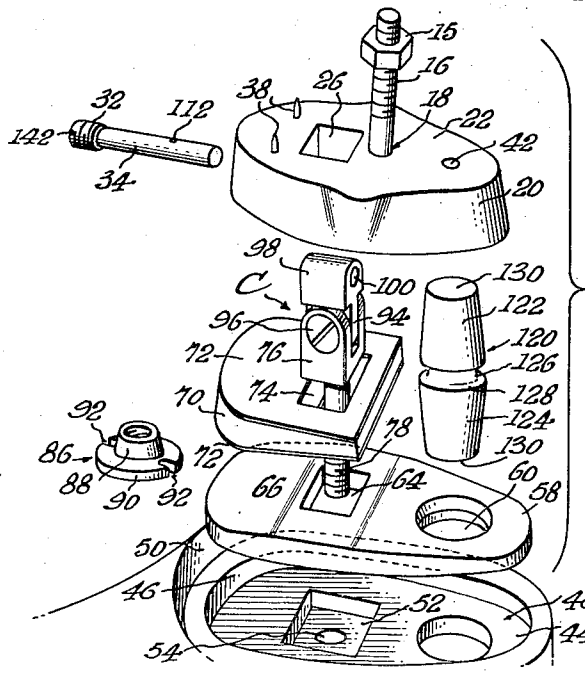


Fig.3.

INVENTOR.
Ernest R. Schaefer
BY Bruce F. Wiseman
Joseph H. Crowell

ATTORNEYS

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Fig. 9.

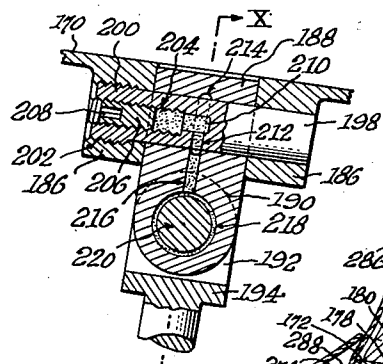
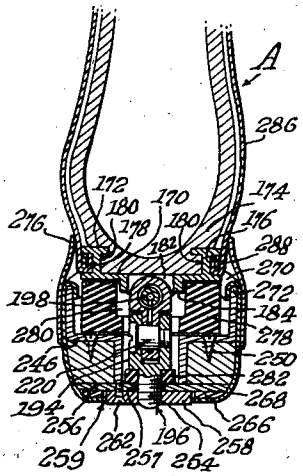


Fig. 6.

Fig. 7.



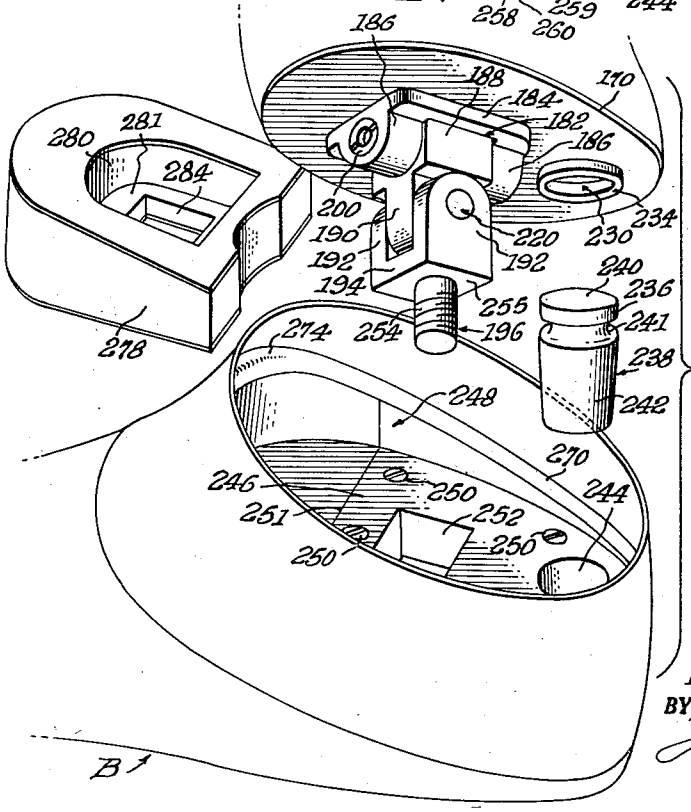
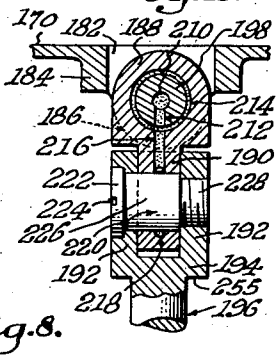


Fig. 8.

Fig. 10.



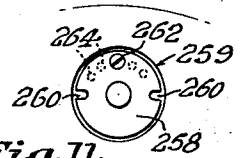


Fig. 11.

INVENTOR.

Ernest R. Schaefer

BY Byron F. Wastman

Joseph N. Cowen

ATTORNEYS.

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2,692,990

ANKLE JOINT

Ernest R. Schaefer, Poughkeepsie, N. Y., assignor to the United States of America as represented by the Secretary of the Army

Application September 29, 1953, Serial No. 383,151

5 Claims. (Cl. 3—32)

(Granted under Title 35, U. S. Code (1952), sec. 266)

The invention described herein may be manufactured and used by or for the Government for governmental purposes, without payment to me of any royalty thereon.

The present invention relates to an improved prosthetic foot and leg assembly and an improved interconnecting ankle joint construction providing naturally simulated movements between such foot and leg, and which may be worn by an amputee having had an amputation of either or both of his natural legs either above or below the knee, or an amputation at one or both ankles.

The improvements of the present construction are related principally to the construction of an improved ankle joint which is adapted to fit interchangeably either a right or left leg or foot prosthesis without inconvenience to the amputee, and which eliminates the need for a selection of a particular joint construction to fit a particular prosthesis. Also, the improved ankle joint construction of the present invention enables a substantially universal articulation of the foot member relative to the ankle joint, thereby providing an amputee with free motion of the foot which can be controlled by a simple adjustment. Additionally, the present improvements comprise means for providing continuous pressure lubrication for all moving parts of the ankle joint for assuring smooth and noiseless operation of such parts at all times.

The foregoing is indicative of the principal objects of the present invention, although further objects and advantages of the present construction will become apparent as the description proceeds, and the features of novelty will be pointed out in particularity in the appended claims.

The invention will be understood more readily by reference to the accompanying drawings, in which

Fig. 1 is a sectional side elevation of one embodiment of an improved ankle joint including the features of the present invention;

Fig. 2 is a sectional elevation taken on the line II—II of Fig. 1, looking in the direction of the arrows;

Fig. 3 is a disassembled perspective view of the construction of Figs. 1 and 2;

Fig. 4 is a fragmentary sectional elevation on an enlarged scale showing one form of longitudinal and lateral pivot means, together with lubricating means therefor;

Fig. 5 is a view similar to Fig. 4 but showing a somewhat modified embodiment of the parts shown in Fig. 4;

Fig. 6 is a sectional elevation of a still further modified embodiment of the construction;

Fig. 7 is a detailed sectional elevation taken on the line VII—VII of Fig. 6, looking in the direction of the arrows;

Fig. 8 is a disassembled perspective view of the embodiment shown in Fig. 6;

Fig. 9 is a fragmentary sectional elevation of longitudinal and lateral pivot means employed in the embodiment of Fig. 6, with lubricating means therefor, the parts being shown on an enlarged scale;

Fig. 10 is an enlarged sectional elevation taken on the line X—X of Fig. 9, looking in the direction of the arrows; and

Fig. 11 is a fragmentary bottom view of the foot element for either of the embodiments of the improved ankle joint of the present invention, the view indicating means enabling adjustment of the said joint for assembly thereof.

Referred to in general terms, it will be seen that the present construction comprises improvements in prosthetic ankle joint constructions interconnecting a prosthetic leg and foot, the latter being adapted for both longitudinal and transverse pivotal movements relative to the leg, and also for a combination of such movements, so that the foot is adapted for substantially universal movements relative to the leg. Such movements are effected by a pair of pivot assemblies disposed at right angles to each other, which enable a longitudinal pivotal fore and aft movement of the foot relative to the leg, a lateral rocking movement of the foot to either side of the leg, or a combination longitudinal and lateral rotary movement which is a resultant of the fore and aft and lateral rocking movements, thereby providing for substantially universal movement between the foot and leg. Also, cooperating with the right-angularly disposed pivots, are resilient means in both the posterior (heel) and anterior (metatarsal) portions of the foot for returning and retaining the foot in normal position relative to the leg following displacements of the foot in any direction.

Referring more particularly to the drawings, it may be pointed out that the improved construction of the present invention provides a universal ankle joint which is adapted to either type of prosthetic appliance that is provided customarily for a leg amputation that has been performed either above the knee or below the knee, or where there has been an amputation of the foot at the ankle, such appliances being referred to customarily as AK, BK, and Symes, respectively. In the drawings, the improved ankle joint construction is employed in connection with either an AK or BK prosthetic leg illustrated in the embodiment illustrated in Figs. 1 through 5 of the drawings, and in Figs. 6 through 10 there is illustrated a construction of the improved joint embodied in a Symes-type of prosthesis.

Referring more particularly to Figs. 1 through 5, reference character A represents a fragment of a mechanical or prosthetic leg of either an AK or a BK type, having a foot element B connected thereto through the improved ankle joint construction designated generally at C. As has been indicated above, the improvements of the present invention are comprised in the ankle joint C to provide longitudinal and lateral tilting movements of the foot member B relative to the leg member A, and also a rotary movement of the foot member, all as selectively controlled by the wearer of the prosthesis. Additionally, the improved ankle joint construction is capable of ready disassembly as well as reassembly, and is suitable equally for right and left leg prostheses, thereby minimizing inconvenience to the wearer, particularly when the wearer is a bilateral amputee, as the present construction is applicable interchangeably to either a right- or left-sided amputation.

The leg member A of Figs. 1, 2, and 3 is shown as being hollow, with the lower end closed by a wooden plug **12** having a hole **14** extending therethrough for the reception of attaching bolt **16** for the improved ankle construction. The attaching bolt **16** also passes through a hole **18** in a top attaching head plate **20** of the improved ankle joint, which head plate, in practice, is a thick metallic casting composed of a light metal, for example, aluminum or magnesium or a light metal alloy. The top surface **22** of this head plate **20** is substantially planar and is in coextensive engagement with the bottom surface of the closure plug **12**. A deep, inwardly tapering heel recess **24** is provided in the head plate **20**, the longitudinal axis of which recess parallels the longitudinal axis of the attaching bolt **16** and is centrally located with respect to the sides of the head plate or section **20**, this recess **24** being located symmetrically in the casting of the head plate or section **20** with respect to the attaching bolt **16** and the rear and lateral surfaces of the said casting. A square hole **26** extends vertically all the way through the head plate **20** in advance of the attaching bolt **16**, and a horizontally-extending bore **28** is provided in the head plate **20**, which bore passes from the front face of the head plate to the square hole **26** and extends beyond the latter, terminating just short of the attaching bolt **16**. The bore **28** is threaded internally adjacent to its forward end, as is designated at **30**, for receiving externally

threaded head 32 of a tubular pivot screw 34 which is mounted in the bore 28 and extends to rear closure 36 of this bore.

The head plate 20 is provided with spaced forward pins 38 which extend into the leg plug 12 and hold the head plate properly positioned relative to this leg plug or closure 12, the rear attachment of the head plate being effected by a screw 40 which is located in a screw hole 42 that communicates with the heel recess 24 in the head plate 20.

The foot element B is constructed of any suitable material, preferably willow wood, which is relatively tough and light in weight. In the top of the foot B is a cavity 44 providing an upwardly opening recess 46 which encloses completely the improved ankle joint and all associated parts. The cavity 44 extends from the forward or metatarsal arch portion of the foot B to the heel thereof and is deepened into a circular heel recess 48 which corresponds in size and shape with the heel recess 24 in the head plate 20, and, when the elements are assembled, becomes aligned therewith. The metatarsal arch portion of the foot B defines a forward abutment 50 for the cavity 44, such extending above the forward peripheral portions of the cavity, the bottom of this cavity being provided also with a square recess 52, a hole 54 extending from this recess 52 into an enlarged bottom recess 56 in the instep portion of the foot B.

The cavity 44 in the foot B is approximately oval in peripheral contour, with the wide area of the oval towards the toe of the foot. This cavity 44 receives and seats a base plate 58 of the ankle joint assembly provided by the present construction. This base plate 58 is received snugly in the cavity 44 and is provided with a round hole 60 in its heel or restricted end, which hole corresponds in size and shape to, and which registers with, the heel recess 48 in the bottom of cavity 44. The peripheral surface of the cavity 44 forms a seat for a flexible collar 62 that extends upwardly and encloses the lower portions of the head plate 20, the cavity 44 also housing the ankle joint and associated parts, the said abutment portion 50 acting as a retaining stop for the forward portions of the collar 62.

A square hole 64 in the base plate 58 registers with the square recess 52 in the bottom of cavity 44 when the base plate 58 is seated in the cavity, the top surface 66 of the base plate sloping downwardly both forwardly and rearwardly, a clearance 68 being provided between this top surface 66 and the planar bottom surface of the head plate 20. This clearance 68 is closed forwardly by a wedge-shaped resilient (rubber) cushion 70 which has a top and bottom wear-resisting leather covering 72, the covering 72 being in engagement with the bottom surface of the head plate 20 and the forward downwardly sloping top surface of the base plate 58. The resilient cushion 70 forms a forward cushion for longitudinal pivotal motion of the foot B, and the tightness with which this foot is drawn against the cushion 70 controls the said longitudinal pivotal motion of the foot B. This cushion 70 is provided with a square hole 74 extending therethrough, which is provided to register with the square hole 64 in the base plate 58.

The above-mentioned longitudinal pivotal movement of the foot B relative to the leg A is effected by providing a pivot bolt having an enlarged bifurcated upper or head end 76 from which depends a threaded shank 78, the bifurcated head end extending into the square hole 26 in the head plate 20, this hole 26 being sufficiently large to allow for a loose play between the outside of the said end 76 and the sides of the hole 26. The head 76 also is received in the square hole 74 in the forward cushion 70 and also in the square hole 64 of the base plate 58, the head 76 seating on a resilient collar 80 which is inserted in the square recess 52 in the foot B and which has a hole 82 that is aligned with the hole 54 that extends through the foot B, the threaded shank 78 extending through these holes 82 and 54 and through the bottom of the foot B. The latter hole opens into the enlarged recess 56 for reception of a control nut 86 received on shank 78, the nut having an internally threaded flange 88, the said internal threads of which are complemental to the threads on the shank 78. The control nut 86 acts to pull upon the shank 78, and the flange 90 of this nut 86 desirably is provided with diametrically opposite peripheral recesses 92 for receiving a spanner wrench, by means of which the nut 86 may be tightened or loosened with respect to the threaded shank 78. When the parts are assembled, the aligned and registering openings 74 through the anterior cushion 72, and 64 in the base plate 58, and the recess 52 in the foot member, define a shaft in which is located the movable pivot joint comprising the aforesaid bifurcated head 76, shank 78, and a large pivot screw 96 which is received in the furcations of the bifurcated head 76, this screw 96 passing through aligned holes in the said furcations of the bifurcated head 76. This pivot screw 96 extends transversely of the ankle assembly as will be clear from the drawings.

The said furcations of the head 76 of this movable pivot joint receive between them a tongue portion 94 of a second pivot member, this tongue 94 having a hole therethrough registering with the holes in the furcations of the said head 76 for mounting the said tongue portion or element on the pivot screw 96, this tongue portion 94 depending from and being integral with a head portion including a bearing sleeve 98 having a bearing opening 100 therethrough which receives the tubular pivot screw 34 that has been referred to above. As has been referred to above, the pivot screw 34 is received in the bore 28 provided therefor which extends into the head plate 20 from the center of the forward surface thereof, and which registers with the opening 100 in the bearing sleeve 98, the pivot screw 34 being disposed in a plane above and at right angles to the aforesaid pivot screw 96.

Therefore, the foot element B pivots longitudinally on the pivot screw 96, it having imparted thereto fore and aft pivotal movements simulating the walking movements of a natural foot. Also, lateral pivotal movements of the foot element B from side to side are accomplished by the movements of the foot element B about this pivot screw 34, such lateral movements corresponding to lateral twisting motions of a natural foot. Additionally, it will be noted that a clearance 102 is provided between the bifurcated head 76 and the inside surfaces of the square hole 26 provided in the head section (or head plate) 20 into which the bearing sleeve 98 is received, so that eccentric or wobbling rotary motions, which may be considered to be composites of the aforesaid longitudinal and lateral pivotal movements, also may be imparted to the foot element B in similitude to such rotary movements in a natural foot.

It is apparent that the moving parts of the ankle joint construction must have smooth and silent movements at all times, and consequently, the present invention contemplates the provision of efficient lubricating instrumentalities for effecting the requisite smooth and silent operations. Such lubricating instrumentalities include a continuous suppy or reservoir of lubricant and means for supplying requisite portions of lubricant from such reservoir under pressure to engaging surfaces of relatively moving or movable parts.

Such lubricating instrumentalities may take variously modified specific adaptations. Thus, for example, the pivot screw 34 may be made tubular by provision of a bore 104, which is threaded internally for a substantial distance as is indicated at 106 for receiving an externally-threaded lubricant-injecting screw plug 108 that is recessed suitably at its forward end, as is indicated at 110 for reception of an operating tool for moving the said lubricant-injecting screw along the threads 106.

The before-mentioned bore 104 in pivot screw 34 communicates with a port 112 that extends through the wall of the screw 34, the said port 112 opening into an annular channel 113 which encloses the screw 34, and also into a duct 114 in the tongue 94 that leads to an annular channel 116 about the pivot screw 96. The said bore 104 in pivot screw 34 receives a supply of fluid lubricant 118, and forms a reservoir for containing a continuous supply of this lubricant, which is introduced into the said bore after removal of the screw plug 108. After placement of the supply of lubricant 118 in the bore, the injection screw plug 108 is inserted and advanced along the threads 106 of the bore 104, such advancement of the lubricant injection screw 108, after engagement thereof with the supply of lubricant, forcing portions of the lubricant from the said supply through port 112 and into channel 113 and thence through duct 114 into channel 116, this action being repeated whenever fresh increments of the lubricant are desired from the reservoir supply thereof in the pivot screw 34. In this manner there is maintained a continuously efficient

lubrication of all moving parts of the construction, lubricant thus forced under pressure into channel **113** lubricating lateral pivotal movements of the foot element B about the pivot screw **34**; and lubricant forced through duct **114** into channel **116** around the pivot screw **96** lubricates longitudinal fore and aft pivotal movements of the foot on this pivot screw **96**.

In order to further cushion these fore and aft pivotal movements of the foot B, a resilient cushion is provided also for the heel portions of the foot. Such cushion is indicated generally at **120** and it consists of two equal and oppositely directed conical sections **122** and **124** joined together by an intermediate section **126** which is characterized by an annular groove **128** that provides a central area of reduced diameter on which the cushion element can compress in an even manner. As will be seen from the drawings, each conical section **122** and **124** is equal in height, slope, and diameter, and each tapers uniformly from the grooved intermediate section **126** to a planar end **130**, one of which seats on the bottom of heel recess **48** in the heel of foot B, the other of which seats against the top of recess **24** of the head plate **20**, the latter recess substantially enclosing the top section of the cushion, while the bottom section of the cushion is substantially enclosed by the annular side wall of recess **48** together with that of hole **60** in the base plate **58**. It will be observed that there is provided the aforesaid substantial space **68** between the rear portions of the assembly which is maintained by the forward resilient cushion **70** and the rearwardly sloping surface of the base plate **58** that extends from the longitudinal pivot **96** and the heel of the foot, which space is enclosed by the flexible collar **62**, which also encloses the forward surface of the resilient cushion **70** and a substantial portion of the head plate **20**, the collar **62** extending all the way around the foot and enclosing all connecting and operating elements of the assembly which connects the foot to the head section or plate **20**.

In addition to the above, a resilient sole cushion **134** is provided beneath the sole portion of foot B and a resilient heel cushion **136** is provided beneath the heel of the foot. Leather coverings **138** and **140** are provided for these cushions, respectively.

It will be noted in connection with the foregoing embodiment of the improved construction that the threads **30** in the bore **28** of the head plate **20** are located only adjacent to the forward end of the bore, the externally threaded end **32** of the tubular pivot screw **34** being complemental to these threads **30**, the lubricant-injection screw **108** meshing with the internal threads **106** in the pivot screw. The threaded head **32** of the pivot screw **34** is provided with a kerf **142** for receiving a screwdriver or similar tool for manipulating the pivot screw.

In the modification of lubricating means shown in Fig. 5 of the accompanying drawings, the head plate **20** is internally threaded as is indicated at **144** through substantially the entire length of the said bore which is designated at **146**, in which is positioned a pivot screw **147** having a complementarily-threaded head **148** and an interior tubular recess **150** for holding a reservoir of lubricant. This recess **150** communicates with a feeding port **152** for lubricant, this opening into annular channel **154** surrounding the pivot screw **147**. This channel communicates with lubricant duct **155** in pivot bearing **156**, the duct **155** conveying lubricant into annular recess **158** surrounding pivot screw **160** which corresponds to pivot screw **96** of the previously described modification. In the showing of Fig. 5, a supply of lubricant **162** is placed directly into the internally threaded bore **144** in the head plate **20** instead of such supply of lubricant being placed in the tubular pivot pin; and also, in accordance with Fig. 5, the lubricant feed screw **164** is inserted in the bore **144** instead of in the tubular pivot pin or bolt.

The pivot pin **147** is provided with an operating kerf **166**, and the feed screw **164** has an operating kerf **168** therein, whereby the feed screw **164** may be advanced along the threads **144**, forcing lubricant from the supply **162** thereof into the duct **150**, thence through feed port **152**, annular channel **154**, duct **155** and into annular recess **158** for lubricating both the pivot pin **147** and large pivot screw **160**.

It will be apparent from the drawings that the structural details of the present ankle joint assembly are subject to many different modifications without departing from the inventive concept. Thus, while Fig. 5 shows a

modified lubricating structure from that shown in Figs. 1–4, a modified embodiment of the general assembly is shown in Figs. 6–10.

In this modification, the head plate **170** is a relatively thin plate which is cast with an annular flange **172** which is embedded in reinforcement **174** for firm anchorage of the head section to the lower end of leg A. This reinforcement **174** may be any suitable material, for example, a synthetic plastic material which intimately engages and anchors the flange **172**. This flange **172** with its web **176** and head section plate **170** define oppositely directed channels **178**, **180**, the former being an outer peripheral channel for a purpose to be referred to hereinafter, while the latter is an inner channel that is filled with anchoring plastic reinforcement **174**.

The head section plate **170** also is cast with an opening **182** therethrough which is positioned in advance of the vertical axis of the plate and which is enclosed by a flange **184** which is integral with the underside of the plate and which is formed with approximately hemi-spherical aligned bearing lugs **186**, between which is received a block or head **188** from which projects a tongue **190** that is received between furcations **192** of bifurcated head **194** of movable pivot bolt **196** that extends through the foot member B as will be referred to hereinafter.

The bearing lugs **186** and the head **188** have horizontally registering holes therethrough for reception of horizontally extending pivot pin **198** which has a threaded head end **200** meshing with threads **202** in the forward end of the hole in forward bearing lug **186**. The pivot pin **198** is provided with a threaded bore **204** for receiving lubricant and also a lubricant feed screw **206** having an end socket **208** for receiving a suitable tool for advancing or retracting the feed screw **206** relative to the threaded bore **204**.

The inner end portion of the bore **204** is constricted, as is indicated at **210**, this constricted portion of the bore delimiting the end of inward movement of the lubricant feed screw **206**, and the said constricted end portion of the bore is provided with a lubricant feed port **212** which communicates with an annular channel **214** that encloses the pivot pin for lubrication thereof. The channel **214** communicates with lubricant feed duct **216** in the pivot tongue **190**, this duct opening into an annular lubricant-receiving channel **218** which encloses large pivot screw **220** that is received in registering holes in the furcations **192** of bifurcated head **194** of the pivot bolt **196**, it being apparent that such holes are in aligned register for receiving this pivot screw **220** which comprises three sections, namely, an enlarged head **222** having a kerf **224** for receiving an operating tool such as a screwdriver, a smooth-surfaced collar **226** and a threaded shank **228**, this last section having the smallest diameter, the threads of which mesh with threads in the opening which receives this shank. The pivot pin **198** provides for lateral pivotal movement of the foot while the large pivot screw **220** provides for longitudinal fore and aft pivotal movements of the foot.

The head section plate **170** also is formed adjacent to its heel portion with a recess **230** by elevating a portion of the plate **170** as shown at **232** for forming the top of the recess, which recess is completed by an annular flange **234** which is integral with the under surface of the plate **170**.

This recess **230** defines a retaining seat for the top section **236** of a resilient heel cushion **238**, the top surface **240** of which is substantially planar for flat engagement with the top **232** of the recess **230**. In the present instance, the resilient heel cushion or plug is composed of two unequal sections. The top section **236** of this heel cushion is substantially shorter than the lower section **242** and is substantially cylindrical in contour, whereas the lower section **242** is conically tapered in contour and is retained in recess **244** in the base section or plate **246**. The sections **236** and **242** of the heel cushion are defined by a deep annular groove **241** that forms an area of maximum but uniform yielding between the sections of the heel cushion.

The base section or plate **246** is secured in place in the cavity **248** of the foot B by screws **250**, the plate **246** being countersunk in the bottom of the cavity **248** and forms a partial bottom surface for such cavity, terminating short of the forward wall of the cavity as is indicated at **251**.

The base plate **246** is provided in the instep portion of the foot with a square opening **252** that extends through

the foot for receiving threaded shank 254 of the pivot bolt 196 and also the bifurcated head 194 thereof, this latter defining a substantially square shoulder 255 with the bolt 196.

A bottom plate 256 is provided in the foot member B and extends from the heel of the foot forwardly to substantially the ball portion of the foot, this bottom plate having an opening 257 therethrough which receives the shank 254 of the pivot bolt 196. The plate 256 forms the bottom for the square opening 252 in the aforesaid base plate 246, the opening 257 being substantially smaller that the square opening 252 but concentrically aligned therewith. The said square opening 252 receives the bifurcated head 192 of the pivot bolt, this head having its square shoulder surface 255 seated on a resilient block or washer 282 interposed between the bifurcated head 192 and the bottom plate 256, the end of threaded shank 254 projecting through this bottom plate and receiving a locking washer or nut 258 which is countersunk in opening 259 in a sole plate 266 which extends through the entire foot member in direct engagement with the underside of the aforesaid bottom plate 256, this latter plate being secured by screws 261 penetrating into the wood of the foot member B.

The nut 258 locks the parts of the assembly together and performs additionally other functions which will be described hereinafter. It is operated by a spanner wrench receivable in diametrically oppositely located peripheral notches 260 and a set screw 262 inserted in an appropriate screw hole 264 of an arcuate series thereof provided in the instep portion adjusts the foot member angularly with respect to its mating foot.

A sole plate 266 is provided for the entire foot as aforesaid, this plate and foot member being enclosed in a leather binding 268 which is held in place by folding its edge, as shown at 270, over peripheral flange 272 of the base plate 246, and also, as is indicated by peripheral fold 274, over the periphery of the foot cavity 248, this binding having its fold cemented or otherwise secured to the interior of the cavity 248 adjacent to the peripheral edge thereof. The foot member and lower extremity of the leg are enclosed in a flexible cuff 276, which also encloses the angle joint assembly.

Interposed between the head plate 170 and the base plate 246 and in advance of the resilient heel cushion plug 238 is a thick resilient anterior cushion 278 having a large cavity 280 therein having a bottom 281 provided with a square hole 284. The bifurcated head 192 of the vertically disposed pivot bolt 196 is received in this square hole 284. The side walls of the cavity 280 are substantialy straight and define a clearance between them and the bifurcated head 192 as is true also of the opening 252 in the foot. The bearing lugs 186 and intervening head 188, together with the pivot pin 198, are received in the cavity 280 with an intervening clearance. The leg is provided with a concealing covering 286 simulating a sock or other covering, which is folded in channel 178 and held against the web 176 by means of tightly applied cord wrappings 288.

Comparing the two principal embodiments of the present construction shown in the drawings, reference again may be made to Figs. 1, 2, and 3, as well as to Figs. 4 and 5, which may be regarded as auxiliary views to the construction of Figs. 1, 2, and 3.

From Figs. 1 through 3, it will be seen that the thick head plate 20 is affixed permanently to bottom closure 12 of the leg by the anchor bolt assembly composed of the section 18, threaded shank 14 and lock nut 15 thereon. Also forward and rear permanent attachment is afforded by anterior pins 38 and posterior screw 40, this head plate 20 defining a closure for cavity 44 in the foot member B, the base plate 58 seating on the bottom of this cavity with the round posterior (heel) opening 60 registering with the posterior recess 48 in the bottom of the foot cavity 44. The recesses 48 and 60 diverge upwardly to receive and to conform to the shape of the lower section 124 of the resilient heel cushion 120. Corresponding recess 24 in the head plate 20 receives the top section 122 of this resilient heel cushion 120, these sections 122 and 124 being identical, but opposite, in shape.

The forward or anterior (metatarsal) cushion 70 has a gradual rear taper, its thickest portion being located in what corresponds to the metatarsal portions of a natural foot. The upper surface of this anterior resilient cushion 70 is in engagement throughout its extent with the corresponding area of the bottom surface of the head plate 20, this latter having planar top and bottom surfaces, and is of uniform thickness throughout.

The opening 74 of this anterior cushion registers with recess 52 in the bottom of cavity 46 in the foot member, the bifurcated head 76 of movable pivot joint 78 seating on the bottom of this recess 52 and projecting upwardly through opening 64 in the base plate 58 and into opening 74 in the forward or anterior cushion 70, the pivot screw 96 extending through the furcations of the bifurcated head and being positioned within the opening 74 of the anterior cushion. This pivot screw 96 extends transversely relative to the foot member and provides for longitudinal pivotal movements of the foot (fore and aft pivotal movements) through pivotal rocking of tongue 94 on this pivot screw 96, the bearing head 98 for pivot bolt 34 seating on the radially curved ends of the furcations of the bifurcated pivot head 76 and follows the radial contour of the ends of such furcations during longitudinal pivotal movements of the foot member about the pivot screw 96. Bearing 100 in the bearing head 98 receives the pivot pin 34 which is inserted in the bore 28 extending rearwardly through the head plate 20 from the front surface thereof, this pivot pin 34 being secured in position through intermeshing of head 32 on the head of the pin with internal threads 30 in the forward end of the bore 28. Lateral pivotal movement of the foot member occurs on this pivot pin 34.

It will be seen also that the base plate 58 increases in thickness from the forward surface thereof to its mid-portion which is rearward of opening 64, the plate 58 then decreasing in thickness to its rear surface which abuts against the heel portions of the cavity 44, so that the clearance space 68 between the head plate 20 and the base plate 58 rapidly widens towards the heel of the foot member, there being relative sliding movement between the head plate 20 and collar 62 mounted on the foot member. The cushion 80, seated in recess 52 and engaged by both the base plate 58 and bifurcated head 76 of the pivot bolt 78, absorbs vertically directed impacts during walking, this cushion 80 being continuously under compression.

The pivot screws 96 and 34 are disposed at right angles to each other as aforesaid, with the screw 34 positioned above pivot screw 96. This latter, as has been pointed out above, extends in a direction transversely of the foot member to provide for longitudinal (fore and aft) pivoting of the foot during walking, while the former (that is, pivot screw 34) extends through the head plate 20 in a longitudinal direction, thereby enabling the foot member to pivot laterally from side to side by the bearing 98 turning on this screw 34. It will be seen also from the drawings that there are provided clearances between the bearing 98 and the sides of opening 26 in the head plate 20, and between the bifurcated head 76 and the sides of the opening 64 in the base plate 58. Therefore, there are enabled to be applied to the foot member not only the above-mentioned longitudinal pivotal movements which correspond to normal walking motions of a natural foot, and also side to side (lateral) movements which correspond to similar lateral movements of a natural foot, but the foot member also is enabled to utilize a combination of these motions as is the case with a natural foot, to produce "wobbling" rotary motions which closely simulate corresponding movements of a natural foot.

It is apparent also that to assure smooth and noiseless movements of the foot member there must be an efficient lubrication of the pivots, and pressure lubrication thereof is effected by confining a continuously maintained body of lubricant within the confines of the bore extending into the head plate 20, either by placing the lubricant directly into the bore which has been prepared therefor, as shown in Fig. 5, or by maintaining the body of lubricant within the longitudinally extending pivot pin when the latter is tubular for this purpose, as is indicated in Fig. 4.

There being maintained a continuous supply of lubricant, such may be pressure-injected around the pivots by advancing the lubricant injection screws 108 in Fig. 4 or 164 in Fig. 5 so as to pressure-inject a requisite increment of lubricant into the lubricating channels surrounding both pivot screws, and which are in communication one with the other through the lubricant passage duct provided in the bearing tongue (94 or 156) that is

received between the furcations of the bifurcated head of the pivot bolt.

It will be seen additionally that during walking, as is normally the case, the weight of the wearer is applied to the heel or posterior portions of the foot member, thus causing the rear or heel portions of the head section **20** to be depressed into the collar **62** against the resiliency of the posterior cushion **120** which is compressed under the weight of the wearer. As the wearer's weight becomes shifted forwardly during walking with corresponding longitudinal pivoting of the foot member, the anterior resilient cushion **70** becomes compressed progressively forwardly and the compression on the posterior or heel cushion **120** is released and the latter comes under tension by virtue of the attachment of the heel portion of head plate **20** to the leg closure **12** through screw **40**. When the foot member is lifted from the ground during walking, the release of compression on the anterior cushion **70** and expansion thereof and the attendant release of tension on the posterior cushion **120** automatically return the foot member to normal position relative to the leg; and it will be seen readily from the drawings that in all pivotal movements of the foot member, one of these resilient cushions is under compression while the other is under tension, the compressional and tensional forces being applied alternately, resulting in automatic return of the foot member to normal position whenever the weight of the wearer is relieved from the foot member.

Accordingly, it will be seen that the improved ankle joint construction of the present invention enables the foot member to perform all of the motions possible in a natural foot, and that the inherently resilient posterior and anterior cushioning members function in a manner entirely analogous to the posterior and anterior muscles and ligaments of a natural foot which, in the present prosthesis, these resilient cushioning members are designed to replace.

The action of the resilient members **278** and **238** in the modified structural embodiment shown in Figs. 6, 7, and 8 of the accompanying drawings is entirely similar to the action of the cushioning members **70** and **120** and consequently no further explanation is needed. The same applies to the action of the pivot members **198** and **220** of the embodiment of Figs. 6, 7, and 8, and also to the action and operation of the slightly modified lubricating system shown in Fig. 9.

In the embodiment of the construction shown in Figs. 1, 2, and 3, disassembling may be effected by unscrewing washer nut **90** by a spanner wrench engaged in notches **92**, this enabling the foot member B to be removed bodily along with the cushion **80** and the anterior and posterior cushions **70** and **120**. This provides free access to the top pivot screw or pin **34** (or **147**) for requisite advancement of the injection screw **108** or **164** as the case may be for supplying lubricant as needed from the continuously maintained source thereof to the pivot members. Removal of top pivot member **34** will release bearing **98** and pivot bolt **78** for removal from the head plate **20**, if desired.

Generally, similar operations afford access to pivot member **198** in the modified construction illustrated in Figs. 6, 7, and 8. That is, by unscrewing washer **258**, the foot member B may be removed from its mounting along with resilient cushioning members **278**, **238**, and **282**, this last being retained, however, in the foot member by bottom plate **256**. This provides access to the pivot member **198** for enabling requisite manipulation of the lubricant injection screw **206**.

It will be observed also that the aligned openings **74** in the anterior cushion **70** and **64** in the base plate **58** (modification of Figs. 1, 2, and 3) and correspondingly, the openings **284** in the anterior cushion **278** and **252** in the foot member (modification of Figs. 6, 7, and 8) actually define a shaft or well for the reception of the movable pivot joints **96** and **220** of these respective modifications, and that the locking washers or nuts **90** and **258**, in addition to being the means for maintaining the foot members and ankle joint assembly, constitute means for controlling the amount of movement of the ankle joints and foot members. In this connection, it will be seen that head plates **20** and **170**, respectively, are secured rigidly to the leg member, and the joint members **96** and **220** and associated parts are held securely in place by pivot screws **34** or **198**. With the forward and heel cushion members in position, the enclosing foot members are positioned bodily in place with the threaded shanks **78** and **254** inserted through holes **54** and **252** and held by the said locking or control nuts **90** or **258**. As the said nuts are tightened, the foot members will be drawn increasingly tightly against the anterior resilient cushion **70** or **278**, which becomes correspondingly compressed, as well as the resilient heel (posterior) cushions **120** or **238**, and the greater will be the force required to move the foot members around the ankle joints and the more limited becomes the amount of such movement. Conversely, the movable parts are loosened for greater movement with attendant release of pressure on the anterior and posterior cushions by loosening the said locking or control nuts. The movements of the ankle joints therefore, are readily adjustable as to their magnitude to the weight of the individual wearer. The actuation of the said nuts is effected by means of a spanner wrench inserted in the opposite peripheral notches provided for this purpose, this wrench being in practice a key with which the wearer is provided and which is of standard size.

In the embodiment of the construction shown in Figs. 1 through 3, the top ankle plate **20** has the pair of symmetrically placed pins **38** on the forward portion of the top surface **22** of the plate, these pins **38** being provided for obtaining the correct amount of "toe in" or "toe out" of the foot element B before the prosthesis is assembled. Thus, "toe out" is an angle away from the body of approximately 15° for correct setting, or according to the "toe in" or "toe out" which the individual may have.

The movable joints **76**, **192** of both modifications are secured in the top ankle plate by the pivot screw **34** or **198** which allows the joint to have motion laterally from side to side. The lower part of the movable joint fits into the shaft or well provided therefor in the lower ankle plate **58** or **246**, which plate seats in the foot member. The lower part of the movable joints, including the bifurcated head and threaded shank thereof, together with the pivot screw which passes through the bifurcated head of each joint, allows longitudinal forward and backward pivotal movements of the foot members similar to normal walking movements of a natural foot, while the pivot screws mounted in the head plates at right angles to the bifurcated head allow for lateral or side-to-side pivotal movements of the foot members. The combinations of the longitudinal forward and backward movements and the lateral side-to-side movements of the foot members produce an eccentric rotary twisting or wobbling motion of the foot members referred to above.

In both forms of the construction illustrated in Figs. 1 through 3 and Figs. 6 through 8, the entire ankle joint mechanism is enclosed by the recess in the shoe members taken with the head plates which are secured rigidly to the leg and which are recessed to receive the vertically movable or adjustable pivot joint, the heel cushion, and the fixed pivot screw which extends into the head plates at right angles to the vertically adjustable pivot joint. The forward or anterior resilient cushion member which is mounted between the forward portions of the head plates and the base plates in the recess of the foot member and engaged thereby, is apertured suitably to receive the bifurcated head of such joint and the pivot screw which extends therethrough transversely of the foot member and provides for the longitudinal pivotal movement of the foot member about this pivot screw which is held in the tongue projection of the complemental joint member that is fixedly held by the pivot screw that is mounted in the head plate and extends therein in a direction longitudinally of the foot member, that is, at right angles to the pivot screw of the vertically movable joint. In a similar manner, the posterior or heel cushion is retained in a recess in the head plate and in the bottom of the recess of the foot member.

As the adjusting nuts in the bottoms of the foot members are tightened, the foot members are pulled upwardly to compress both the forward and heel cushions, the amount depending upon the tightness of the foot member against the head plate, which tightness is adjusted in accordance with the weight of the wearer. It will be seen that the resilient heel cushion replaces the heel muscles and ligaments of a natural foot, and the anterior

resilient cushion replaces the anterior or forward muscles and ligaments of a nutural foot, and during wearing, the weight of the wearer is applied alternately to the anterior resilient cushion and to the resilient heel cushion in the manner in which the weight of the individual is shifted between the forward and heel portions of the natural foot so that when the wearer's weight is exerted mainly on the forward cushion, it is compressed further, and the heel cushion can expand, and contrarily, application of the wearer's weight principally on the heel cushion compresses the cushion and allows the anterior cushion to expand, the resulting movements of the foot member thereby imitating closely the movements of a natural foot, with elimination of transmission of walking impacts or shocks to the wearer.

From the foregoing description, it will be seen that the present invention provides an improved prosthetic ankle joint which fits all types of prosthetic legs or where an amputee has been provided with a prosthetic shin member and foot therefor for replacement of a natural foot which has been amputated at the ankle, which enables the prosthetic foot to be moved in all directions simulating the movements of a natural foot, and which, like a natural foot, is returned automatically to normal position responsively to completion of its movements. The ankle construction of the present invention can be used interchangeably on a right or left leg, or where there has been a double amputation.

Having thus described my invention, what I claim as new and wish to secure by Letters Patent is:

1. In a prosthetic appliance including a leg member and a foot member, the improvements which comprise an ankle joint structure interconnecting the leg member and the foot member enabling substantially universal pivotal movements of the foot member relative to the leg member, the said ankle joint structure comprising a head plate permanently and rigidly secured to the leg member, a base plate in the foot member and defining the bottom of an open top cavity in the foot member, an adjustable joint extending through the foot member and having a threaded shank extending from the bottom of the foot member and a head portion in the cavity of the foot member, a complemental joint member secured in the said head plate and extending into the head portion of the adjustable joint, a pivot member interconnecting the said head and extending portion of the complemental joint member, the said pivot member extending transversely of the foot member and enabling longitudinal pivotal movements of the foot member similar to movements of a natural foot during walking, a pivot screw mounted in the head plate in a longitudinal direction of the foot member and extending through the complemental joint member for enabling lateral pivotal movements of the foot member, a resilient anterior cushion intermediate forward portions of the head plate and the base plate, a resilient heel cushion retained in the said plate and base plate rearwardly of the foot member, and adjusting means on the threaded shank of the adjustable joint securing the foot member to the leg member under a selected tightness proportional to the weight of a wearer of the prosthetic appliance.

2. In a prosthetic appliance including a leg member and a foot member, the foot member being separable from the leg member, the improvements which comprise an ankle joint structure pivotally interconnecting the foot member to the leg member and comprising an ankle joint assembly mounted in the foot member and including a head plate and a base plate, means rigidly securing the head plate to the leg member, the base plate being secured to the bottom of an open top cavity in the foot member, a vertically adjustable ankle joint assembly mounted in the foot member and including a head portion, a shank portion extending through the foot member to the bottom thereof, a complemental joint member having an upper portion mounted in the head plate and a tongue portion extending into the head portion of the adjustable joint assembly and a pivot member interconnecting the said head portion and tongue portion and extending transversely of the foot member providing longitudinal pivotal movements of the foot member relative to the leg member simulating walking movements of a natural foot, a second pivot member mounted in the head plate and extending through the upper portion of the complemental joint member enabling lateral side-to-side pivotal movements of the foot member, a forward resilient cushion compressionally retained between forward portions of the head plate and base plate and simulating forward muscles and ligaments of a natural foot, a resilient heel cushion also retained between rear portions of the head plate and heel portions of the foot member and simulating heel muscles and ligaments of a natural foot, the forward cushion having an opening therethrough for receiving the head portion of the vertically adjustable ankle joint assembly with a clearance thereabout for enabling eccentric rotary pivotal movement of the foot member, the forward cushion and heel cushion being alternately relaxed and compressed responsively to shifting of a wearer's weight between forward and heel portions of the foot member, and means on the shank portion of the adjustable joint assembly for controlling amplitudes of pivotal movements of the foot member in accordance with the weight of the wearer.

3. In a prosthetic appliance including a leg member and a foot member separably connected thereto, the improvements which comprise an ankle joint structure intermediate the said members and pivotally interconnecting them together, the foot member having an extensive open top cavity therein receiving and enclosing principal elements of the ankle joint structure, the said ankle joint structure comprising a vertically disposed adjustable ankle joint having a head and a shank, the said head being positioned in the cavity, a complemental fixedly mounted joint member extending into the said head, pivot means pivotally interconnecting the head and complemental member and extending transversely relatively to the foot member, and enabling the foot member to pivot in a longitudinal fore and aft direction with movements simulating walking movements of a natural foot, a resilient yieldable forward cushion in the cavity adapted to be yieldingly compressed during forward application of a wearer's weight thereon during walking, a rear yieldable resilient cushion also mounted in the cavity adjacent to heel portions thereof adapted to be yieldingly compressed during rearward application thereto of the wearer's weight during walking, the said cushions being alternately compressed and expanded as the wearer's weight is shifted from one to the other during walking, each cushion returning the foot member to normal position responsively to release of the wearer's weight therefrom, the forward cushion member simulating in its action natural muscles and ligaments in forward portions of a natural foot and the rear cushion simulating in its action natural heel muscles and ligaments of a natural foot, and means on the shank of the ankle joint and engaging the foot member for movably adjusting the latter relative to the ankle joint and cushions for initially compressing the latter equally against the weight of the wearer when the said weight is applied equally to the cushions and for controllably limiting amplitudes of movement of the foot member in accordance with the weight of the wearer when uniformly applied to the said cushions.

4. In a prosthetic appliance including a leg member and a foot member separably connected thereto, the improvements which comprise an ankle joint structure intermediate the said members and pivotally interconnecting them together, the foot member having an extensive open top cavity therein receiving and enclosing principal elements of the ankle joint structure, the said ankle joint structure comprising a vertically disposed adjustable ankle joint having a head in the cavity and a threaded shank extending from the head through the foot member and extending from the bottom thereof, a head plate rigidly secured to the leg member, a base plate defining the bottom surface of the cavity and rigidly secured to the foot member in the bottom of the cavity, a forward resilient and elastic cushion member intermediate the head plate and the base plate, and enclosing the head of the adjustable ankle joint, a complemental joint member for the adjustable ankle joint having a head portion mounted in the said head plate and a tongue portion depending therefrom and engaging with the head of the adjustable ankle joint, pivot means interconnecting the tongue portion of the complemental joint member and the head of the adjustable ankle joint and extending transversely relative to the foot member, a pivot member secured in the head plate and extending longitudinally of the foot member at right angles to the adjustable ankle joint and to the complemental joint member and extending through the head portion of the lat-

ter for enabling lateral pivotal movements of the foot member, the transversely extending pivot means in the head of the adjustable ankle joint and complemental joint member enabling longitudinal pivotal movements of the foot members, a resilient elastic heel cushion member in the cavity of the foot member and retained between the head plate and base plate, the forward cushion member and the heel cushion member becoming alternately expanded and compressed during shifting of a wearer's weight while walking, and adjusting means on the shank of the adjustable ankle joint for selectively tightening and loosening the foot member relative to the forward and heel cushion members, the said cushion members simulating forward and heel muscles and ligaments of a natural foot and returning the foot member to normal position following pivotal movements thereof in any direction.

5. The construction as claimed in claim 4 wherein the pivot member in the head plate is tubular for receiving and maintaining a supply of lubricant in the pivot member, a lubricant-receiving channel in the head portion of the complemental joint member surrounding the said pivot member, the latter being provided with a port communicating with the channel and with the supply of lubricant in the pivot member, a second lubricant-receiving channel being provided in the tongue portion of the complemental joint member around the pivot means interconnecting the said tongue portion and head of the adjustable ankle joint, a lubricant-delivery passage in the said tongue portion interconnecting the channel in the head portion of the complemental joint member with the second channel, and lubricant-injecting pressure means in the head plate acting on the supply of lubricant in the pivot member in the head plate for supplying lubricant from the said pivot member into the lubricant-receiving channels.

No references cited.