Artificial Limbs

A Review of Current Developments

COMMITTEE ON PROSTHETICS
RESEARCH AND DEVELOPMENT

COMMITTEE ON PROSTHETICS
EDUCATION AND INFORMATION

National Academy of Sciences
National Research Council

NATIONAL ACADEMY OF SCIENCES—NATIONAL RESEARCH COUNCIL

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COMMITTEE ON PROSTHETICS RESEARCH AND DEVELOPMENT
COMMITTEE ON PROSTHETICS EDUCATION AND INFORMATION

The *Committee on Prosthetics Research and Development* and the *Committee on Prosthetics Education and Information,* units of the Division of Engineering and Industrial Research and the Division of Medical Sciences, respectively, advise the Veterans Administration and the Department of Health, Education, and Welfare in the conduct of research and education activities in the fields of prosthetics and orthotics; they provide means for correlating Government- and privately sponsored research in those fields.

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VOL. 7 AUTUMN 1963 NO. 2

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2101 Constitution Ave. Washington, D. C. 20418

Artificial Limbs is a publication of the Committee on Prosthetics Research and Development and the Committee on Prosthetics Education and Information, National Academy of Sciences—National Research Council, issued twice a year, in the spring and in the autumn, in partial fulfillment of Veterans Administration Contract V1005M-1914, Vocational Rehabilitation Administration Contracts SAV-1019-64 and 63-110, and Public Health Service Grant AM 07145-07 from the National Institute of Arthritis and Metabolic Diseases. The opinions expressed by contributors are their own and are not necessarily those of either of the committees. Library of Congress Catalog Card No. 55-7710.

Variety

WILLIAM J. ERDMAN, II, M.D.[1]

In virtually every area of knowledge, be it anthropology, engineering, psychology, or zoology, there is a need for dissemination of information at various levels of sophistication. Information in the form contained in research reports is necessary for further progress by other research groups but is seldom found to be directly useful by practitioners. Technical documents intended to assist the practitioner in carrying out his day-to-day responsibilities are of little value to the lay people or nonspecialists who, for one reason or another, have an interest in the subject. Limb prosthetics is no exception to this rule.

For example, a detailed report on the physical constants of various segments of the human body is of little interest to the chief of a prosthetics clinic team or to the practicing prosthetist, but is indispensable to the designer of artificial limbs. Definitive manuals on fabrication procedure, so essential to the prosthetist, are of little or no concern to the physician, patient, or rehabilitation counselor. Thus, information in a variety of forms is needed if all concerned with problems of amputation, including the amputee, are to carry out their responsibilities effectively and efficiently.

In the early days of the Artificial Limb Program, a lady amputee once wrote to the Mellon Institute complaining that, whereas she could obtain a four-page pamphlet on a new can opener, there were no printed instructions available concerning proper use of an expensive artificial leg. Similar observations have been made by other amputees in their desire to overcome their disabilities. Though in recent years there has been a great increase in the specialized literature pertaining to amputees, little information and no truly comprehensive documents have been prepared especially for the amputee, his family, or other nonspecialists. Accordingly, the Editorial Board of ARTIFICIAL LIMBS decided to devote the major portion of this issue to an article that might be of value to nontechnical personnel concerned with rehabilitation of the amputee.

Quite naturally, a patient has an avid interest in his condition which is not satisfied by his physician's sometimes cursory or too-technical explanation, or the patient may be embarrassed to ask questions that seem simple to others. There will be many areas about which he will not have the intellectual ability to raise questions until he has experienced the need to know. He may not quickly gain psychological insight adequate to ask realistic questions. It is hoped that *Limb Prosthetics Today,* by providing the patient and his family with early and ready access to correct, up-to-date information, will prevent them from arriving at erroneous conclusions or oscillating

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between unrealistic hopes and unwarranted fears, and thus will materially assist them all to meet their problems.

Though prepared primarily for use by amputees and their families, *Limb Prosthetics Today* may also prove valuable to others. The nontechnical approach should make it useful as an introductory text to future practitioners: undergraduate medical students, residents, students in physical and occupational therapy, and apprentice prosthetists. Rehabilitation counselors and administrative personnel responsible for the welfare of amputees might gain a more accurate picture of the problems and potentialities of the patients they serve. Where more technical information is desired, the documents cited in the bibliography accompanying *Limb Prosthetics Today* may be studied.

It is not anticipated that regular readers of ARTIFICIAL LIMBS will necessarily learn any new information from *Limb Prosthetics Today,* though some may appreciate a review or the updating of previous information. Present readers, however, are in a position to make a critical analysis of the level of the presentation, its clarity, and the appropriateness of various items for amputees and for the nonspecialist professional persons concerned with amputees; and the Editorial Board invites any comments that will assist in future revisions.

For the more sophisticated reader, this issue of ARTIFICIAL LIMBS contains an article by Edward Peizer concerning the effects of socket attitude on the gait of a bilateral, above-knee amputee. In addition to emphasizing the necessity for accurate alignment, this research report demonstrates how certain instrumentation can be employed 10 uncover facts previously bidden.

Both the specialist and the general practitioner in any field will always appreciate a thoughtful book review by a world-famous authority. Such reviews may well point out the many excellent features justifying purchase of a new book, yet note any aspect considered controversial or potentially misleading. For all readers, thus, we are happy to inaugurate signed book reviews *as* a new feature. As a first step, Charles Frantz has provided a thoughtful analysis of an important new book, *The Limb-Deficient Child.*

It is hoped a wide variety of readers will find this issue of ARTIFICIAL LIMBS interesting and useful.

Limb Prosthetics Today

A. BENNETT WILSON, JR., B.S.M.E.[1]

Loss of limb has been a problem as long as man has been in existence. Even some prehistoric men must have survived crushing injuries resulting in amputation, and certainly some children were born with congenitally deformed limbs with effects equivalent to those of amputation. In 1958 the Smithsonian Institution reported the discovery of a skull dating back about 45,000 years of a person who, it was deduced, must have been an arm amputee, because of the way his teeth had been used to compensate for lack of limb. Leg amputees must have compensated partly for their loss by the use of crude crutches and, in some instances, by the use of peg legs fashioned from forked sticks or tree branches (Figs. 1 and 2).

The earliest known record of a prosthesis being used by man was made by the famous Greek historian, Herodotus. His classic "History," written about 484 B.C., contains the story of the Persian soldier, Hegistratus, who, when imprisoned in stocks by the enemy, escaped by cutting off part of his foot, and replaced it later with a wooden version.

A number of ancient prostheses have been displayed in museums in various parts of the world. The oldest known is an artificial leg unearthed from a tomb in Capua in 1858, thought to have been made about 300 B.C., the period of the Samnite Wars. Constructed of copper and wood, the Capua leg was destroyed when the Museum of the Royal College of Surgeons was bombed during World War II. The Alt-Ruppin hand (Fig. 3), recovered along the Rhine River in 1863,

Fig. 1. Mosaic from the Cathedral of Lescar, France, depicts an amputee supported at the knee by a wooden pylon. Some authorities place this in the Gallo-Roman era. From Putti, V., *Historic Artificial Limbs,* 1930.

Fig. 2. Pen drawing of a fragment of antique vase unearthed near Paris in 1862 which shows a figure whose missing limb is replaced by a pylon with a forked end.

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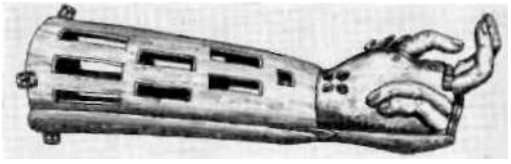


Fig. 3. Alt-Ruppin Hand (Circa 1400). The thumb is rigid; the fingers move in pairs and are sprung by the buttons at the base of the palm; the wrist is hinged. Putti, V., *Chir. d. org. di movimento,* 1924-25.

and other artificial limbs of the 15th century are on display at the Stibbert Museum in Florence. Most of these ancient devices were the work of armorers. Made of iron, these early prostheses were used by knights to conceal loss of limbs as a result of battle, and a number of the warriors are reported to have returned successfully to their former occupation. Effective as they were for their intended use, these specialized devices could not have been of much use to any group other than the knights, and the civilian amputees for the most part must have had to rely upon the pylon and other makeshift prostheses.

Although the use of ligatures was set forth by Hippocrates, the practice was lost during the Dark Ages, and surgeons during that period and for centuries after stopped bleeding by either crushing the stump or dipping it in boiling oil. When Ambroise Pare, a surgeon in the French Army, reintroduced the use of ligatures in 1529, a new era for amputation surgery and prostheses began. Armed with a more successful technique, surgeons were more willing to employ amputation as a lifesaving measure and, indeed, the rate of survival must have been much higher. The practice of amputation received another impetus with the introduction of the tourniquet by Morel in 1674, and removal of limbs is said to have become the most common surgical procedure in Europe. This in turn led to an increase in interest in artificial limbs. Pare, as well as contributing much in the way of surgical procedures, devised a number of limb designs for his patients. His leg (Fig. 4) for amputation through the thigh is the first known to employ articulated joints. Another surgeon, Verduin, introduced in 1696 the first known limb for below-knee

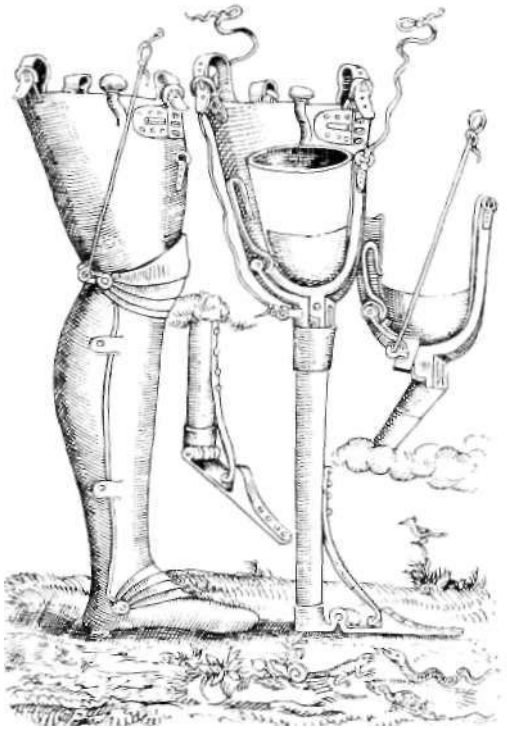


Fig. 4. Artificial leg invented by Ambroise Pare (middle sixteenth century). From Pare, A, *Oeuvres Completes,* Paris, 1840. From the copy in the National Library of Medicine.

amputees that permitted freedom of the knee joint (Fig. 5), in concept much like the thigh-corset type of below-knee limb still used by many today. Yet, for reasons unknown, the Verduin prosthesis dropped from sight until it was reintroduced by Serre in 1826 and. until recently, was the most popular type of below-knee prosthesis used.

After Pare's above-knee prosthesis, which was constructed of heavy metals, the next real advance seems to be the use of wood, introduced in 1800 by James Potts of London. Consisting of a wooden shank and socket, a steel knee joint, and an articulated foot, the Potts invention (Fig. 6) was equipped with artificial tendons connecting the knee and the ankle, thereby coordinating toe lift with knee flexion. It was made famous partly because it was used by the Marquis of Anglesea after

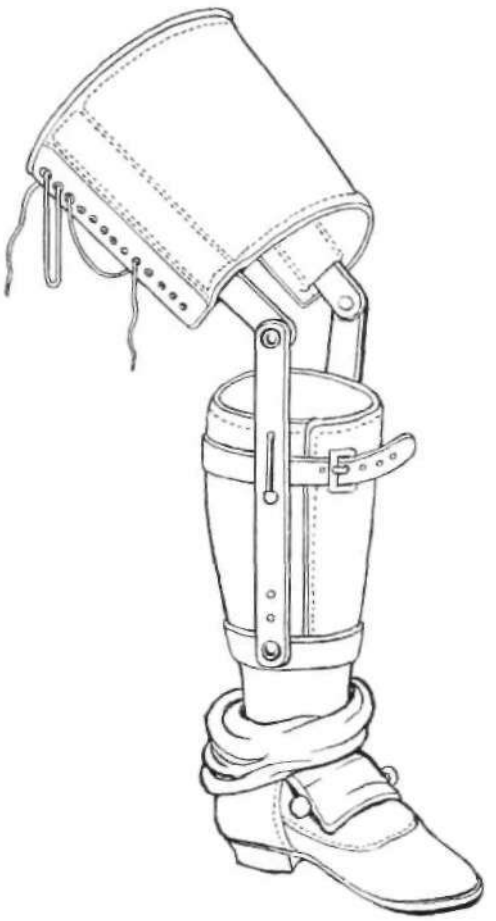


Fig. 5. Verduin Leg (1696). From MacDonald, J., *Am. J. Surg.,* 1905.

he lost a leg at the Battle of Waterloo. Thus it came to be known as the Anglesea leg. With some modifications the Anglesea leg was introduced into the United States in 1839. Many refinements to the original design were incorporated by American limb fitters and in time the wooden above-knee leg became known as the "American leg."

The Civil War produced large numbers of amputees and consequently created a great interest in artificial limbs, no doubt inspired partly by the fact that the federal and state governments paid for limbs for amputees who had seen war service.

J. E. Hanger, one of the first Southerners to lose a leg in the Civil War, replaced the cords in the so-called American leg with rubber bumpers about the ankle joint, a design used almost universally until rather recently. Many patents on artificial limbs were issued between the time of the Civil War and the turn of the century, but few of the designs seem to have had much lasting impact.

During this period, with the availability of chloroform and ether as anesthetics, surgical procedures were greatly improved and more functional amputation stumps were produced by design rather than by fortuity.

World War I stirred some interest in artificial limbs and amputation surgery but, because the American casualty list was

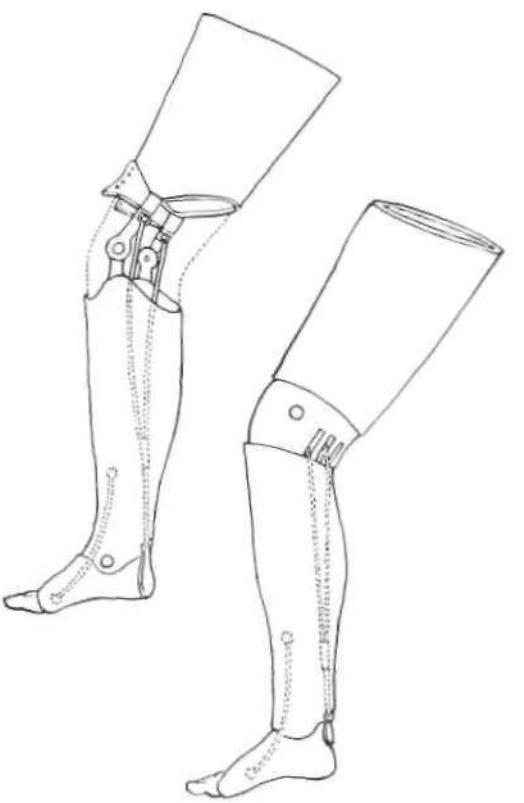


Fig. 6. Anglesea Leg (1800). Below knee at left above knee at right. Knee, ankle, and foot are articulated. From Bigg, H. H.. *Orthopraxy,* 1877.

relatively small, this interest soon waned and, because of the economic depression of the Thirties, some observers think, very little progress was made in the field of limb prosthetics between the two World Wars. Perhaps the most significant contributions were the doctrines set forth and emphasized by Haddan and Thomas, a prosthetist-surgeon team from Denver, that fit and alignment of the prosthesis were the most critical factors in the success of any limb and that much better end-results could be expected if prosthetists and physicians worked together.

Early in 1945, the National Academy of Sciences, at the request of the Surgeon General of the Army, initiated a research program in prosthetics. The initial reaction of the research personnel was that the development of a few mechanical contrivances would solve the problem. However, it soon became evident that much more must be known about biomechanics and other matters before real progress could be made. Devices and techniques based on fundamental data have materially changed the practice of prosthetics during the past dozen years. However, the best conceivable prosthesis is but a poor substitute for a live limb of flesh and blood, and so the research program is still continuing. Fiscal support for research and development by some 20 laboratories is provided by the Veterans Administration, the Vocational Rehabilitation Administration, the National Institutes of Health, the Children's Bureau, the Army, and the Navy. The over-all program is coordinated by the Committee on Prosthetics Research and Development of the National Academy of Sciences—National Research Council.

Soon after the close of World War II, the Artificial Limb Manufacturers Association, which had been formed during World War I, engaged the services of a professional staff to coordinate more effectively the efforts of individual prosthetists. Known today as the American Orthotics and Prosthetics Association, this organization consists of some 415 limb and brace shops, and plays a large part in keeping individual prosthetists and orthotists advised of the latest trends and developments in prosthetics and orthotics.

In 1949, upon the recommendation of the Association, the American Board for Certification of Prosthetists and Orthotists was established to ensure that prosthetists and orthotists met certain standards of excellence, much in the manner that certain physicians' specialty associations are conducted. Examinations are held annually for those desiring to be certified. In addition to certifying individuals as being qualified to practice, the American Board for Certification approves individual shops, or facilities, as being satisfactory to serve the needs of amputees and other categories of the disabled requiring mechanical aids. Certified prosthetists wear badges and shops display the symbol of certification (Fig. 7).

Fig. 7. Symbol of certification by the American Board for Certification in Orthotics and Prosthetics.

The research program, with the cooperation of the prosthetists, has introduced a sufficient number of new devices and techniques to modify virtually every aspect of the practice of prosthetics. To reduce the time lag between research and widespread application, facilities have been established within the medical schools of three universities for short-term courses in special aspects of prosthetics. Courses are offered to each member of the prosthetics-clinic team—the physician, the therapist, and the prosthetist. Also, special courses are offered to vocational rehabilitation counselors and administrative personnel concerned with the welfare of amputees. Approximately 2,100 physicians, 1,900 therapists, and 1,400 prosthetists have been enrolled in these courses during the period 1953 through 1962.

Prior to 1957 medical schools offered little in the way of training in prosthetics to doctors and therapists. To encourage the inclusion of prosthetics into medical and paramedical curricula, the National Academy of Sciences organized the Committee on Prosthetics Education and Information, and as a result of the efforts of this group many schools have adopted courses in prosthetics at both undergraduate and graduate levels.

Today there are approximately 200 amputee-clinic teams in operation throughout the United States. Each state, with assistance from the Vocational Rehabilitation Administration, carries out programs that provide the devices and training required to return the amputee to gainful employment. The Children's Bureau, working through a number of states, has made it possible for child amputees to receive the benefit of the latest advances in prosthetics. The Veterans Administration provides all eligible veterans with artificial limbs. If the amputation is related to his military service, the beneficiary receives medical care and prostheses for the remainder of his life. The Public Health Service, through its hospitals, provides limbs and care to members of the Coast Guard and to qualified persons who have been engaged in the Maritime Service.

In addition to these Government agencies that are concerned with the amputee, there are several hundred rehabilitation centers throughout the United States that assist amputees, especially those advanced in age, in obtaining the services needed for them to return to a more normal life.

Thus, through the cooperative efforts of Government and private groups, considerable progress has been made in the practice of prosthetics and there is little need for an amputee to go without a prosthesis.

REASONS FOR AMPUTATION

Amputation may be the result of an accident, or may be necessary as a lifesaving measure to arrest a disease. A small but significant percentage of individuals are born without a limb or limbs, or with defective limbs that require amputation or fitting (like that of an amputee).

In some accidents a part or all of the limb may be completely removed; in other cases, the limb may be crushed to such an extent that it is impossible to restore sufficient blood supply necessary for healing. Sometimes broken bones cannot be made to heal, and amputation is necessary. Accidents that cause a disruption in the nervous system and paralysis in a limb may also be cause for amputation even though the limb itself is not injured. The object of amputation in such a case is to improve function by substituting an artificial limb for a completely useless though otherwise healthy member. Amputation of paralyzed limbs is not performed very often but has in some cases proven to be very beneficial. Accidents involving automobiles, farm machinery, and firearms seem to account for most traumatic amputations. Freezing, electrical burns, and power tools also account for many amputations.

Diseases that may make amputation necessary fall into one of three main categories—vascular, or circulatory, disorders; cancer; and infection. The diseases that cause circulatory problems most often are arteriosclerosis, or hardening of the arteries, diabetes, and Buerger's disease. In these cases not enough blood circulates through the limb to permit body cells to replace themselves, and unless the limb, or part of it, is removed the patient cannot be expected to live very long. In nearly all these cases the leg is affected because it is the member of the body farthest from the heart and, in accordance with the principles of hydraulics, blood pressure in the leg is lower than in any other part of the bod}'. Vascular disorders are, of course, much more prevalent among older persons. Considerable research is being undertaken to determine the cause of vascular disorders so that amputation for these reasons may at least be reduced if not eliminated, but at the present time vascular disorders are the cause of a large number of lower-extremity amputations.

In many cases amputation of part or all of a limb has arrested a malignant or cancerous condition. In view of present knowledge, the entire limb is usually removed. Malignancy may affect either the arms or legs. Much time

and effort are being spent to develop cures for the various types of cancer.

Since the introduction of antibiotic drugs, infection has been less and less the cause for amputation. Moreover, even though amputation may be necessary, control of the infection may allow the amputation to be performed at a lower level than would be the case otherwise.

Recently, "thalidomide babies" have been given extensive press coverage; however, thalidomide is by no means the sole cause of congenital malformations. Absence of all or part of a limb at birth is not an uncommon occurrence. Many factors seem to be involved in such occurrences, but what these factors are is not clear. The most frequent case is absence of most of the left forearm, which occurs slightly more often in girls than in boys. However, all sorts of combinations occur, including complete absence of all four extremities. Sometimes intermediate parts such as the thigh or upper arm are missing but the other parts of the extremity are present, usually somewhat malformed. In such cases amputation may be indicated; however, even a weak, malformed part is sometimes worth preserving if sensation is present and the partial member is capable of controlling some part of the prosthesis. Extensive studies are being carried out to determine the reasons for congenital malformations.

LOSSES INCURRED

Many of the limitations resulting from amputation are obvious; others less so. An amputation through the lower extremity makes standing and locomotion without the use of an artificial leg or crutches difficult and impracticable except for very short periods. Even when an artificial leg is used, the loss of joints and the surrounding tissues, and consequently loss of the ability to sense position, is felt keenly. The sense of touch of the absent portion is also lost, but in the case of the lower-extremity amputee this is not quite as important as it might seem because the varying pressure occurring between the stump and the socket indicates external loading. In the upper-extremity amputee, sense of touch is more important.

Most lower-extremity amputees cannot bear the total weight of the body on the end of the stump, and other parts of the anatomy must be found for support.

Muscles attached at each end to bones are responsible for movement of the arms and legs. Upon a signal from the nervous system muscle tissue will contract, thus producing a force which can move a bone about its joint (Fig. 8). Because muscle force can be produced only by contraction, each muscle group has an opposing muscle group so that movement in two directions can take place. This arrangement also permits a joint to be held stable in any one of a vast number of positions for relatively long periods of time. How much a muscle can contract is dependent upon its length, and the amount of force that can be generated is dependent upon its circumference.

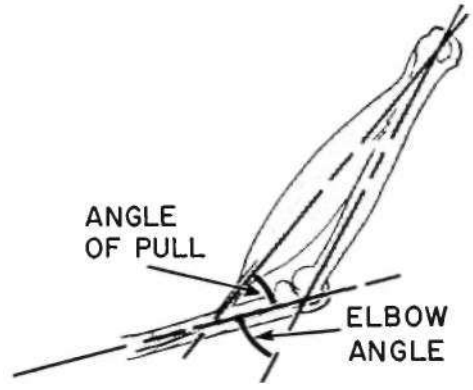


Fig. 8. Schematic drawing of muscular action on skeletal system. The motion shown here is flexion, or bending, of the elbow.

Muscles that activate the limbs must of course pass over at least one joint to provide a sort of pulley action; some pass over two. Thus, some muscles are known as one-joint muscles, others as tw[r]o-joint muscles. When muscles are severed completely, they can no longer transmit force to the bone and, when not used, wither away or atrophy. It will be seen later that these facts are very important in the rehabilitation of amputees.

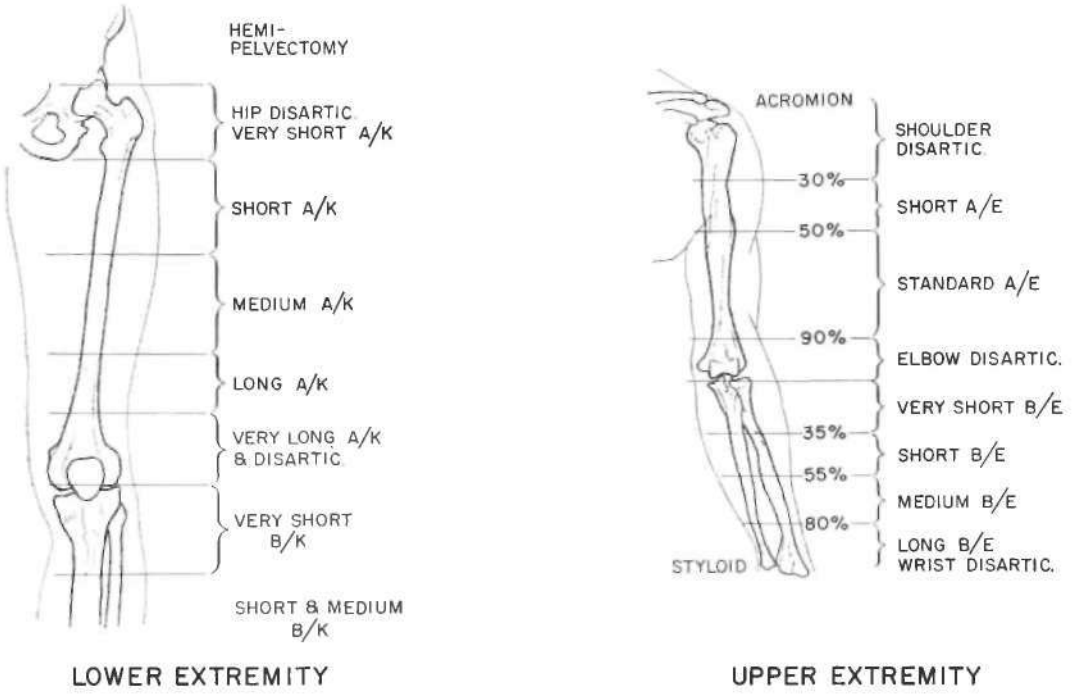


Fig. 9. Classification of amputation by level.

TYPES OF AMPUTATION

Amputations are generally classified according to the level at which they are performed (Fig. 9). Some amputation levels are referred to by the name of the surgeon credited with developing the amputation technique used.

LOWER-EXTREMITY AMPUTATIONS

Syme's Amputation

Developed about 1842 by James Syme, a leading Scottish surgeon, the Syme amputation leaves the long bones of the shank (the tibia and fibula) virtually intact, only a small portion at the very end being removed (Fig. 10). The tissues of the heel, which are ideally suited to withstand high pressures, are preserved, and this, in combination with the long bones, usually permits the patient to bear the full weight of his body on the end of the stump. Because the amputation stump is nearly as long as the unaffected limb, a person with Syme's amputation can usually get about the house without a prosthesis even though normal foot and ankle action has been lost. Atrophy of the severed muscles that were formerly attached to bones in the foot to provide ankle action results in a stump with a bulbous end which, though not of the most pleasing appearance, is quite an advantage in holding the prosthesis in place.

Since its introduction, Syme's operation has been looked upon with both favor and disfavor among surgeons. It seems to be the consensus now that "the Syme" should be performed in preference to amputation at a higher level if possible. In the case of most women, though, "the Syme" is undesirable because of the difficulty of providing a prosthesis that matches the shape of the other leg.

Below-Knee Amputations

Any amputation above the Syme level and below the knee joint is known as a below-knee amputation. Because circulatory troubles have often developed in long below-knee

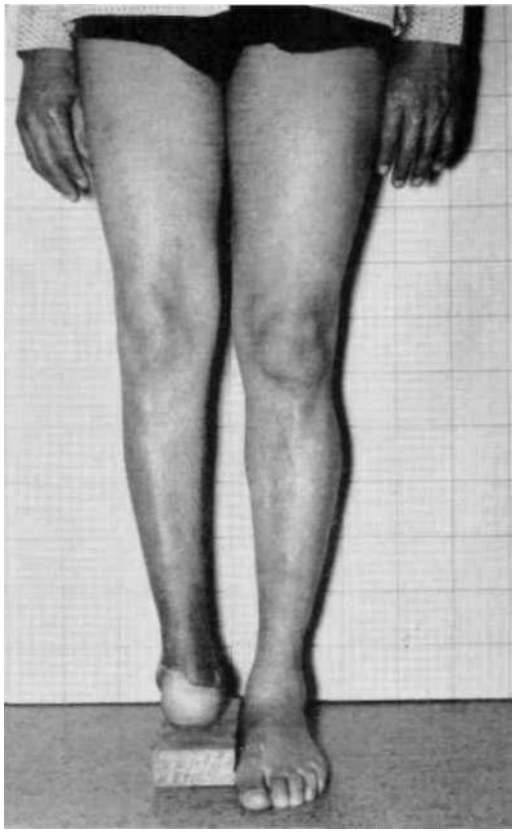


Fig. 10. Excellent Syme stump.

stumps, and because the muscles that activate the shank are attached at a level close to the knee joint, the below-knee amputation is usually performed at the junction of the upper and middle third sections (Fig. 11). Thus nearly full use of the knee is retained—an important factor in obtaining a gait of nearly normal appearance. However, it is rare for a below-knee amputee to bear a significant amount of weight on the end of the stump; thus the design of prostheses must provide for weight-bearing through other areas. Several types of surgical procedures have been employed to obtain weight-bearing through the end of the below-knee stump, but none has found widespread use.

Knee-Bearing Amputations

Complete removal of the lower leg, or shank, is known as a knee disarticulation. When the operation is performed properly, the result is an efficient, though bulbous, stump (Fig. 12) capable of carrying the weight-bearing forces through the end. Unfortunately, the length causes some problems in providing an efficient prosthesis because the space used normally to house the mechanism needed to control the artificial shank properly is occupied by the end of the stump. Nevertheless, prostheses have been

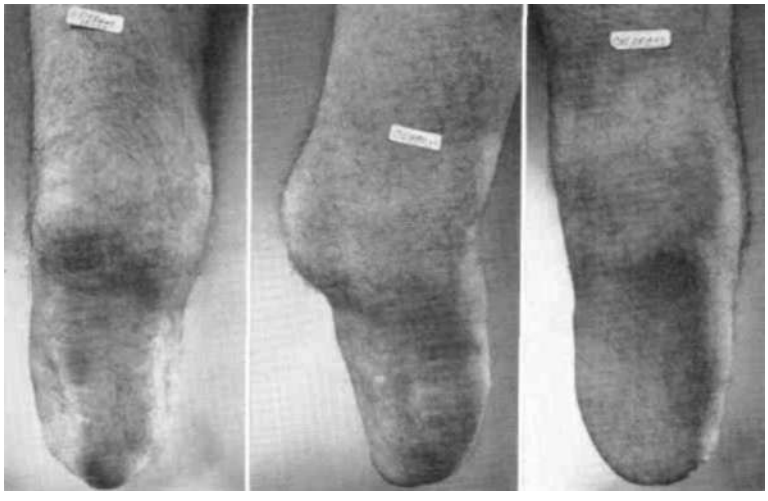


Fig. 11. Typical, well-formed, right below-knee stump. *Courtesy Veterans Administration Prosthetics Center.*

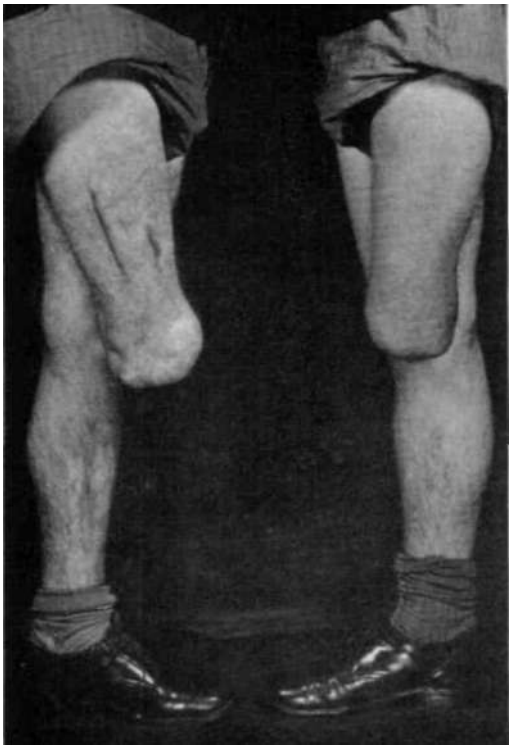


Fig. 12. Typical knee-disarticulation stumps.

highly beneficial in knee-disarticulation cases. Development of adequate devices for obtaining control of the shank is currently under way, and such devices should be generally available in the near future.

Several amputation techniques have been devised in an attempt to overcome the problems posed by the length and shape of the true knee-disarticulation stump. The Gritti-Stokes procedure entails placing the kneecap, or patella, directly over the end of the femur after it has been cut off about two inches above the end. When the operation is performed properly, excellent results are obtained, but extreme skill and expert postsurgical care are required. Variations of the Gritti-Stokes amputation have been introduced from time to time but have never been used widely.

Above-Knee Amputations

Amputations through the thigh are among the most common (Fig. 13). Total body weight cannot be taken through the end of the stump but can be accommodated through the ischium, that part of the pelvis upon which a person normally sits.

Hip Disarticulation and Hemipelvectomy

A true hip disarticulation (Fig. 14) involves removal of the entire femur, but whenever feasible the surgeon leaves as much of the upper portion of the femur as possible in order to provide additional stabilization between the prosthesis and the wearer, even though no additional function can be expected over the true hip disarticulation. Both types of stump

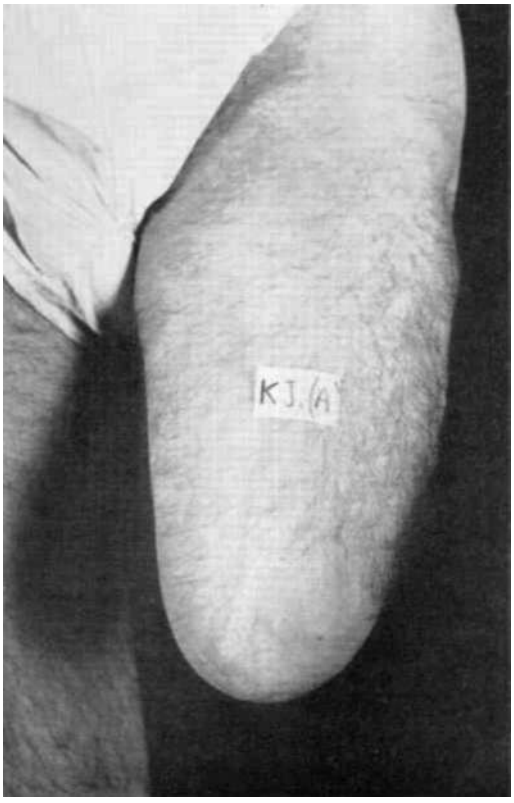


Fig. 13. Typical, well-formed above-knee stump. *Courtesy Veterans Administration Prosthetics Center.*

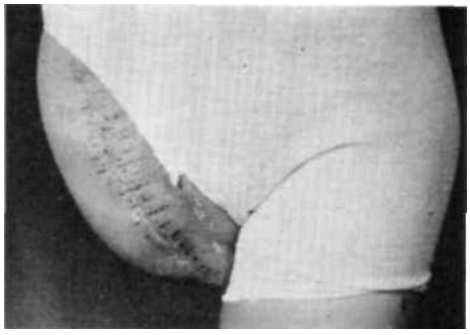


Fig. 14. Patient with true hip-disarticulation amputation.

are provided with the same type of prosthesis. With slight modification the same type of prosthesis can be used by the hemipelvectomy patient, that is, when half of the pelvis has been removed. It is surprising how well hip-disarticulation and hemipelvectomy patients have been able to function when fitted with the newer type of prosthesis.

UPPER-EXTREMITY AMPUTATIONS

Partial-Hand Amputations

If sensation is present the surgeon will save any functional part of the hand in lieu of disarticulation at the wrist. Any method of obtaining some form of grasp, or prehension, is preferable to the best prosthesis. If the result is unsightly, the stump can be covered with a plastic glove, lifelike in appearance, for those occasions when the wearer is willing to sacrifice function for appearance. Many prosthetists have developed special appliances for partial-hand amputations that permit more function than any of the artificial hands and hooks yet devised and, at the same time, permit the patient to make full use of the sensation remaining in the stump. Such devices are usually individually designed and fitted.

Wrist Disarticulation

Removal of the hand at the wrist joint was once condemned because it was thought to be too difficult to fit so as to yield more function than a shorter forearm stump. However, with plastic sockets based on anatomical and physiological principles, the wrist-disarticulation case can now be fitted so that most of the pronation-supination of the forearm—an important function of the upper extremity—can be used. In the case of the wrist disarticulation (Fig. 15), nearly all the normal forearm pronation-supination is present. Range of pronation-supination decreases rapidly as length of stump decreases; when 60 per cent of the forearm is lost, no pronation-supination is possible.

Amputations Through the Forearm

Amputations through the forearm are commonly referred to as below-elbow amputations and are classified as long, short, and very short, depending upon the length of stump (Fig. 9). Stumps longer than 55 per cent of total forearm length are considered long, between 35 and 55 per cent as short, and less than *35* per cent as very short.

Long stumps retain the rotation function in proportion to length; long and short stumps without complications possess full range of elbow motion and full power about the elbow, but often very short stumps are limited in both power and motion about the elbow. Devices and techniques have been developed to make full use of all functions remaining in the stump.

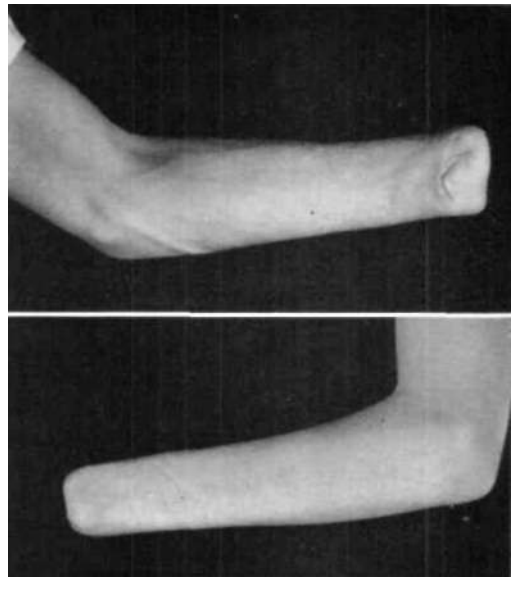


Fig 15. A good wrist-disarticulation **stump.**

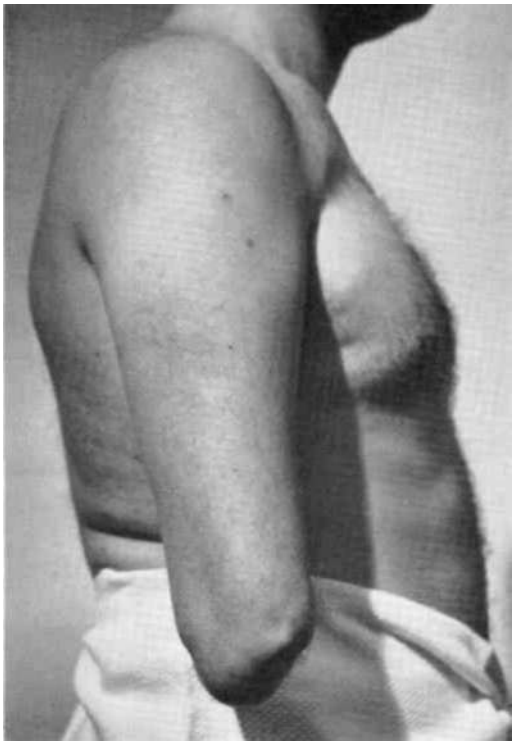


Fig. 16. Amputation through the elbow.

Disarticulation at the Elbow

Disarticulation at the elbow consists of removal of the forearm, resulting in a slightly bulbous stump (Fig. 16) but usually one with good end-weight-bearing characteristics. The long bulbous end, while presenting some fitting problems, permits good stability between socket and stump, and thus allows use of nearly all the rotation normally present in the upper arm—a function much appreciated by the amputee.

Above-Elbow Amputation

Any amputation through the upper arm is generally referred to as an above-elbow amputation (Fig. 9). In practice, stumps in which less than 30 per cent of the humerus remains are treated as shoulder-disarticulation cases; those with more than 90 per cent of the humerus remaining are fitted as elbow-disarticulation cases.

Shoulder Disarticulation and Forequarter Amputation

Removal of the entire arm is known as shoulder disarticulation but, whenever feasible, the surgeon will leave intact as much of the humerus as possible to provide stability between the stump and the socket (Fig. 17). When it becomes necessary to remove the clavicle and scapula, the operation is known as a forequarter, or interscapulothoracic, amputation. The very short above-elbow, the shoulder-disarticulation, and the forequarter cases are all provided with essentially the same type of prosthesis.

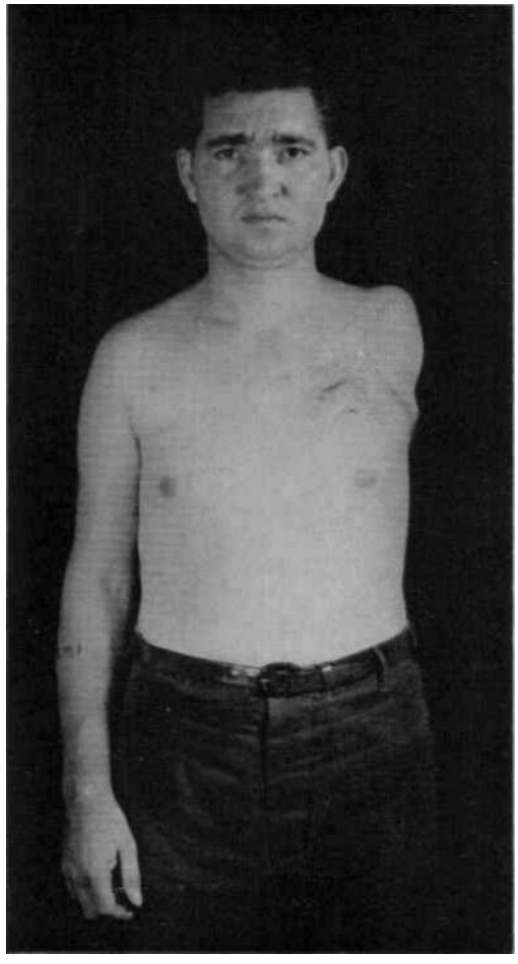


Fig. 17. A true shoulder disarticulation.

THE POSTSURGICAL PERIOD

The period between the time of surgery and time of fitting the prosthesis is an important one if a good functional stump, and thus the most efficient use of a prosthesis, is to be obtained. The surgeon and others on his hospital staff will do everything possible to ensure the best results, but ideal results require the wholehearted cooperation of the patient.

It is not unnatural for the patient to feel extremely depressed during the first few days after surgery, but after he becomes aware of the possibilities of recovery, the outlook becomes brighter, and he generally enters cooperatively into the rehabilitation phase.

As soon as the stump has healed sufficiently, exercise of the stump is started in order to keep the muscles healthy and reduce the possibility of muscle contractures. Contractures can be prevented easily, but it is most difficult and sometimes impossible to correct them. At first exercises are administered by a therapist or nurse; later the patient is instructed concerning the type and amount of exercise that should be undertaken. The patient is also instructed in methods and amount of massage that should be given the stump to aid in the reduction of the stump size. Further, to aid shrinkage, cotton-elastic bandages are wrapped around the stump (Fig. 18) and worn continuously until a prosthesis is fitted. The bandage is removed and reapplied at regular intervals—four times during the day, and at bedtime. It is most important that a clean bandage is available for use each day.

The amputee is taught to apply the bandage unless it is physically impossible for him to do so, in which case some member of his family must be taught the proper method for use at home.

To reduce the possibility of contractures, the lower-extremity stump must not be propped upon pillows. Wheel chairs should be used as little as possible; crutch walking is preferred, but the above-knee stump must not be allowed to rest on the crutch handle (Fig. 19).

THE PHANTOM SENSATION

After amputation the patient almost always has the sensation that the missing part is still present (Fig. 20). The exact cause of this is as yet unknown. The phantom sensation usually recedes to the point where it occurs only infrequently or disappears entirely, especially if a prosthesis is used. In a large percentage of cases, moderate pain may accompany the phantom sensation but, in general, this too eventually disappears entirely or occurs only infrequently. In a small percentage of cases severe phantom pain persists to the point where medical treatment is necessary.

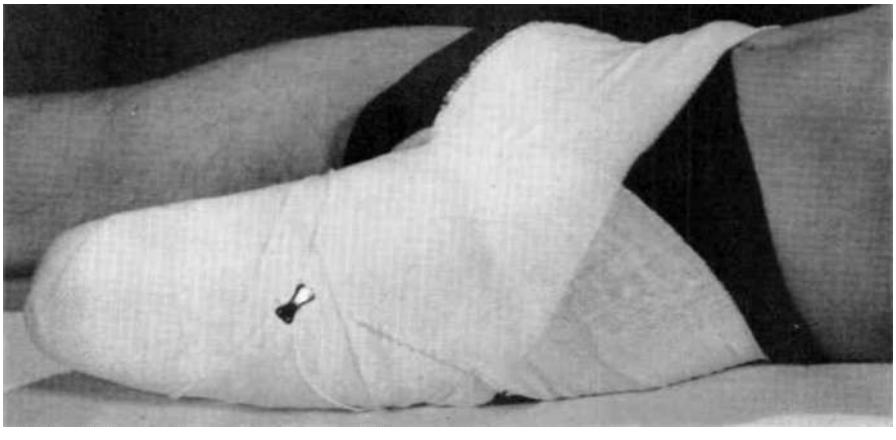


Fig. 18. Compression wrap for above-knee amputation. The wrap of elastic bandage aids in shrinking the stump.

Fig. 19. Actions to be avoided by lower-extremity amputees during the immediate postoperative period.

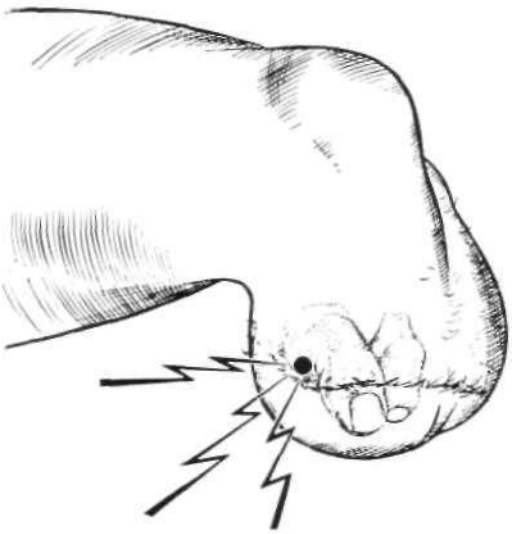


Fig. 20. One form of the "phantom" sensation. Here the two toes seem to reside in the stump itself.

TIME OF FITTING

Surgeons increasingly have become aware that best results are obtained with artificial limbs when they are fitted as early as possible after surgery, that is, when pain and soreness have disappeared. This time will vary, depending upon type of amputation and condition of the patient. The earliest time is about six weeks after the operation. Below-knee stumps as a rule require a longer healing period than above-knee and upper-extremity stumps. An elderly patient whose legs have been amputated by reason of vascular insufficiency usually requires a longer healing period than an otherwise-healthy young person whose legs have been amputated as the result of an accident.

PROSTHESES FOR VARIOUS TYPES OF AMPUTATION

Much time and attention have been devoted to the development of mechanical components, such as knee and ankle units, for artificial limbs, yet by far the most important factors affecting the successful use of a prosthesis are the fit of the socket to the stump and the alignment of the various parts of the limb in relation to the stump and other parts of the body.

Thus, though many parts of a prosthesis may be mass-produced, it is necessary for each limb to be assembled in correct alignment and fitted to the stump to meet the individual requirements of the intended user. To make and fit artificial limbs properly requires a complete understanding of anatomical and physiological principles and of mechanics; craftsmanship and artistic ability are also required.

In general, an artificial limb should be as light as possible and still withstand the loads imposed upon it. In the United States willow and woods of similar characteristics have formed the basis of construction for more limbs than any other material, though aluminum, leather-and-steel combinations, and fibre have been used widely. Wood construction is still the type most used in the United States for above-knee prostheses, but plastic laminates similar to those so popular in small-boat construction are the materials of choice for virtually all other types of prostheses. Plastic laminates are light in weight, easy to keep clean, and do not absorb perspiration. They may be molded easily and rapidly over contours such as those found on a plaster model of a stump. Plastic laminates can be made extremely rigid or with any degree of flexibility required in artificial-limb construction. In some instances, especially in upper-extremity sockets, the fact that most plastic laminates do not permit water vapor to pass to the atmosphere has caused discomfort, but recently a porous type has been developed by the Army Medical Biomechanical Research Laboratory (formerly the Army Prosthetics Research Laboratory). Except experimentally, its use thus far has been restricted to artificial arms. Of course, most of the mechanical parts are made of steel or aluminum, depending upon their function.

As in the case of the tailor making a suit, the first step in fabrication of a prosthesis is to take the necessary measurements for a good fit. If the socket is to be fabricated of a plastic laminate, an impression of the stump is made. Most often this is accomplished by wrapping the stump with a wet plaster-of-Paris bandage and allowing it to dry, as a physician does in applying a cast when a bone is broken (Fig. 21).

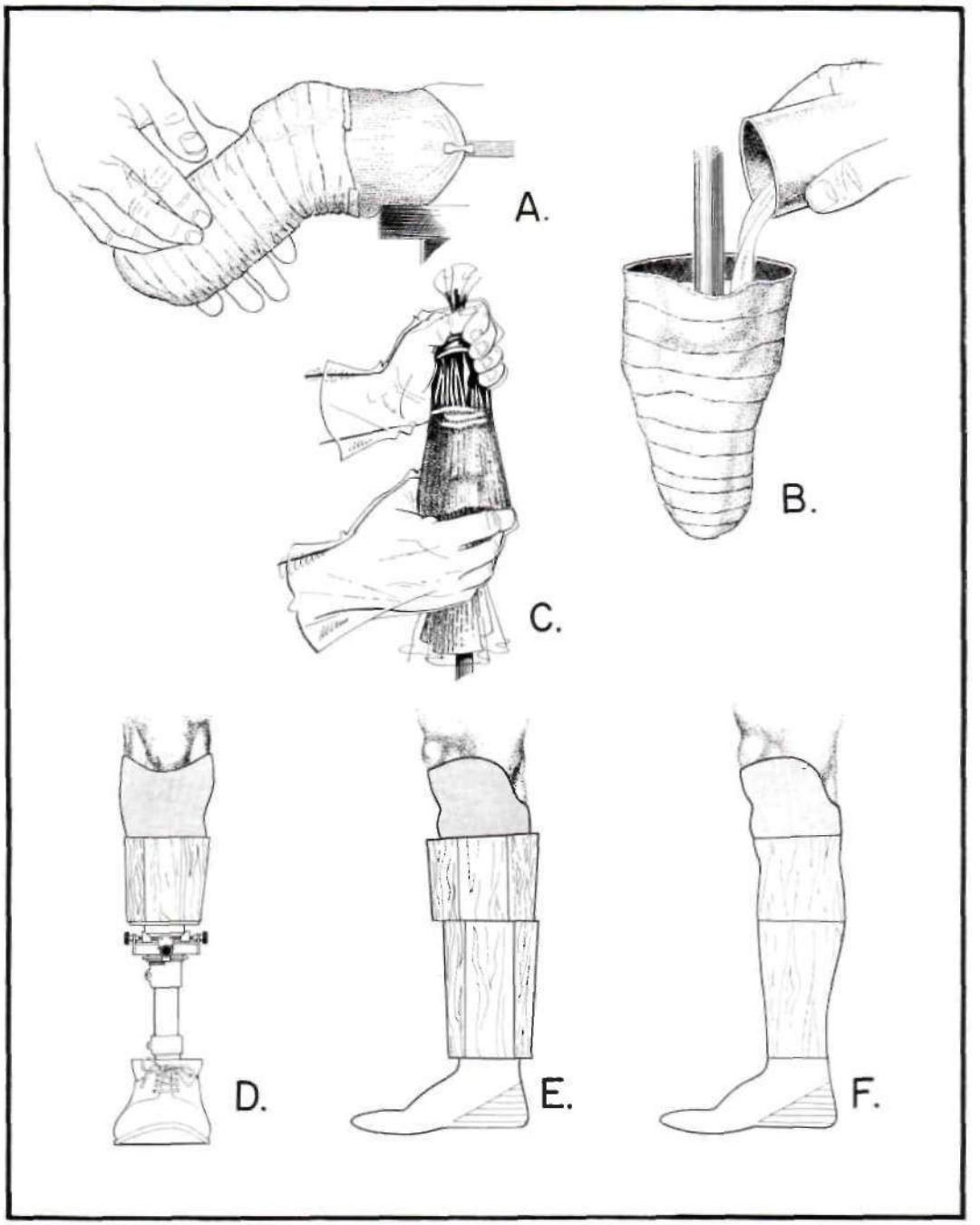


Fig. 21. Steps in the fabrication of a plastic prosthesis for a below-knee amputation. *A,* Taking the plaster cast of the stump; *B,* pouring plaster in the cast to obtain model of the stump; *C,* introducing plastic resin into fabric pulled over the model to form the plastic-laminate socket; *D,* the plastic-laminate socket mounted on an adjustable shank for walking trials; *E,* a wooden shank block inserted in place of the adjustable shank after proper alignment has been obtained; *F,* the prosthesis after the shank has been shaped. To reduce weight to a minimum the shank is hollowed out and the exterior covered with a plastic laminate.

The cast, or wrap, is removed from the stump and filled with a plaster-of-Paris solution to form an exact model of the stump which—after being modified to provide relief for any tender spots, to ensure that weight will be taken in the proper places, and to take full advantage of the remaining musculature—can be used for molding a plastic-laminate socket. Often a "check" socket of cloth impregnated with beeswax is made over the model and tried on the stump to determine the correctness of the modifications.

For upper-extremity cases the socket is attached to the rest of the prosthesis and a harness is fabricated and installed for operation of the various parts of the artificial arm. For the lower-extremity case the socket is fastened temporarily to an adjustable, or temporary, leg for walking trials (Fig. 22). With this device, the prosthetist can easily adjust the alignment until both he and the amputee are satisfied that the optimum arrangement has been reached. A prosthesis can now be made incorporating the same alignment achieved with the adjustable leg.

There are many kinds of artificial limbs available for each type of amputation, and much has been written concerning the necessity for prescribing limbs to meet the needs of each individual. This of course is true particularly in the case of persons in special or arduous occupations, or with certain medical problems, but actually limbs for a given type of amputation vary to only a small degree. Following are descriptions of the artificial limbs most commonly used in the United States today.

LOWER-EXTREMITY PROSTHESES

Prostheses for Syme's Amputation

Perhaps the major reason Syme's amputation was held in such disfavor in some quarters was the difficulty in providing a comfortable, sufficiently strong prosthesis with a neat appearance. The short distance between the end

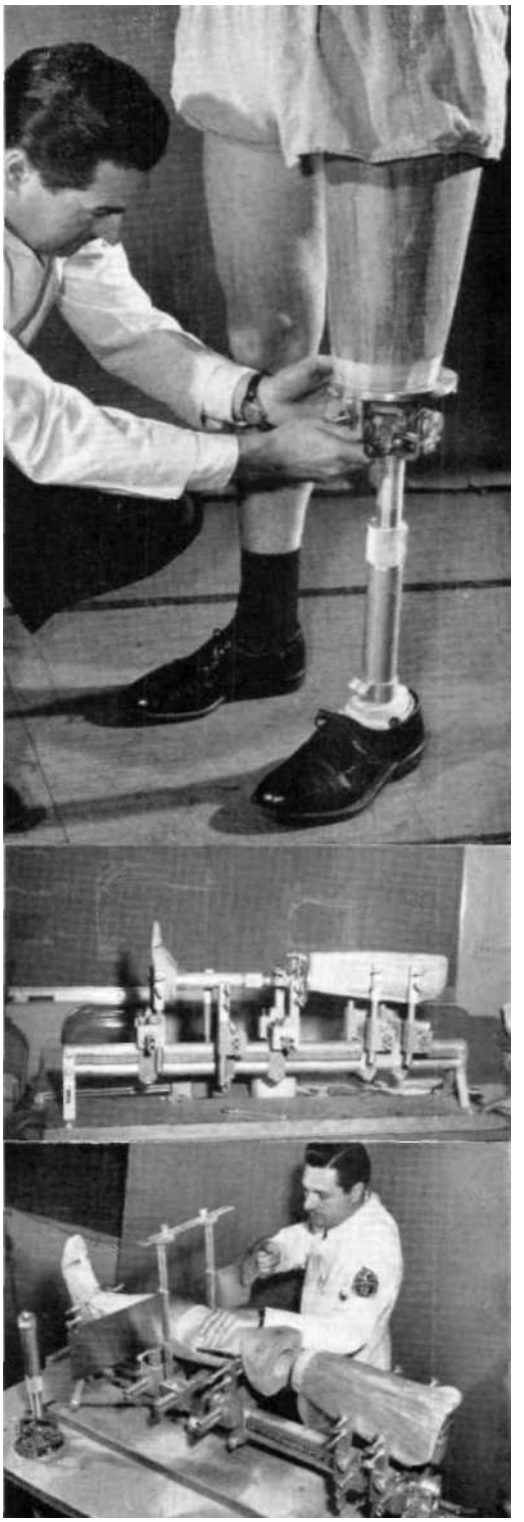
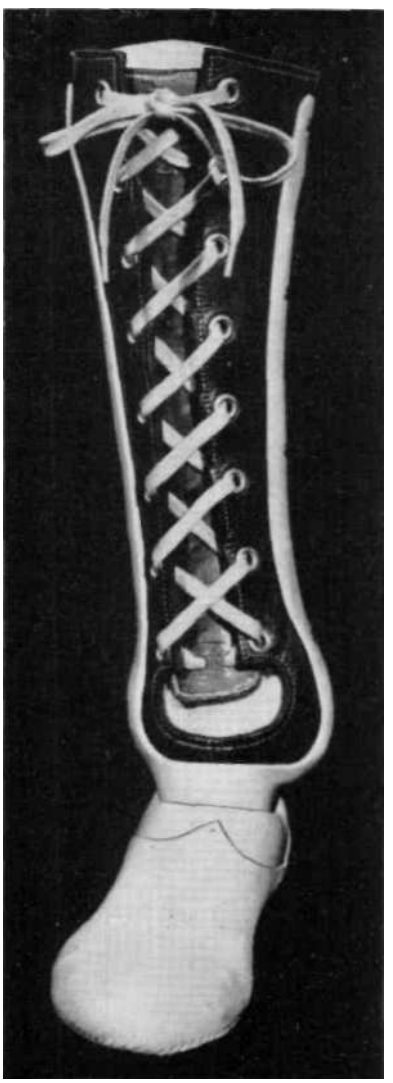


Fig. 22. Using the above-knee adjustable leg and alignment duplication jig. Top, Adjusting the adjustable leg during walking trials; Center, the socket and adjustable leg in the alignment duplication jig; Bottom, replacement of the adjustable leg with a permanent knee and shank.

of the stump and the floor made it extremely difficult to provide for ankle motion needed. Most Syrae prostheses were of leather reinforced with steel side bars resulting in an ungainly appearance (Fig. 23). Research workers at the Prosthetic Services Centre at the Department of Veterans Affairs of Canada were quick to realize that the use of the proper plastic laminate might solve many of the problems long associated with the Syme prosthesis. After a good deal of experimentation, the Canadians developed a model in 1955 which, with a few variations, is used almost universally in both Canada and the United States today (Fig. 24).



Fig, 23. Syme prosthesis with side bars mounted on medial and lateral aspects of the shank. This type of construction has been virtually replaced by plastic laminates.

Fig. 24. The Syme prosthesis adopted by the Canadian Department of Veterans Affairs. The posterior opening extends the length of the shank.

Necessary ankle action is provided by making the heel of the foot of sponge rubber. The socket is made entirely of a plastic laminate. A full-length cutout in the rear permits entry of the bulbous stump. When the cutout is replaced and held in place by straps, the bulbous stump holds the prosthesis in place. In the American version (Fig. 25), a window-type

Fig. 25. Two views of the Canadian-type Syme prosthesis as modified bj the Veterans Administration Prosthetics Center,

cutout is used on the side because calculations show that smaller stress concentrations are present with such an arrangement.

In those cases where, for poor surgery or other reasons, full body weight cannot be tolerated on the end of the stump, provisions can be made to transfer all or part of the load to the area just below the kneecap. When this procedure is necessary, it can be accomplished more easily by use of the window-type cutout.

Prostheses for Below-Knee Amputations

Until recently most below-knee amputees were fitted with wooden prostheses carved out by hand (Fig. 26). A good portion of the body weight was carried on a leather thigh corset, or lacer, attached to the shank and socket by means of steel hinges. The shape of corset and upper hinges also held the prosthesis to the stump. The distal, or lower, end of the socket was invariably left open. Other versions of this prosthesis used aluminum, fibre or molded leather, as the materials for construction of the shank and socket, but the basic principle was the same. Many thousands of below-knee amputees have gotten along well with this type of prosthesis, but there are many disadvantages. Because the human knee joint is not a simple, single-axis hinge joint, relative motion is bound to occur between the prosthesis and the stump and thigh during knee motion when single-jointed side hinges are used, resulting in some chafing and irritation. To date it has not been possible to devise a hinge to overcome this difficulty. Edema, or accumulation of body fluids, was often present at the lower end of the stump. Most of these prostheses were exceedingly heavy, especially those made of wood.

In an attempt to overcome these difficulties, the Biomechanics Laboratory of the University of California, in 1958, designed what is known

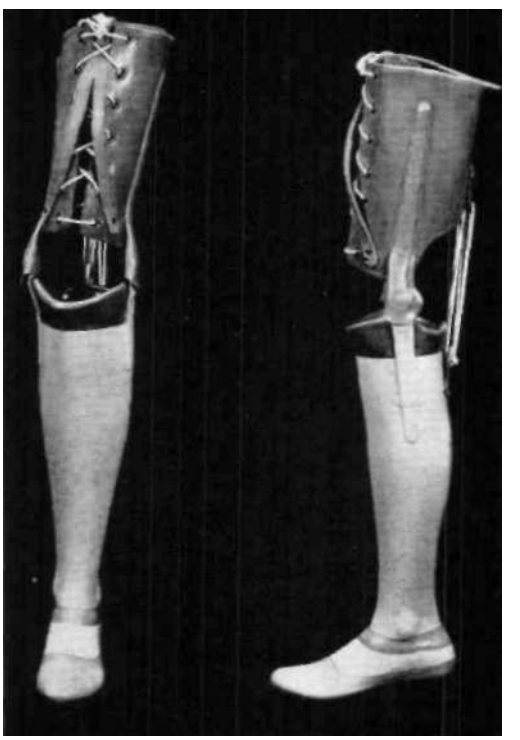


Fig. 26. Below-knee prosthesis with wood socket-shank, thigh corset, and steel side bars. *Courtesy Veterans Administration Prosthetics Center.*

as the patellar-tendon-bearing (PTB) below-knee prosthesis (Fig. 27). In the PTB prosthesis no lacer and side hinges are used, all of the weight being taken through the stump by making the socket high enough to cover all the tendon below the patella, or kneecap. The patellar tendon is an unusually inelastic tissue which is not unduly affected by pressure. The sides of the socket are also made much higher than has usually been the practice in the past in order to give stability against side loads. The socket is made of molded plastic laminate that provides an intimate fit over the entire area of the socket, and is lined with a thin layer of sponge rubber and leather. Because it is rare for a below-knee stump to bear much pressure on its lower end, care is taken to see that only a very slight amount is present in that area. This feature has been a big factor in eliminating the edema problem in many instances. The PTB prosthesis is generally suspended by means of a simple cuff, or strap, around the thigh just above the kneecap, but sometimes a strap from the prosthesis to a belt around the waist is used.

After the socket has been made, it is installed on a special adjustable leg (Fig. 28) so that the prosthetist can try various alignment combinations with ease. When both prosthetist and patient are satisfied, the leg is completed uti-

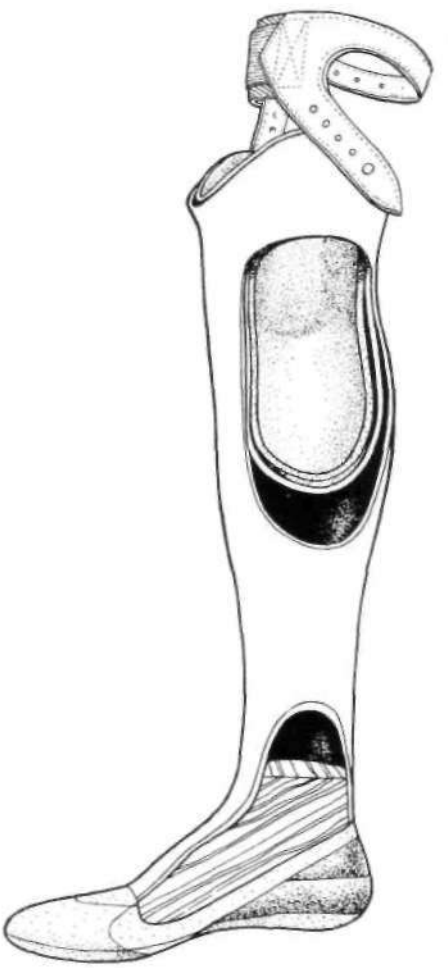


Fig. 27. Cutaway view of the patellar-tendon-bearing leg for below-knee amputees.

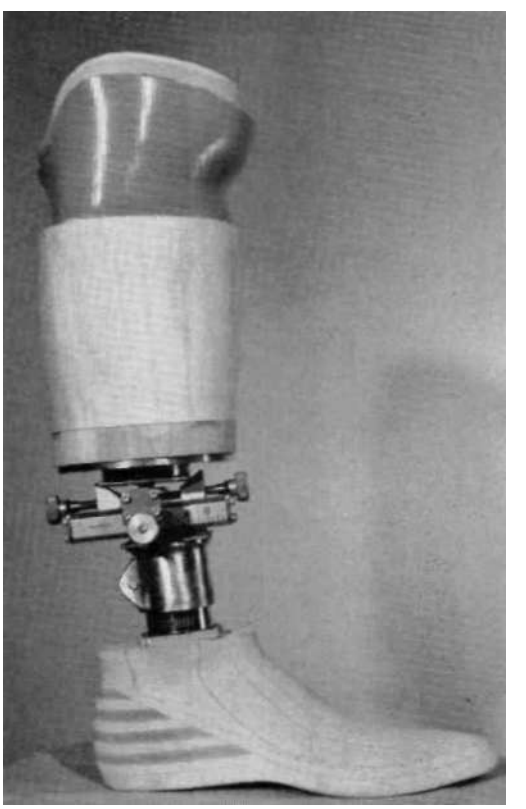


Fig. 28. Trial below-knee adjustable leg.

lizing the alignment determined with the adjustable unit.

The shank recommended is of plastic laminate and the foot prescribed is usually the SACH (solid-ankle, cushion-heel) design but other types can be used.

It is now general practice in many areas to prescribe the PTB prosthesis in most new cases and in many old ones, and if side hinges and a corset are indicated later, these can be added.

Stumps as short as 2-1/2 in. have been fitted successfully with the PTB prosthesis.

In special cases, such as extreme flexion contracture, the so-called kneeling-knee, or bent-knee, prosthesis may be indicated. The prosthesis used is similar to that used for the knee-disarticulation case.

Prostheses for the Knee-Disarticulation and Other Knee-Bearing Cases

Because of the bulbous shape of the true knee-disarticulation stump, it is not possible to use a wooden socket of the type used on the tapered above-knee stump. To allow entry of the bulbous end, a socket is molded of leather to conform to the stump and is provided with a lengthwise anterior cutout that can be laced to hold the socket in position (Fig. 29). Because of the length of the knee-disarticulation and supracondylar stump, it is not possible to install any of the present knee units designed for above-knee prostheses and, therefore, heavy-duty below-knee joints are generally used. Most prosthetists try to provide some control of the shank during the swing phase of walking by inserting nylon washers between the mating surfaces of the joint to provide friction and by using checkstraps. Better devices for control of the knee joint are being developed and should be available in the near future.

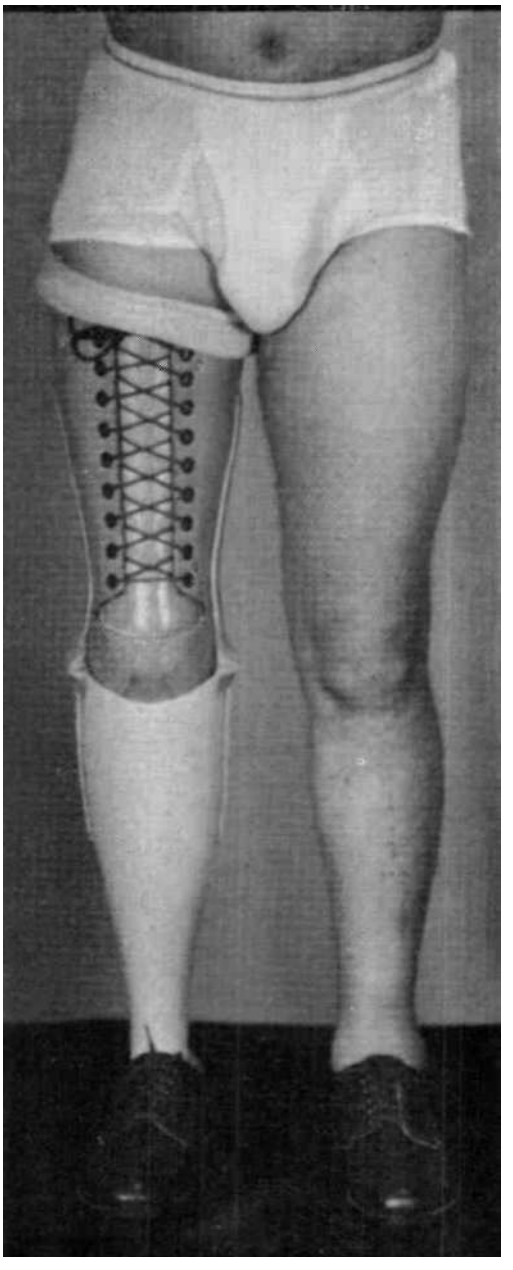


Fig. 29. Typical knee-disarticulation prosthesis.

Prostheses for Above-Knee Cases

The articulated above-knee leg is in effect a compound pendulum actuated by the thigh stump. If the knee joint is perfectly free to rotate when force is applied, the effects of inertia and gravity tend to make the shank rotate too far backward and slam into extension as it rotates forward, except at a very slow rate of walking. The method most used today to permit an increase in walking speed is the introduction of some restraint in the form of mechanical friction about the knee joint. The limitation imposed by constant mechanical friction is that for each setting there is only

one speed that produces a natural-appearing gait. When restraint is provided in the form of hydraulic resistance, a much wider range of cadence can be obtained without introducing into the gait pattern awkward and unnatural motions.

Throughout the past century much time and effort have been spent in providing an automatic brake or lock at the knee in order to provide stability during the stance phase and to reduce the possibility of stumbling. Stability during the stance phase can be obtained by aligning the leg so that the axis of the knee is behind the hip and ankle axes. For most above-knee amputees in good health, such an arrangement has been quite satisfactory, but an automatic knee brake is indicated for the weaker or infirm patients.

The prosthesis prescribed most commonly today for the above-knee amputee consists of a carved wooden socket, a single-axis knee unit with constant but adjustable friction, a wooden shank, and a SACH foot. The shank and socket are reinforced with an outer layer of plastic laminate to reduce the amount of wood required and thus keep weight to an optimum.

When an automatic brake is indicated, the Bock, the "Vari-Gait" 100, and the Mortensen knee units (Fig. 30) are the ones most generally used. All are actuated upon contact of the heel with the ground. The Bock and "Vari-Gait" units can be used with almost any type of foot, while a foot of special design is necessary when the Mortensen mechanism is used.

The "Hydra-Cadence" above-knee leg (Fig. 31) was until recently the only unit available that provided hydraulic friction to control the shank during the swing phase of walking. In addition to this feature, incorporated in the Hydra-Cadence design is provision for coordinated motion between the ankle action and the knee action. After the knee has flexed 20 deg., the toe of the foot is lifted as the knee is flexed further, thus giving more clearance between the foot and the ground as the leg swings through. Other hydraulic units recently made available are the Regnell (a Swedish design) and the DuPaCo. Still others are in advanced stages of development.

A number of methods for suspending the above-knee leg are available. For younger, healthy patients, the suction socket (Fig. 32A) is generally the method of choice. In this design the socket is simply fitted tightly enough to retain sufficient negative pressure, or suction, between the stump and the bottom of the socket when the leg is off the ground. Special valves are used to control the amount of negative pressure created so as not to cause discomfort. No stump sock is worn with the suction socket. A major advantage of this type of suspension is the freedom of motion permitted the wearer, thus allowing the use of all the remaining musculature of the stump. Another important advantage is the decreased amount of piston action between stump and socket. Additional comfort is also obtained by elimination of all straps and belts.

In some cases additional suspension is provided by adding a "Silesian Bandage," (Fig. 32B), a light belt attached to the socket in such a way that there is very little restriction to motion of the various parts of the body.

Patients with weak stumps and most of those with very short stumps will require a pelvic belt connected to the socket by means of a "hip" joint (Fig. 32C). Because the connecting joint cannot be placed to coincide with the normal joint, certain motions are restricted. Pelvic-belt suspension is generally indicated for the older patient because of the problems encountered in donning the suction socket, especially that of bending over to remove the donning sock.

Shoulder straps, at one time the standard method of suspending above-knee prostheses, are still sometimes indicated for the elderly patient.

Prior to the introduction of the suction socket into the United States soon after the close of World War II, virtually all above-knee sockets had a conical-shaped interior and were known as plug fits, most of the weight being borne along the sides of the stump. Such a design does not permit the remaining musculature to perform to its full capabilities. In the development of the suction socket, a design known as the quadrilateral socket (Fig. 32) evolved, and now is virtually the standard for above-knee sockets regardless of

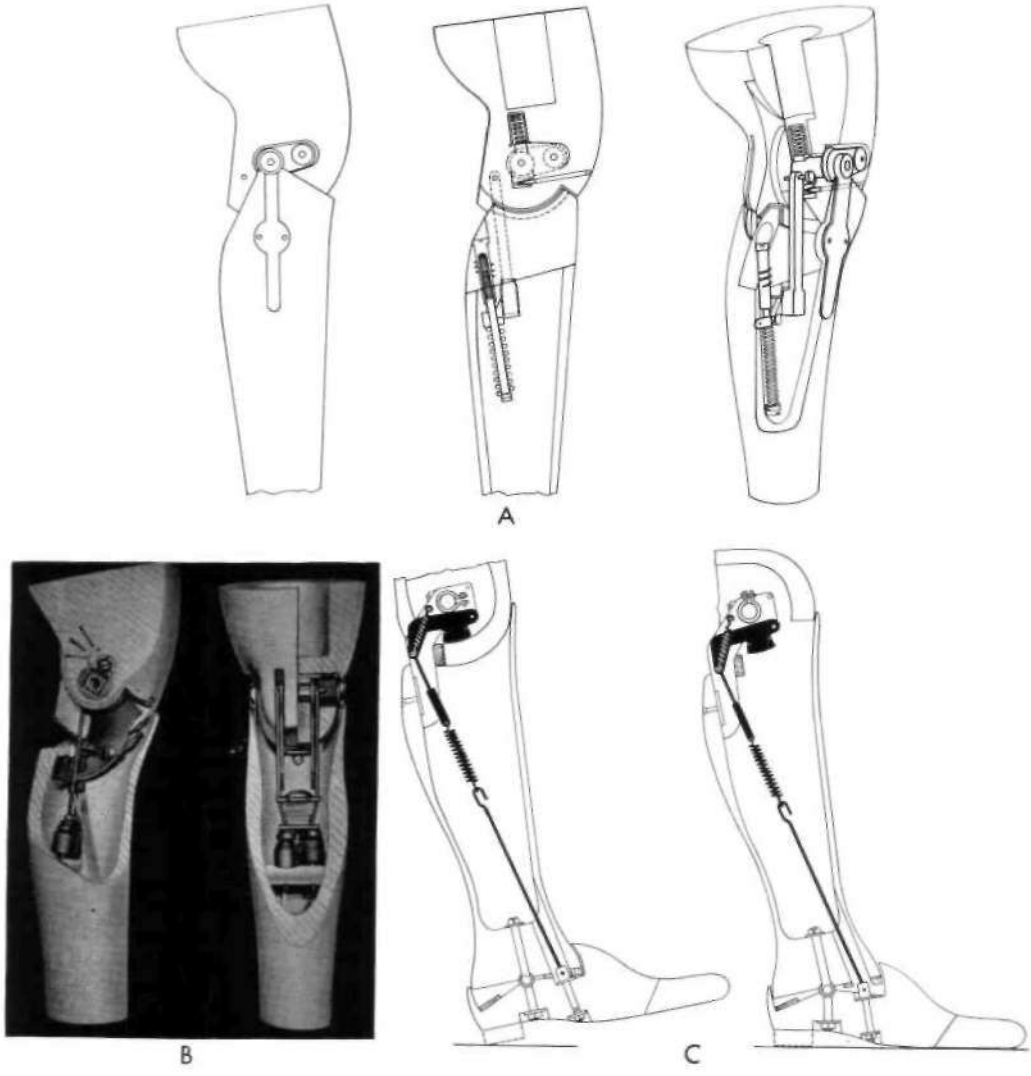


Fig. 30. Some examples of weight-actuated knee units. *A,* Bock "Safety-knee"; *B,* Vari-Gait knee; *C,* Mortensen leg.

the type of suspension used. When the pelvic belt or suspender straps are used, the socket is fitted somewhat looser than in the case of the suction socket, and the stump sock is generally worn to reduce skin irritation from the pumping action of the loose socket. Most of the body weight is taken on the ischium of the pelvis, that part which assumes the load when an individual is sitting.

The quadrilateral socket, because of the method employed to permit full use of the remaining muscles, does not resemble the shape of the stump but, as the name implies, is more rectangular in shape. Until recently the standard method of fitting a quadrilateral socket called for no contact over the lower end of the stump, a hollow space being left in this area. Although this method was quite successful there remained a sufficient number of cases that persistently developed ulcers or edema over the end of the stump. Experiments involving the use of slight pressure over

the stump-end led to the development of what is known as the plastic total-contact socket (Fig. 32A). As the name implies, the socket is in contact with the entire surface of the stump. The total-contact socket has helped to cure most of the problem cases and is now being used routinely in many areas.

In fitting the above-knee prosthesis, the prosthetist carves the interior of the socket using measurements of the stump as a guide. When a satisfactory fit has been achieved the socket is usually mounted on an adjustable leg for alignment trial, after which the wooden shank and the knee are substituted for the adjustable unit and the leg is finished by applying a thin layer of plastic laminate over the shank and the thigh piece.

In the case of the total-contact socket, the prosthetist obtains a plaster cast of the stump, usually with the aid of a special casting jig (Fig. 33), and thus obtains a model of the stump over which the plastic socket can be formed.

Prostheses for Hip-Disarticulation and Hemipelveclomy Cases

A prosthesis (Fig. 34) developed by the Canadian Department of Veterans Affairs in 1954 and modified slightly through the years has become accepted as standard practice. In the Canadian design a plastic-laminate socket is used, and the "hip" joint is placed on the front surface in such a position that, when used with an elastic strap connecting the rear end of the socket to a point on the shank ahead of the femur, stability during standing and walking can be achieved without the use of a lock at the hip joint. The location of the hip joint in the Canadian design also facilitates sitting, a real problem in earlier designs.

A constant-friction knee unit is most often used with the hip-disarticulation prosthesis, but some prosthetists have reported successful use of hydraulic knee units.

The hemipelvectomy patient is provided with the same type of prosthesis but the socket design is altered to allow for the loss of part of the pelvis.

UPPER-EXTREMITY PROSTHESES

The major role of the human arm is to place the hand where it can function and to transport objects held in the hand. The energy for operation of the hand substitute in upper-extremity prostheses is derived from relative motion between two parts of the body. Energy for operation of the elbow joint, when necessary, can be obtained in the same way. The stump, of course, is also a source of energy for control of the prosthesis in all except the shoulder-disarticulation and forequarter cases. Force and motion can be obtained through a cable connected between the device to be operated and a harness across the chest or shoulders.

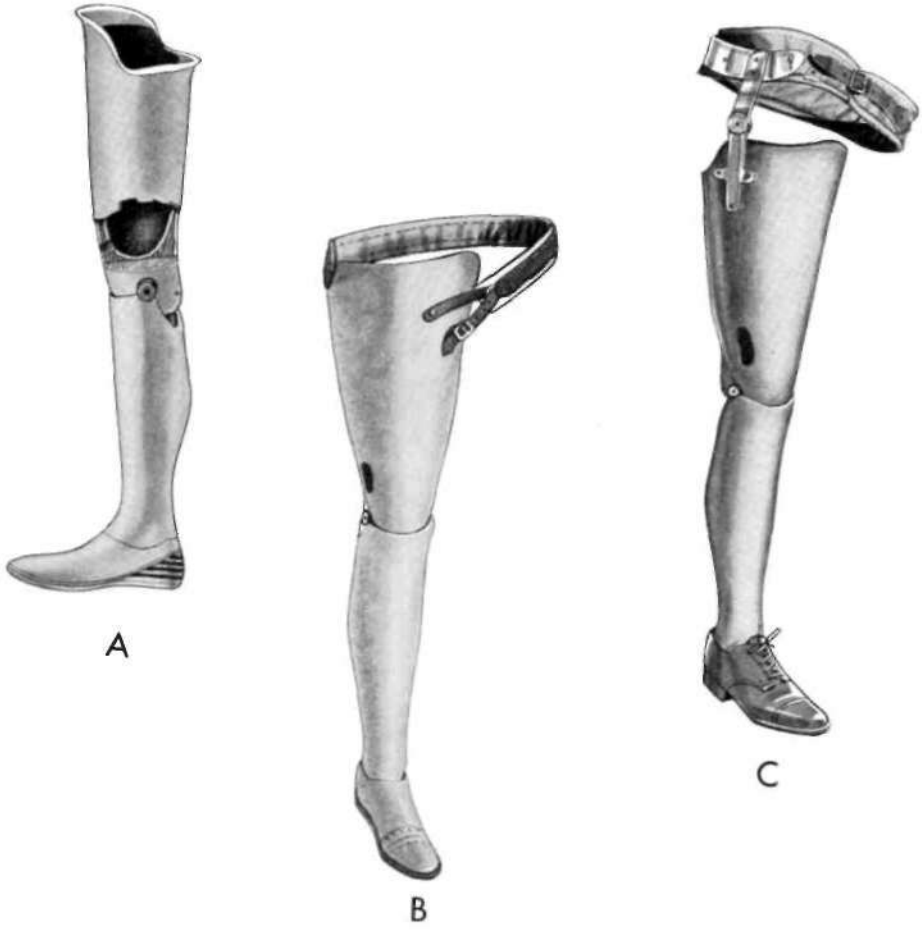


Fig. 32. Above-knee sockets and methods of suspension. *A*, Total-contact suction socket; *B*, above-knee leg with Silesian bandage for suspension; C, above-knee leg with pelvic belt for suspension. Most above-knee sockets have a quadrilateral-shaped upper portion as shown.

Hand Substitutes—Terminal Devices

All upper-extremity prostheses for amputation at the wrist level and above have, in common, the problem of selection of the terminal device, a term applied to artificial hands and substitute devices such as hooks. In some areas of the world there is a tendency to supply the arm amputee with a number of devices, each designed for a specific task such as eating, shaving, hairgrooming, etc. In the United States such an approach has been considered too clumsy, and opinion has been that the terminal device should be designed so that most upper-extremity amputees can perform the activities of daily living with a single device, or at most with two devices.

The so-called split hooks are much more functional than any artificial hand devised to date. The arm amputee must rely heavily upon visual cues in handling objects and the hook offers more visibility. The hook also offers more prehension facility, and can be more easily introduced into and withdrawn from pockets than a device in the form of a hand. Therefore, the hook is used in manual occupations and those avocations requiring manual dexterity. When extensive contact with the public is necessary and for social

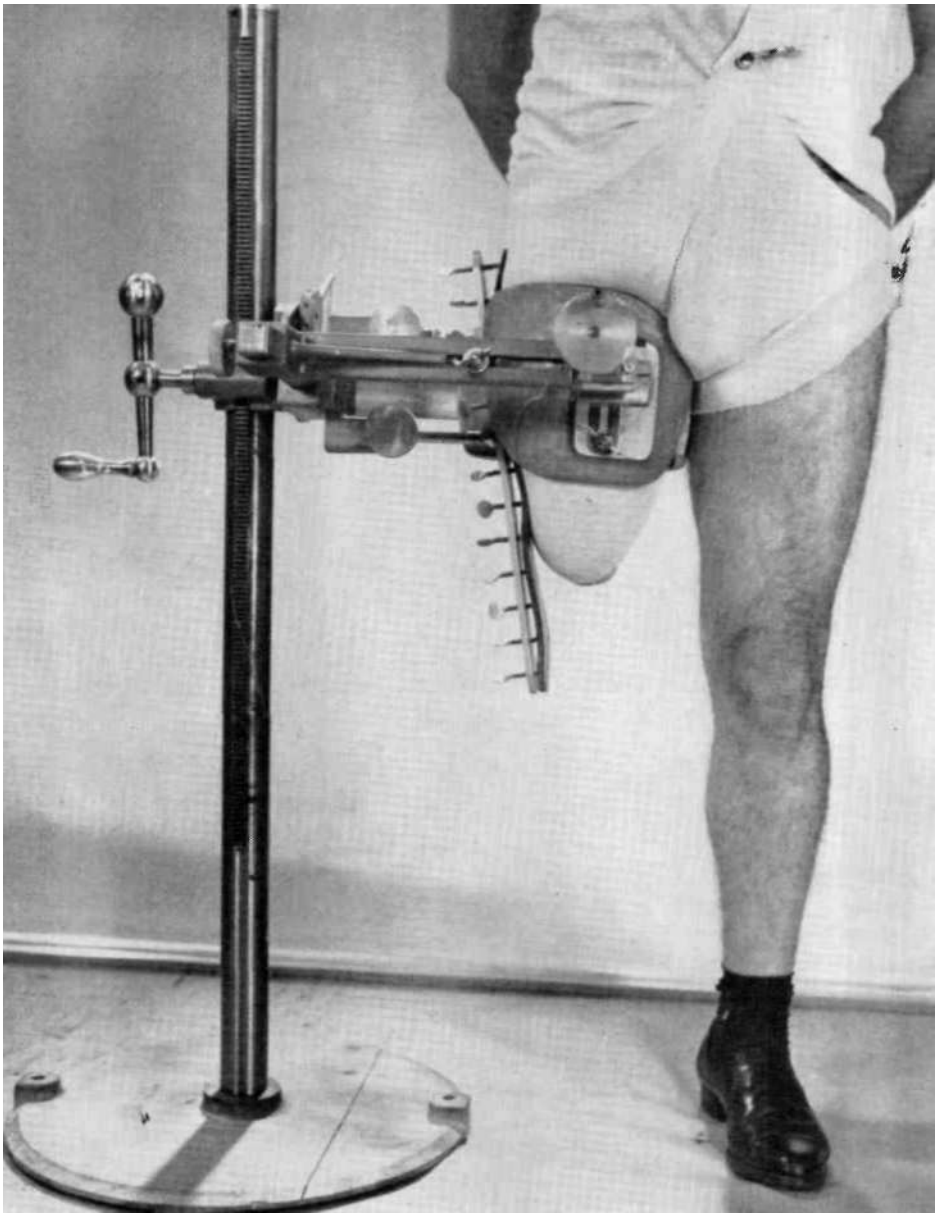


Fig. 33. Special jig developed by the Veterans Administration Prosthetics Center to facilitate casting above-knee stumps.

occasions, the hand is of course generally preferred. Many amputees have both types of devices, using each as the occasion warrants.

Two basic types of mechanism have been developed for terminal-device operation—voluntary-opening and voluntary-closing. In the former, tension on the control cable opens the fingers against an elastic force; in the latter, tension in the control cable closes the fingers against an elastic force. Each type of mechanism has its advantages and disadvantages, neither being superior to the

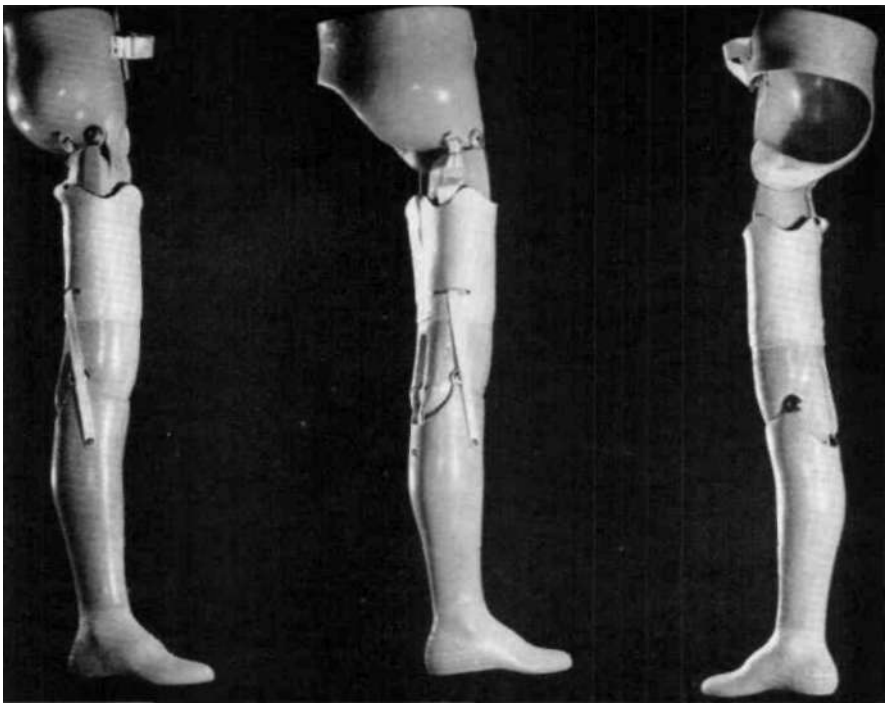


Fig. 34. Hip-disarticulation prosthesis, known as the Canadian-type because its principle was originally conceived by workers at the Department of Veterans Affairs of Canada.

other when used in a wide range of activities. Both hands and hooks are available with either type of mechanism.

The major types of terminal devices are shown in Figures 35 and 36.

Prostheses for the Wrist-Disarticulation Case

One of the problems in fitting the wrist disarticulation in the past has been to keep the over-all length of the prosthesis commensurate with the normal arm. The development of very short wrist units, especially for wrist-disarticulation cases, has materially reduced this problem. However, these units are available in only the screw, or thread, type, and cannot be obtained in the bayonet type which lends itself to quick interchange of terminal devices,

The socket for the wrist-disarticulation case need not extend the full length of the forearm and is fitted somewhat loosely at the upper, or proximal, end to permit the wrist to rotate. A simple figure-eight harness and Bowden cable are used to operate the terminal device (Fig. 37).

Prostheses for the Long Below-Elbow Case

The prosthesis for the long below-elbow case is essentially the same as that for the wrist-disarticulation patient except that the quick-disconnect wrist unit can be used when desired.

Prostheses for the Short Below-Elbow Case

The socket for the short below-elbow stump, where there is no residual rotation of the forearm, is usually fitted snugly to the entire slump, and often rigid hinges connecting the socket to a cuff about the upper arm are used to provide additional stability. Either the figure-eight harness or the chest-strap harness may be used, the latter being preferred when heavy-duty work is required since it tends to spread the loads involved in lifting over a broader area than is the case with the figure-eight design.

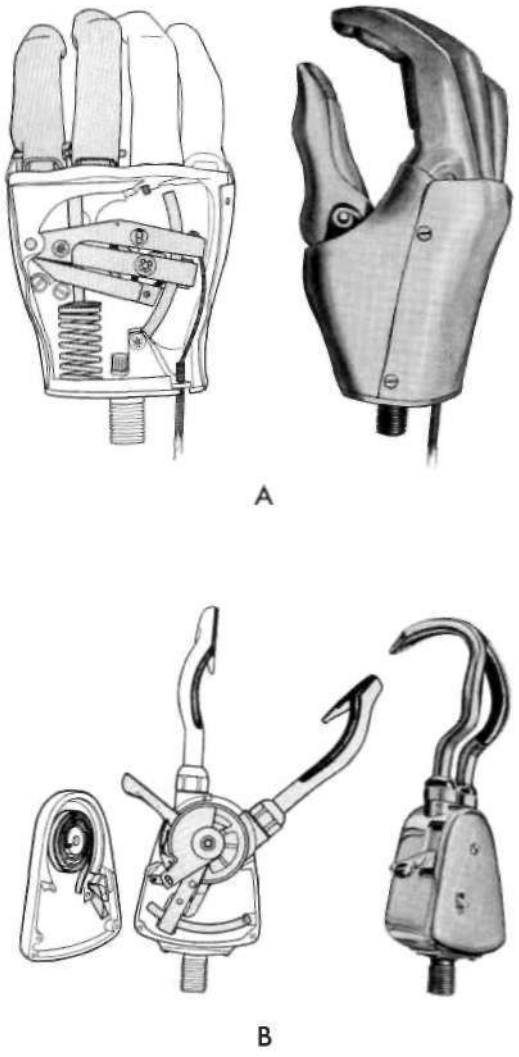


Fig. 35. Voluntary-closing terminal devices. *A,* APRL-Sierra Hand; left, cutaway view showing mechanism; right, assembled hand without cosmetic glove; *B,* APRL-Sierra Hook.

A wrist-flexion unit, which permits the terminal device to be tilted in toward the body for more effective use, can be provided in the short below-elbow prosthesis but is seldom prescribed for unilateral cases.

Prostheses for the Very Short Below-Elbow Case

Often the very short below-elbow case cannot control the prosthesis of the short below-elbow type through the full range of motion, either because of a muscle contracture or because the stump is too short to provide the necessary leverage.

When a contracture is present that limits the range of motion of the stump, a "split-socket" and "step-up" hinge may be used. With this arrangement of levers and gears, movement of the stump through one degree causes the prosthetic forearm to move through two degrees; thus, a stump that has only about half the normal range of motion can drive the forearm through the desired 135 deg. However, when the step-up hinge is used, twice the normal force is required. When the stump is incapable of supplying the force required, it can be assisted by employing the "dual-control" harness wherein force in the terminal-device control cable is diverted to help lift the forearm. When the elbow stump is very short or has a very limited range of motion, an elbow lock operated by stump motion is employed to obtain elbow function.

Recently a number of prosthetists have reported success in fitting very short below-elbow cases with an arm which is bent to give a certain amount of preflexion. This type of fitting, which was developed in Munster, West Germany, eliminates the necessity for using the rather clumsy step-up hinges and split socket, thus providing improved prosthetic control without a disadvantageous force feedback. Furthermore, the harness is not necessary for suspension of the prosthesis. The maximum forearm flexion may be limited to about 100 deg., but this does not appear to be a significant disadvantage to unilateral amputees (Fig. 38).

Prostheses for the Elbow-Disarticulation Case

Because of the length of the elbow-disarticulation stump, the elbow-locking mechanism is installed on the outside of the socket. Otherwise the prosthesis and harnessing methods (Fig. 39) are identical to those applied to the above-elbow case.

Prostheses for the Above-Elbow Case

For the above-elbow prosthesis to operate efficiently, it is necessary that a lock be provided in the elbow joint, and it is, of course, preferable that the lock is engaged and disengaged without resorting to the use of the other hand or pressing the locking actuator

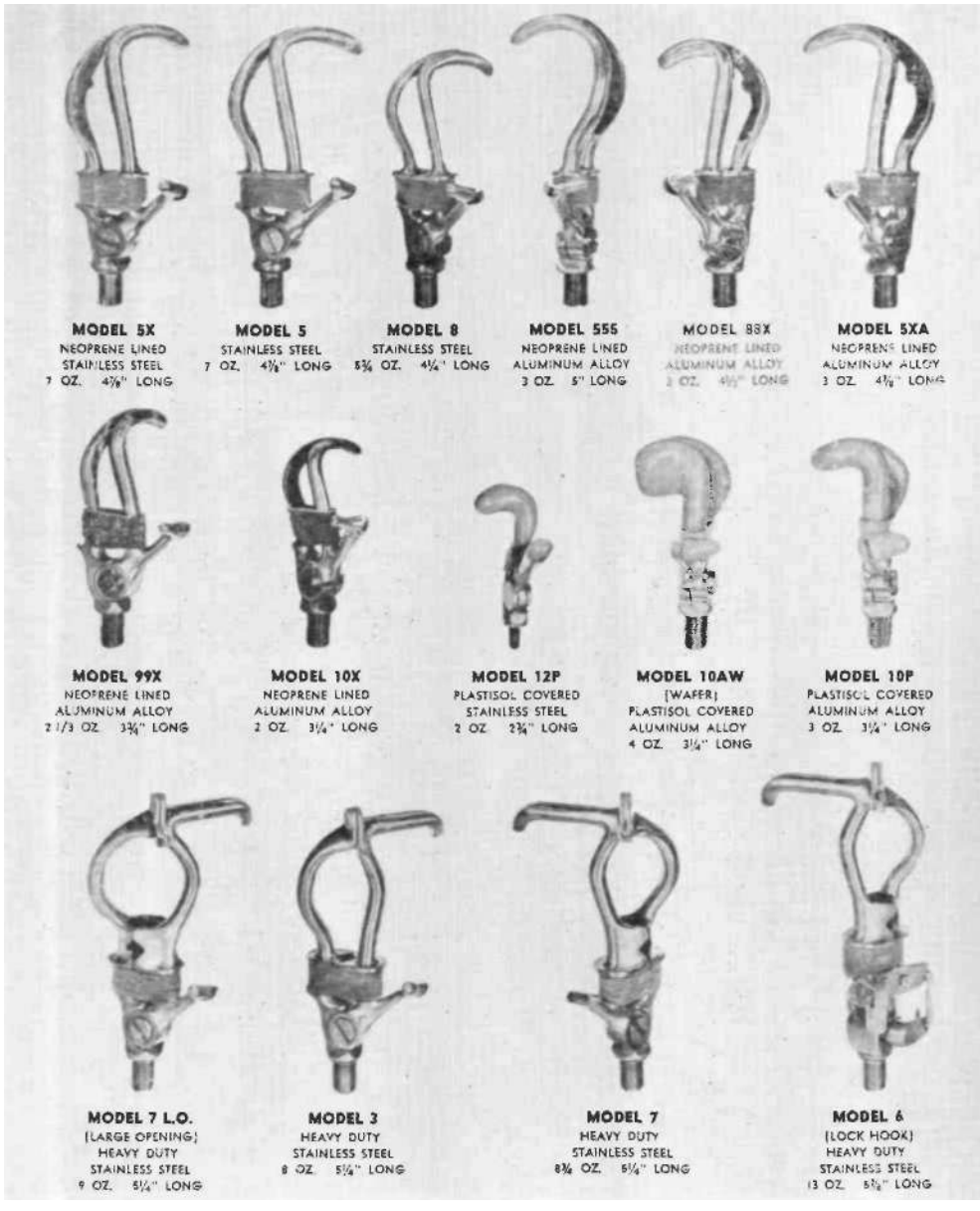


Fig. 36. Voluntary-opening terminal devices. The wide range of models offered by the D. W. Dorrance Company includes sizes and designs for all ages.

against an external object such as a table or chair.

Several elbow units that can be locked and unlocked alternately by the same motion are available. This action is usually accomplished by the relative motion between the prosthesis and the body when the shoulder is depressed slightly and the arm is extended somewhat. The motion required is so slight that with practice the amputee can accomplish the action without being noticed. These elbow units contain a turntable above the elbow axis that permits the forearm to be positioned with respect to the humerus, supplementing the

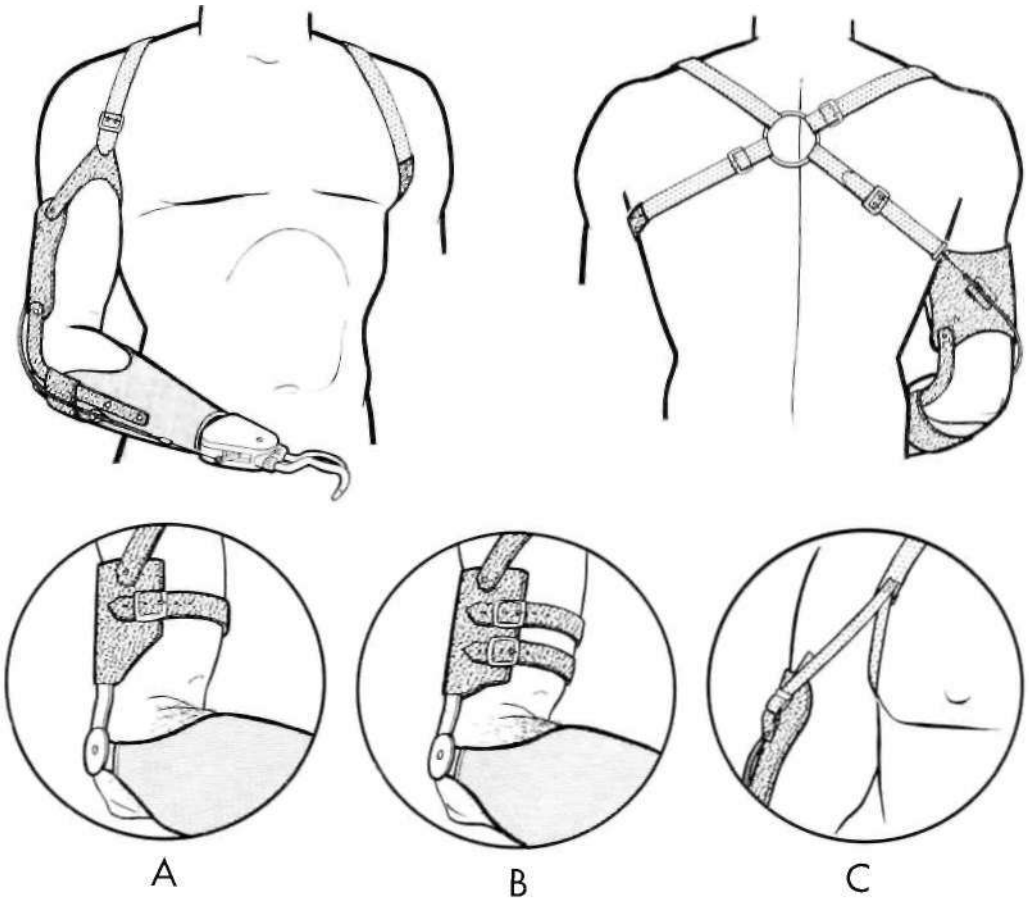


Fig. 37. Typical methods of fitting below-elbow amputees with medium to long stumps. Above, the figure-eight, ring-type harness is r
or pad are used. When more stability between socket and stump is required, rigid (metal) hinges and closed
cuffs can be used (inserts *A* and *B).* In insert C, fabric straps are used for suspension in lieu of a leather billet.

normal rotation remaining in the upper arm and thus allowing the prosthesis to be used more easily close to the mid-line of the body.

The elbow units described above are available with an adjustable coil spring to assist in flexing the elbow when this is desired. The flexion-assist device may be added or removed without affecting the other operating characteristics.

The plastic socket of the above-elbow prosthesis covers the entire surface of the stump. The most popular harness used is the figure-eight dual-control design wherein the terminal-device control cable is also attached to a lever on the forearm so that, when the elbow is unlocked, tension in the control cable produces elbow flexion, and, when the elbow is locked, the control force is diverted to the terminal device (Fig. 40).

The chest-strap harness may also be used in the dual-control configuration.

Prostheses for the Shoulder-Disarticulation and Forequarter Cases

Because of the loss of the upper-arm motion as a source of energy for control and operation of the prosthesis, restoration of the most vital functions in the shoulder-disarticulation case presents a formidable problem; for many years a prosthesis was provided for this type of amputation only for the sake of appearance. In recent years, however, it has been possible

Fig. 38, Comparison of split socket and Miinster-type fitting of short below-elbow case. *A,* Split socket and step-up hinge provides 140 deg. of forearm flexion; *B,* Miinster-type fitting permits less forearm flexion but enables the amputee to carry considerably greater weight with flexed prosthesis unsupported by harness. *Courtesy New York University College of Engineering Prosthetic and Orthotic Research.*

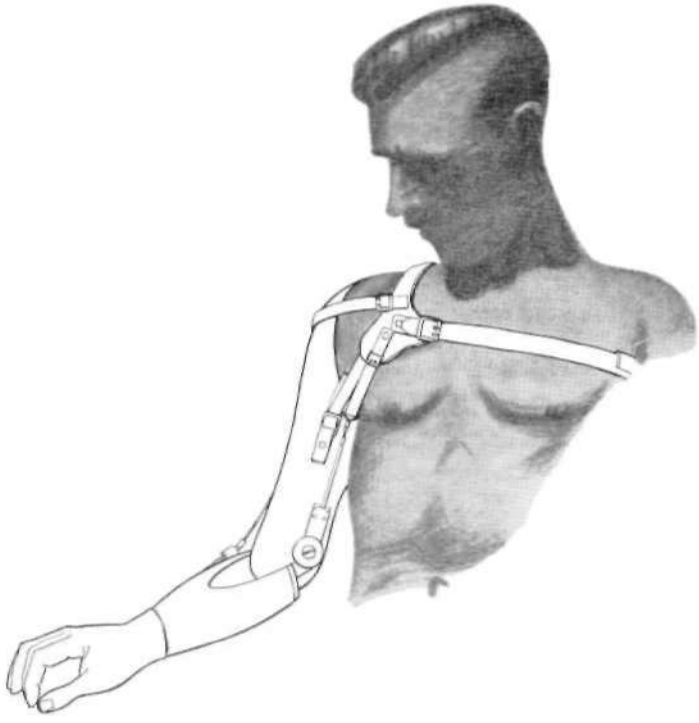


Fig. 39; Typical prosthesis for the elbow-disarticulation case. The chest-strap harness with shoulder saddle is shown here, but the above-elbow figure-eight is also used. See Figure 40.

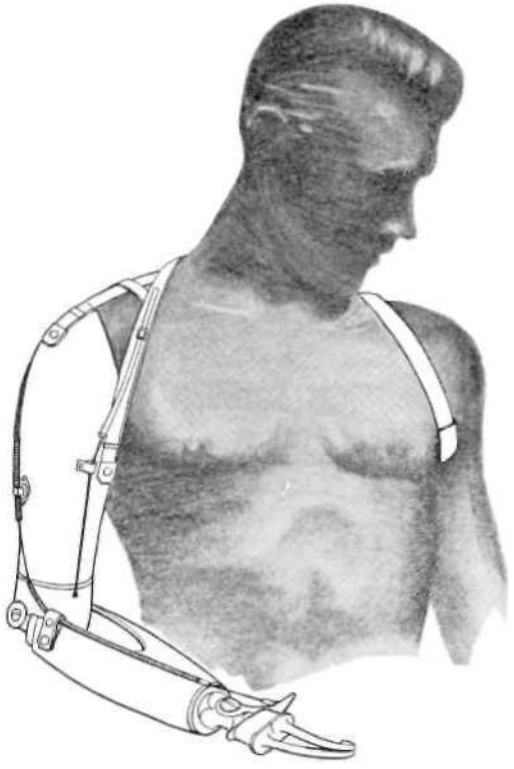


Fig. 40. Typical prosthesis for the above-elbow case. The figure-eight harness is shown here but the chest-strap harness with shoulder saddle may also be used. See Fig. 39.

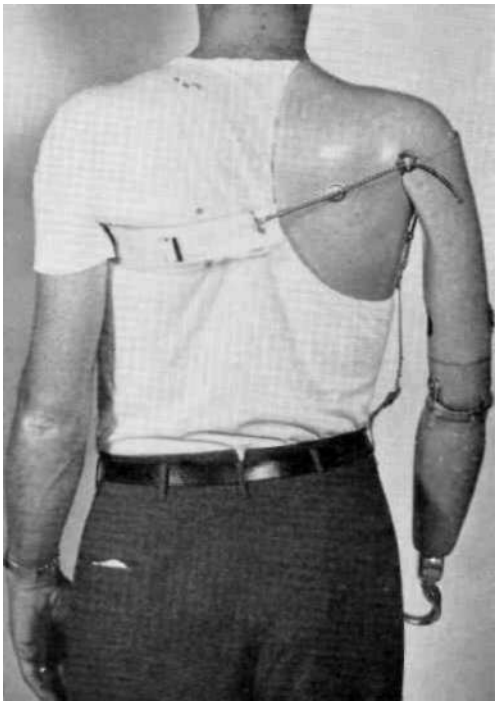


Fig. 41. Typical prosthesis for the shoulder-disarticulation case.

to make available prostheses which provide a limited amount of function (Fig. 41). To date it has not been possible to devise a shoulder joint that can be activated from a harness, but a number of manually operated joints are available. Various harness designs have been employed but, because of the wide variation in the individual cases and the marginal amount of energy available, no standard pattern has developed, each design being made to take full advantage of the remaining potential of the particular patient.

Prostheses for Bilateral Upper-Extremity Amputees

Except for the bilateral, shoulder-disarticulation case, fitting the bilateral case offers few problems not encountered with the unilateral case. The prostheses provided are generally the same as those prescribed for corresponding levels in unilateral cases. Artificial hands are rarely used by bilateral amputees because hooks afford so much more function. Many bilateral cases find that the wrist-flexion unit, at least on one side, is of value. The harness for each prosthesis may be separated, but it is the general practice to combine the two (Fig. 42). In addition to being neater, this arrangement makes the harness easier for the patient to don unassisted.

Some prosthetists have claimed success in fitting bilateral shoulder-disarticulation cases with two prostheses. Because of the lack of sufficient sources of energy for control, most cases of this type are provided with a single, functional prosthesis and a plastic cap over the opposite shoulder which provides an anchor for the harness and also fills this area to present a better appearance (Fig. 43).

LEARNING TO USE THE PROSTHESIS

To derive maximum benefit from his prosthesis, the amputee must understand how it

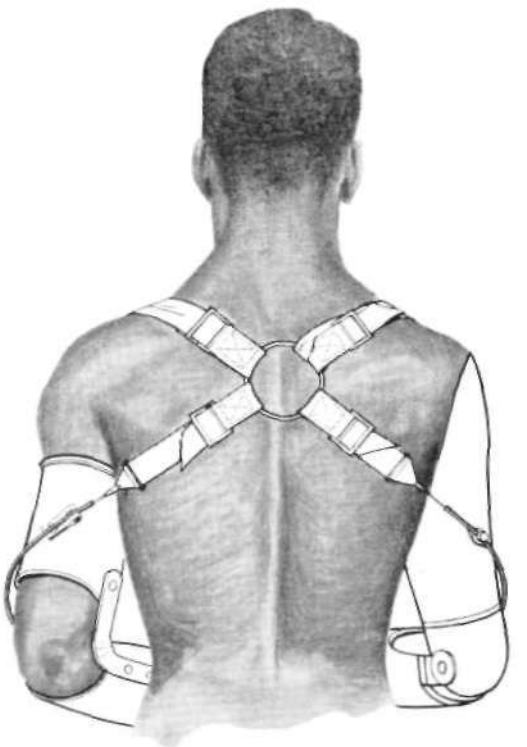


Fig. 42. Harness for the bilateral below-elbow/ above-elbow case.

functions and learn the best means of controlling it. A patient may be of the opinion that he is getting along very well when, in reality, he could do much better. Use of the prosthesis can best be learned under the supervision of an instructor who has had special training.

All amputees using an artificial limb for the first time will need some instruction. In some instances, when a prosthesis is replaced with one of a different design, special instruction will be required. The time required for training depends upon the complexity of the device and the physical condition and degree of coordination of the patient. The time required will vary from a few hours to several weeks. In many instances amputees themselves have become excellent trainers, but more often such training is given by physical or occupational therapists. Usually, physical therapists instruct lower-extremity patients and occupational therapists teach upper-extremity cases.

During the period of instruction, the trainer is careful to observe any effects the use of the prosthesis has on the patient, especially at points where the prosthesis is in contact with the body. Any changes are reported immediately to the physician in charge.

LOWER-EXTREMITY CASES

One of the major goals in training the leg amputee is to enable him to walk as gracefully as possible. Training of the leg amputee is begun as soon as the clinic team is satisfied with fit and alignment, and preferably while the artificial leg is in an unfinished state, or "in the rough." Thus, should there be need for changes in alignment as training progresses, they can be made readily. Often training can be started on an adjustable leg.

A patient with a Syme amputation needs a minimum of training. The average below-knee case will require somewhat more, though usually not extensive, unless other medical problems are present. The training required is usually quite extensive for patients who have lost the knee joint.

The ability to balance oneself is the first prerequisite in learning to walk, and so it is balance that is taught first to the above-knee amputee. Two parallel railings are used to give the patient confidence and reduce the possibility of falling (Fig. 44). Balancing on both legs is practiced first, then on each leg. Walking in a straight line between the parallel bars is repeated until the patient no longer requires use of the hands for support. Walking in a straight line is practiced until the gait is even and smooth.

When a rhythmic gait has been accomplished, more difficult tasks are learned, such as pivoting, turning, negotiating stairs and ramps, and sitting on and arising from the floor.

Most unilateral above-knee patients can use their prostheses quite well without the necessity for a cane. However, in the case of short, weak stumps it may be advisable to employ a cane for additional support and stability. If a cane is necessary, it should be selected to meet the needs of the patient, and it must be used properly if ungainly walking patterns are to be avoided. Canes with curved handles and made from a single piece of wood

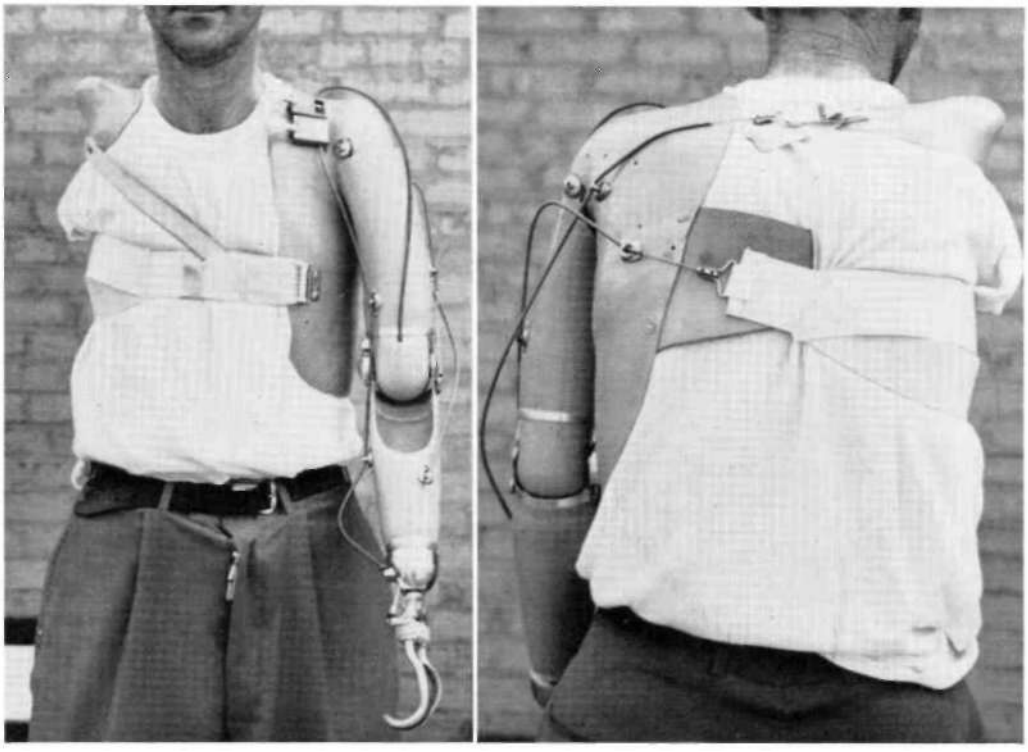


Fig. 43. Special harness arrangement for the bilateral shoulder-disarticulation case.

Tig. 44. Above-knee patient being trained to walk by a physical therapist.

should be used. The shaft should not show any signs of buckling under the full load of the body weight, and should be just long enough so that the elbow is bent slightly when the bottom of the cane rests near the foot. The cane is used on the side opposite the amputation to help maintain balance but is not used to the extent that body weight is centered between the good leg and the cane (Fig. 45). Continued use of the cane in this manner usually results in a limp that is difficult to overcome. It has been found that, for biomechanical reasons, it is helpful for the amputee to carry a briefcase or purse on the side of the amputation.

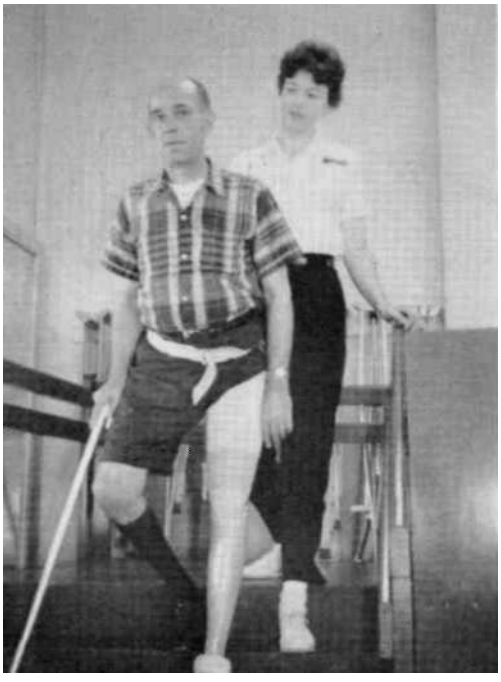


Fig. 45. Above-knee patient being taught correct use of cane.

Training the Hip-Disarticulation Cases

The training of hip-disarticulation cases follows much the same pattern as that for above-knee cases. With the advent of the Canadian-type prosthesis, the training procedure has been considerably simplified. Some special precautions must be taken to avoid stumbling while ascending stairs.

Special Considerations for Bilateral Leg Cases

As would be expected, bilateral-leg cases pose special problems in addition to those of the unilateral cases and, therefore, a good deal of time will usually be required in training. Patients with two good below-knee stumps will seldom require canes. Some bilateral above-knee amputees can get along without canes, but as a general rule at least one cane is required.

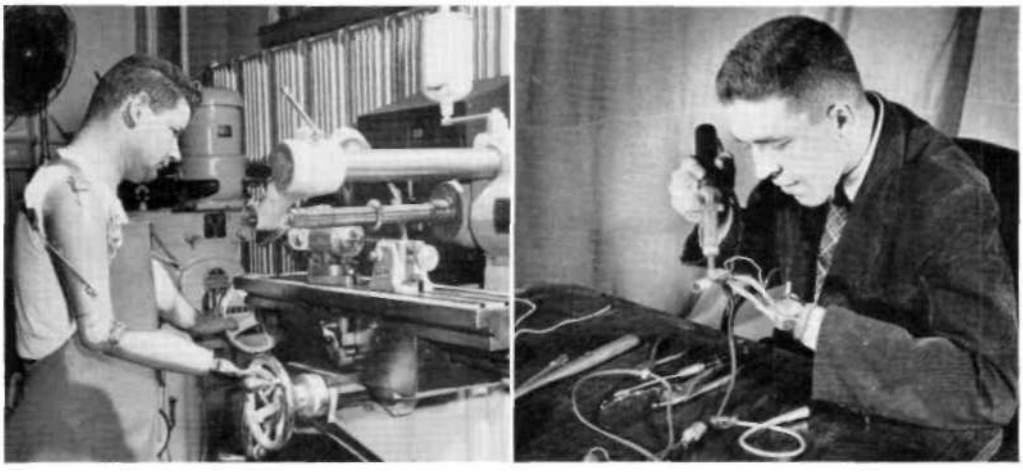


Fig 46. Upper-extremity amputees performing vocational tasks.

UPPER-EXTREMITY CASES

The first objective in the training program for upper-extremity amputees is to ensure that the patient can perform the activities encountered in daily living, such as eating, grooming, and toilet care. When this goal has been attained, attention is devoted to any special training that might be required in vocational pursuits (Fig. 46).

Before the prosthesis is put to useful purposes, the patient is shown how the various mechanisms are controlled and is made to practice these motions until they can be performed in a graceful manner and without undue exertion. In general, the arm amputee soon becomes so adept in these procedures that they are carried out without conscious thought. During this period, the functioning of the prosthesis, especially of the harness and control cables, is watched carefully by the instructor and constantly rechecked to ensure maximum performance.

Only when the patient has mastered use of the various controls is practice in the handling of objects and the performance of activities of daily living undertaken.

CARE of THE STUMP

Even under the most ideal circumstances the amputation stump, when called upon to operate a prosthesis, is subjected to certain abnormal conditions which, if not compensated for, may lead to physical disorders which make the use of a prosthesis impossible.

Lack of ventilation as a result of encasing the stump in a socket with impervious walls causes an accumulation of perspiration and other secretions of glands found in the skin. In addition to the solid matter in the secretions, bacteria will accumulate in the course of a day. Both the solid matter and bacteria can lead to infection, and the solid matter, though it may appear to be insignificant, may result in abrasions and the formation of cysts. For these reasons cleanliness of the stump and anything that comes in contact with it for any length of time is of the utmost importance, even when sockets of the newer porous plastic laminate are used.

The stump, therefore, should be washed thoroughly each day, preferably just before retiring. A soap or detergent containing hexachlorophene, a bacteriostatic agent, is recommended, but strong disinfectants are to be avoided. To be fully effective, the bacteriostatic agent must be used daily. Some six or seven daily applications are necessary before full effectiveness is obtained, and any cessation of this routine lowers the agent's ability to combat the bacteria. A physician who is himself an amputee has suggested that after an amputee takes a bath, the stump should be dried first in order to minimize the risk of introducing infection to it by the towel.

When the prosthesis is used without a stump sock, the stump should be thoroughly dry as moisture may cause swelling that will result in rubbing and irritation. For such cases, it is especially desirable for the stump to be cleansed in the evening.

The stump sock should receive the same meticulous care as the stump. The socks should be changed daily and washed as soon as they are taken off. In this way the perspiration salts and other residue are easier to remove. A mild soap and warm water are used to keep shrinkage to a minimum. Woolite (a cold-water soap) and cold water in recent trials have given excellent results. A rubber ball inserted in the "toe" during the drying process ensures retention of shape.

Elastic bandages should be washed daily in the same manner as stump socks, but should not be hung up to dry; rather they should be laid out on a flat surface away from excessive heat and out of the direct rays of the sun. Hanging places unnecessary stresses on the elastic threads, and heat and sunlight accelerate deterioration.

It is of the utmost importance that any skin disorder of the stump—no matter how slight—receive prompt attention, because such disorders can rapidly worsen and become disabling. The amputee should see a physician for treatment. He should also see his prosthetist; it may be that adjustment of the prosthesis will eliminate the cause of the disorder. In no case should iodine or any other strong disinfectant be used on the skin of the stump.

Sometimes the skin of the stump is rubbed

raw by socket friction. When this happens, the skin should be gently washed with a mild toilet soap. After the stump has been rinsed and dried, Bacitracin ointment, or some other mild antiseptic, should be applied, and the area covered with sterile gauze. The prosthesis should be completely dry before it is put on. If such abrasions occur frequently, the prosthetist should be informed. If there is the slightest sign of infection, the amputee should see a physician.

Small painless blisters should not be opened; they should be washed gently with a mild soap and left alone. Large, painful blisters should be treated by a physician.

BANDAGING THE STUMP

The stump is usually kept wrapped in an elastic bandage from the time healing permits until the time the prosthesis is delivered. Also, bandaging is recommended when for some reason it is impracticable or impossible for the patient to wear his limb routinely. It is therefore highly desirable for the amputee, or at least one member of his family, to be able to apply the bandages. Many amputees can wrap their stumps unaided and, indeed, prefer to do so. Others prefer and, in some instances, require the help of another person.

Recommended methods for applying elastic bandages for below-knee, above-knee, below-elbow and above-elbow patients are shown in Figures 47, 48, and 49, respectively. These illustrations first appeared in a booklet entitled "Industrial Amputee Rehabilitation," prepared by Dr. C. C). Bechtol under the sponsorship of Liberty Mutual Insurance Co. of Boston.

CARE OF THE PROSTHESIS

In addition to the care required in keeping the inside of the socket clean, which has been stressed, best results can be obtained only if the prosthesis is maintained in the best operating condition. Like all mechanical devices, artificial limbs can be expected to receive wear

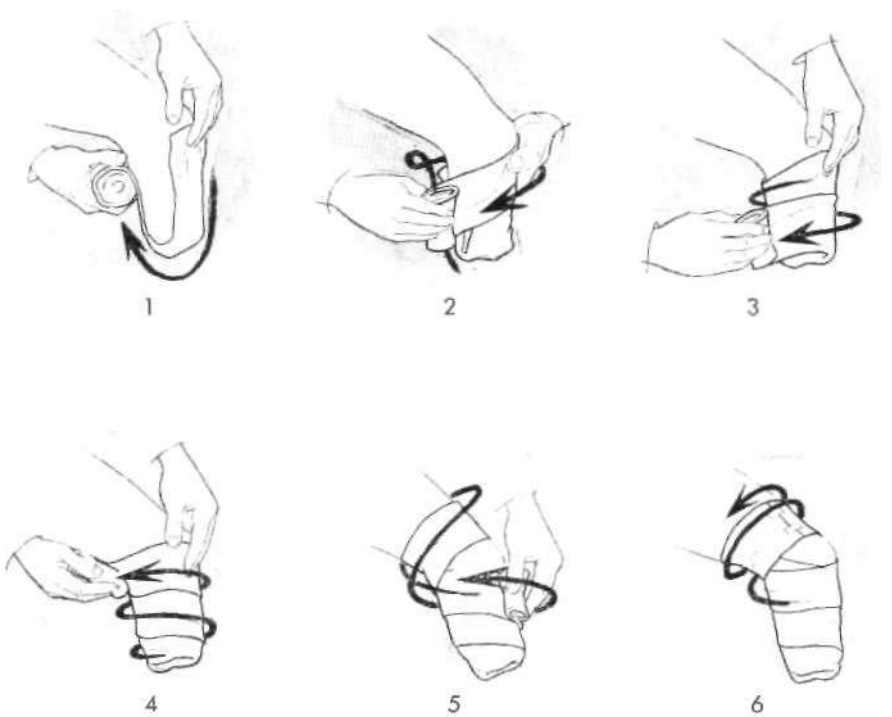


Fig. 47. Recommended method of applying elastic bandage to the below-knee stump. The bandage is wrapped tighter at the end of the stump than it is above.

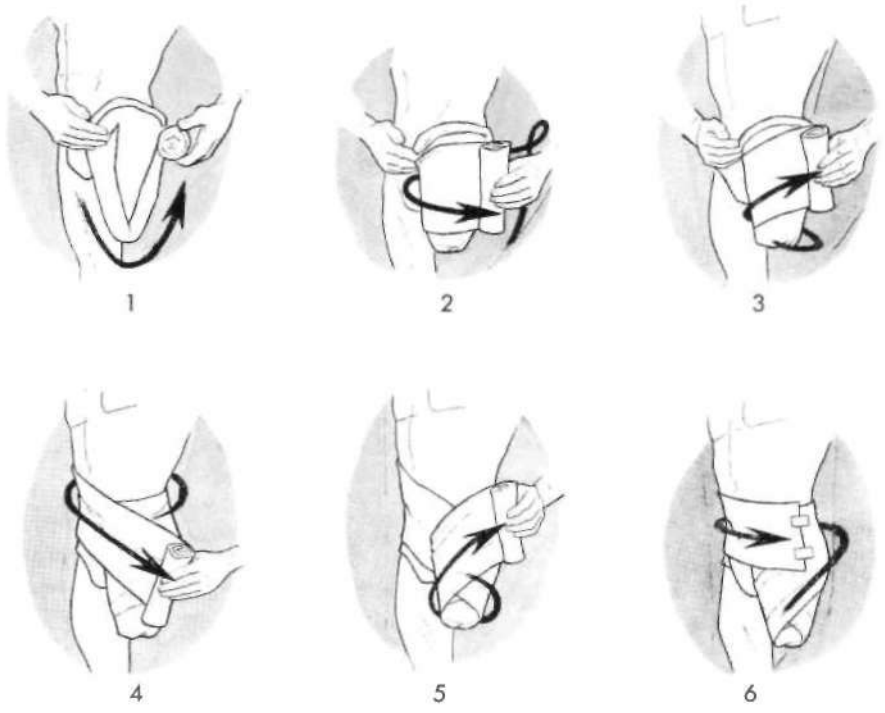


Fig. 48. Recommended method of applying elastic bandage to the above-knee stump. The stump is kept in a relaxed position, and the bandage is wrapped tighter at the end of the stump than it is above.

and be discarded for a new device, but the length of useful life can be extended materially if reasonable care is taken in its use. An example often quoted is that of two identical automobiles. The car given the maintenance recommended by the manufacturer and operated with care will outlast many times the vehicle given spotty maintenance and operated with disregard for the heavy stresses imposed. So it is with artificial limbs. Some amputees require a new prosthesis every few years, or even more often, while others who follow the manufacturer's instructions, apply preventive maintenance practices, and have minor problems corrected without delay, have received satisfactory service from their limbs for periods as long as twenty years.

Manufacturers' instructions vary with the design of the device. They consist mainly of lubrication practices and should be followed closely. Too much lubricant can sometimes produce conditions as troublesome as excessive wear. Looseness of joints and fastenings should be corrected as soon as it is detected, for the wear rate increases rapidly under such a condition. Any cracks that appear in supporting structures should be reinforced immediately in order to avoid complete failure and the necessity for replacement. The foot should be examined weekly for signs of excessive wear.

A point often overlooked by leg amputees, but nevertheless one of the factors affecting optimum use of the artificial limb, is the condition of the shoe. Badly worn or improper shoes can have adverse effects on the stability and gait of the wearer. This is a matter that requires especially close attention in the case of child amputees.

Hooks and artificial hands should be treated with the same care that the normal hand is given. Because the sensation of feeling is absent in the terminal device, the upper-extremity amputee is all too prone to use hooks to pry and hammer and to handle hot objects that are deleterious to the hook materials. Hands with cosmetic gloves should be

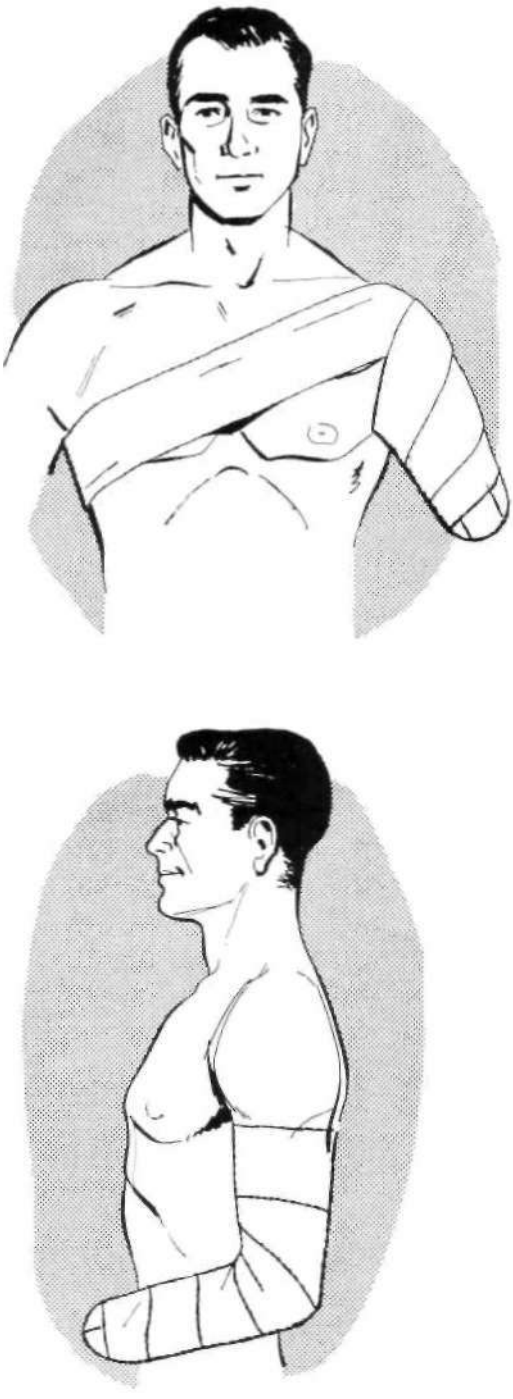


Fig 49. Elastic bandages applied properly to upper-extremity stumps.

washed daily, and of course hot objects and staining materials should be avoided.

SPECIAL CONSIDERATIONS IN TREATMENT OF CHILD AMPUTEES

Only a few years ago it was seldom that a child amputee was fitted with a prosthesis before school age and often not until much later. In recent years experience has shown that fitting at a much earlier age produces more effective results.

If there are no complicating factors, children with arm amputations usually should be provided with a passive type of prosthesis soon after they are able to sit alone, which is generally at about six months of age. Certain gross two-handed activities are thus made possible, crawling is facilitated, the child becomes accustomed to using and wearing the prosthesis, and moves easily into using a body-operated prosthesis as his coordination develops soon after his second birthday.

Lower-extremity child amputees should be fitted with prostheses as soon as they show signs of wanting to stand. The development of muscular coordination of child amputees is the same as for nonhandicapped children and, therefore, this phase may take place as early as eight months or as late as 20 or more months.

Children, especially when fitted at an early age, almost always adapt readily to prostheses. As the child grows, the artificial limb seems to become a part of him in a manner seldom seen in adults (Fig. 50).

Except for the very young, children's prostheses follow much the same design as those for the adult group. Special devices and techniques have been developed for initial fitting of infants and problem cases.

Regardless of where the child amputee resides, or the extent of his parents' financial resources, he need not go without the treatment and prostheses required to make full use of his potentials. To ensure that such services are available, the Children's Bureau of the Department of Health, Education, and Welfare has assisted a number of states in establishing well-organized child-amputee clinics, and the facilities of these states are available to resi-

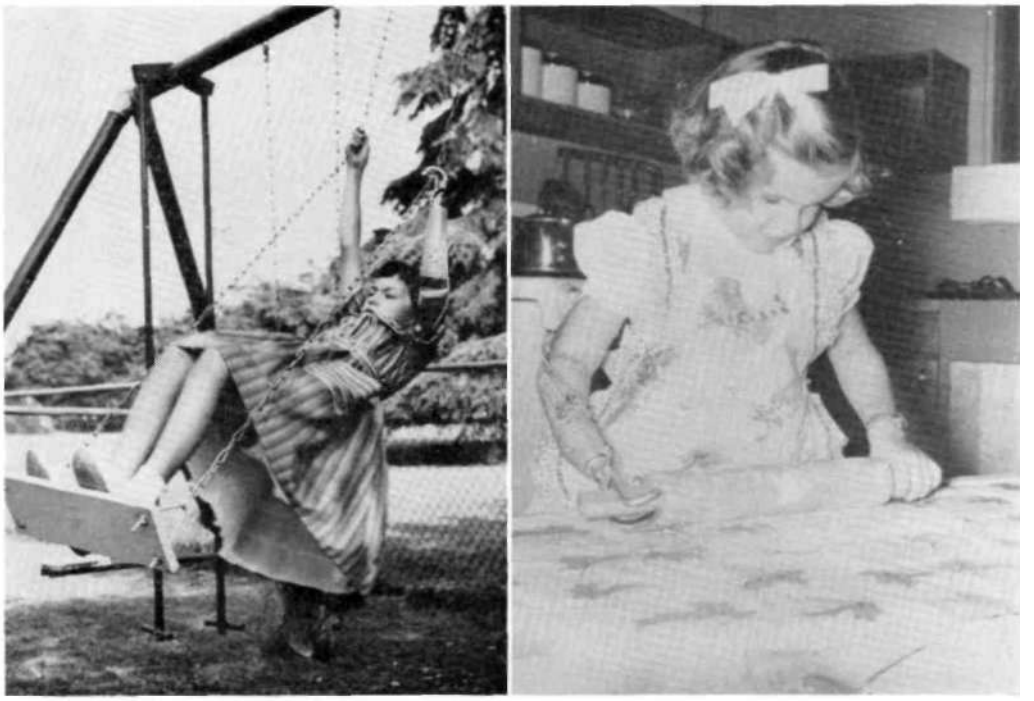


Fig 50. Children with upper-extremity amputations performing two-handed activities.

dents of states where such specialized services are not to be had. There is an agency in each slate that can advise the parents of the proper course of action.

Most children can be treated on an outpatient basis, but for the more severely handicapped many of the clinics have facilities for in-patient treatment. The clinic team for children is often augmented by a pediatrician and a social worker, and sometimes by a psychologist.

Training very young children is one of the most difficult problems of the clinic team. Although the learning ability of young children may be rapid, their attention span is of such short duration that extreme patience is required. Regardless of the ability of the therapist, successful results cannot be achieved without complete cooperation of the parents. The mental attitude of the parents is reflected in the child, and all too often children have rejected prostheses because the parents, consciously or subconsciously, could not accept the fact that a prosthesis was needed. Parents of children born with a missing or deformed limb often experience a sense of guilt, a feeling that only adds to an already difficult problem. The guilt feeling is unwarranted, inasmuch as the knowledge of the causes of congenital defects —and appropriate preventive measures— is very limited. The recent discovery of the effects of thalidomide suggests that other causes may be found.

As a rule, lower-extremity amputees present fewer problems than the upper-extremity cases. It is natural for the child to walk, and almost invariably the lower-extremity patient adapts rather quickly. Parents, however, should keep close observation of the walking habits of the child, the condition of his stump, and the state of repair of his prosthesis, and above all they should present the child before the clinic at the recommended times. A gradual change in walking habit may indicate that the child has outgrown the prosthesis or that excessive wear of the prosthesis has taken place. Any unusual appearance of the stump should be reported to the physician immediately so that remedial

steps may be taken, thereby avoiding more complicated medical problems at a later date. Children give a prosthesis more wear and tear than do adults and it is important that the prosthesis be examined carefully at regular intervals and needed repairs made as soon as possible—not only to ensure the safety of the child but to avoid the necessity for major repairs at a later date.

Many upper-extremity child amputees adapt readily to artificial arms—some even want to sleep with the arm in place—but in many cases the child will need a great deal of encouragement before he will accept the device and make use of it. At first the unilateral amputee may feel that the prosthesis is a deterrent rather than an aid, but with the proper encouragement this feeling is reversed.

Parents can help by continuing the training given in the clinics. From the beginning the artificial arm should be worn as much as possible. Young children should be given toys that require two hands for use and older children should be given household chores that require two-handed activities. In the latter case not only does the child learn to appreciate the usefulness of the prosthesis, but he also gains a feeling of being a useful member of the family and thus a better mental attitude is created.

The child amputee should not be sheltered from the outside world but encouraged to associate with other children and, to the extent that he can, to take part in their activities. Of course there are certain limitations, but the number of activities that can be performed with presently available prostheses is amazing. It goes almost without saying that the child should receive no more special attention than is necessary, and should be made to perform the activities of daily living of which he is capable.

It has been shown that it is preferable for the child amputee to attend a regular school rather than one for the handicapped. Most child amputees can and do take their place in society and the transition from school to work is much easier if they are not shown unnecessary special consideration. Nonhandicapped children soon accept the amputee and make little comment after the initial reaction.

Here again the arm amputee is apt to be faced with the most problems. Some public school officials have hesitated to admit arm amputees wearing hooks for fear that the child may use them as weapons. This attitude is unrealistic. If such incidents have occurred, they are rare indeed. However, arm prostheses should be removed when the child is engaged in body-contact sports such as football.

Cleanliness of the stump, prosthesis, and stump sock is just as important for children as for adults. The same procedures as those outlined on pages 35-36 are recommended.

SPECIAL CONSIDERATIONS IN THE TREATMENT of ELDERLY PATIENTS

Persons who have had amputations during youth or middle age seldom encounter additional problems in wearing their prostheses as they become older. However, for those patients who have an amputation in later life many unusual problems are apt to be present. Most amputations in elderly patients are necessary because of circulatory problems, almost always affecting the lower extremity. For many years the wisdom of fitting such patients with prostheses was debatable, the thought being that the remaining leg, which in most cases was subject to the same circulatory problems as the one removed, would be overtaxed and thus the need for its removal would be hastened. Energy studies in recent years have shown that crutch-walking is more taxing than use of an artificial limb. Experience with rather large numbers of elderly leg amputees has shown that failure of the remaining leg has not been accelerated by use of a prosthesis, and stumps that have been fitted properly have not been troublesome. As a result more and more elderly patients are benefiting by the use of artificial limbs. A rule of thumb used in some clinics to decide whether or not to fit the elderly patient is that if he can master crutch-walking he should be fitted. This measure should be used with discretion because in some instances patients who could not meet the crutch-walking requirement have become successful wearers of prostheses.

Most clinic teams feel that if the patient can use the prosthesis to make him somewhat independent around the house, the effort is fully warranted.

Artificial legs for the older patients, as a rule, should be as light as possible. Except for the most active patients, only a small amount of friction is needed at the knee for control of the shank during the swing phase of walking because the gait is apt to be slow. Suction sockets are rarely indicated because of the effort required in donning them. A quadrilateral-shaped socket is used with one stump sock and a pelvic belt. Silesian bandages have been used successfully, allowing more freedom of motion and increased comfort.

For the elderly below-knee cases, the patellar-tendon-bearing prosthesis is being used quite successfully.

CINEPLASTY

In 1896 the Italian surgeon, Vanghetti, conceived the idea of connecting the control mechanism of a prosthesis directly to a muscle. Several ideas involving the formation of a club-like end or a loop of tendon in the end of a stump muscle were tried out in Italy. Just prior to World War I the German surgeon, Sauerbruch, devised a method of producing a skin-lined tunnel through the belly of the muscle. A pin through the tunnel was attached to a control cable, and thus energy for operation of the prosthesis was transferred directly from a muscle group to the control mechanism. With refinements the Sauerbruch method is available for use today, but it must be used cautiously.

Although tunnels have been tried in many muscle groups, the below-elbow amputee is the only type that can be said to benefit truly from the cineplasty procedure. A tunnel properly constructed through the biceps can supply power for operation of a hand or hook, and there need be no harnessing above the level of the tunnel. Thus, the patient is not restricted by a harness and the terminal device can be operated with the stump in any position. Training the tunneled muscle and care of the tunnel require a great deal of work by the patient; thus if the cineplasty procedure is to be successful the patient must be highly motivated.

Some female below-elbow amputees have been highly pleased with results from a biceps tunnel, but as a rule cineplasty does not appeal to women.

Cineplasty is not indicated for children. Sufficient energy is not available for proper operation of the prosthesis and the effects of growth on the tunnel are not known.

Tunnels have been tried in the forearm muscles but the size of these muscles is such that the energy requirements for prosthesis operation are rarely met. While tunnels in the pectoral muscle are capable of developing great power, in the light of present knowledge the disadvantages tend to outweigh the advantages. It is extremely difficult to harness effectively the energy generated, and very little, if any, of the harness can be eliminated. It is true that an additional source of control can be created, but with the devices presently available little use can be made of this feature.

No application for cineplasty has been found in lower-extremity amputation cases.

Still another type of cineplasty procedure is the Krukenberg operation, whereby the two bones in the forearm stump are separated and lined with skin to produce a lobster-like claw. The result, though rather gruesome in appearance, permits the patient to grasp and handle objects without the necessity of a prosthesis. Because sensation is present, the Krukenberg procedure has been found to be most useful for blind bilateral amputees. Although prostheses can be used with Krukenberg stumps when appearance is a factor, the operation has found little favor in the United States.

AGENCIES THAT ASSIST AMPUTEES

For several centuries at least, governments have traditionally cared for military personnel who received amputations in the course of their duties. But only in recent years, except in isolated cases, has the amputee in civilian life had much assistance in making a comeback. Today there are available services to meet the needs of every category of amputee. Aside from the humanitarian aspects of such programs, it has been found to be good business to return the amputee to productive employment and, in the case of some of the more debilitated, to provide them with devices and training to take care of themselves.

The Armed Services provide limbs for mili-

tary personnel who receive amputations while on active duty, and many of these cases are returned to active duty. After the patient has been discharged from military service, the Veterans Administration assumes responsibility for his medical care and prosthesis replacement for the remainder of his life. The U. S. Public Health Service, through its Marine Hospitals, cares for the prosthetics needs of members of the U. S. Maritime Service.

Each state provides some sort of service for child amputees. If sufficient facilities are not available within a state, provisions can be made for treatment in one of the regional centers set up in a number of states with the help and encouragement of the Children's Bureau of the Department of Health, Education, and Welfare. With assistance from the Vocational Rehabilitation Administration of the Department of Health, Education, and Welfare, every state operates a vocational rehabilitation program designed to help the amputee return to gainful employment. Recently some of these programs have been extended to render assistance to housewives and the elderly as well.

Private rehabilitation centers, almost universally nonprofit and sponsored largely by voluntary organizations, greatly augment the state and federal programs.

Information concerning rehabilitation centers serving a particular area may be obtained from the Association of Rehabilitation Centers, Inc., 828 Davis Street, Evanston, Ill.

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Socket Flexion and Gait of an Above-Knee, Bilateral Amputee

EDWARD PEIZER, PH.D.[1]

M ANY factors affect the gait of an above-knee, bilateral amputee as he walks on his prostheses. Among the factors are his general health and strength, the length and condition of his stumps, the alignment of his prostheses, his comfort, and the type of knee units employed.

While some of these factors are difficult to observe accurately, others lend themselves to objective measurement and evaluation by means of current bioengineering techniques. Not long ago, the Bioengineering Laboratory of the Veterans Administration Prosthetics Center had occasion to evaluate the gait of an above-knee, bilateral amputee, and in the course of the evaluation developed records that show graphically the "before" and "after" effect of increased hip flexion of about 10 deg. in both sockets.

BACKGROUND

An above-knee, bilateral, 26-year-old, male amputee veteran, who was fitted with two suction sockets and two Hydra-Cadence knee units, was referred to the Bioengineering Laboratory for gait evaluation. The amputations resulted from an automobile accident; the patient was a vigorous young man in good health, with well-muscled, strong stumps. He weighed 158 lb. with prostheses, stood 5 ft. 8 in., had 12-in. stumps, and had worn constant-friction knee units for two years. In May 1962, he was fitted with one Hydra-Cadence unit, and approximately three months later was fitted with a second Hydra-Cadence unit.

After he had worn both units for three or four months, evaluation indicated that, although he managed two suction sockets adequately, the two Hydra-Cadence units produced a jerkiness in his gait which was tentatively attributed to the higher energy requirements of the hydraulic units.

The clinic team recommended that both Hydra-Cadence units be replaced with constant-friction units and requested the Bioengineering Laboratory to obtain photographic records of his performance on the Hydra-Cadence units for subsequent comparison with records to be obtained of his performance on the constant-friction units.

On May 15, 1963, the amputee appeared at the Bioengineering Laboratory for evaluation. Preliminary examination of the prostheses indicated only marginal—if not inadequate—initial hip flexion. Observation of the subject's gait tended to confirm this impression; he seemed exceptionally "stable" and found it necessary to jerk his knee forward to initiate the swing phase. This produced a marked lurching pattern in his gait.

The Bioengineering Laboratory recommended realignment of the prostheses, with particular emphasis on increasing initial hip flexion as a step which might improve function and obviate the necessity for refitting with constant-friction knee units. The clinic team concurred. A biomechanical analysis of the amputee's performance with his unaltered prostheses was conducted at the Laboratory on May 15. On May 24, 1963, after the amputee's prostheses were realigned by procedures which did not involve refabrication of the sockets, his performance was re-evaluated.

PROCEDURES

The purpose of the two biomechanical evaluations was to identify changes in the gait pattern of the amputee which might have

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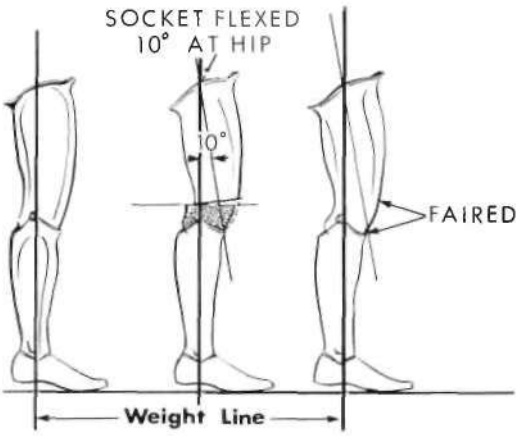

Fig. 1. Socket realignment to provide 10 deg. of initial hip flexion.

occurred as a result of changing the attitude of both sockets so as to increase initial hip flexion (Fig. 1).

Because of the length of the amputee's stumps (12 in.) and the need to maintain cosmetic acceptability, the maximum increase of hip flexion possible was from 0 deg. to 10 deg. This change in attitude was intended to increase the amputee's functional range in hip extension and thereby improve his control of knee stability during stance, with potential effects upon his speed of walking, his stride length, the smoothness of the path followed by his center of gravity, the application of his body weight to the floor, the characteristics of his push-off, and his knee flexion at toe-off. Since the change was simply an increase of flexion, and only in one plane, it was accomplished without the use of the VAPC adjustable coupling *(2)*.

Although the amputee normally walked with the aid of canes, he did not use them during the two evaluations.

For each evaluation, the amputee walked along a level walkway, first in one direction and then in the other, thus making two transits of the walkway on each occasion. Run No. 1 and run No. 3 were made on May 15; run No. 4 and run No. 5 on May 24. Because of equipment failure on run No. 2, no data are shown for that run.

He was targeted with reflective tape at the head, elbow, hip, knee, ankle, and shoe for photography from the side by an interrupted-light camera during the transits. Also, as he proceeded along the walkway, he stepped on a set of force plates (thus providing a measure of the application of his body weight to the floor). Simultaneously, the tachograph (Fig. 2) measured and recorded his acceleration and velocity. Descriptions of these procedures and devices appeared in *Artificial Limbs* in 1954 *(1)*.

RESULTS

AVERAGE VELOCITY

Average velocities, determined by integrating the tachograph curves, are given below in fiftieths of an inch of galvanometer deflection. An increase in velocity may reflect easier initiation of swing phase, an increased push-off force, or greater stride length.

VELOCITY IN TERMS OF GALVANOMETER DEFLECTION
(in 1/50 in.)

Run No.	Prior to Realignment of Prostheses	After Realignment of Prostheses
1	15.9	
3	21.8	
4		27.1
5		24.3

It can be noted that the patient's velocity was greater after realignment of his prostheses—substantially higher in run No. 4, and moderately higher in run No. 5. In Figure 3, the velocity curves prior to realignment fall below the zero velocity level, indicating backward movement. In order to initiate the swing phase, it was necessary for the patient to incline his torso forward, with a consequent rearward thrust of the pelvis. The tachograph recorded this rearward thrust as a backward movement.

AVERAGE STRIDE LENGTH

Stride length is the distance between consecutive heel contacts by the same leg. In this case, increased stride length may be regarded as a result of greater control and strength in hip extension, increased push-off force, and easier initiation of the swing phase.

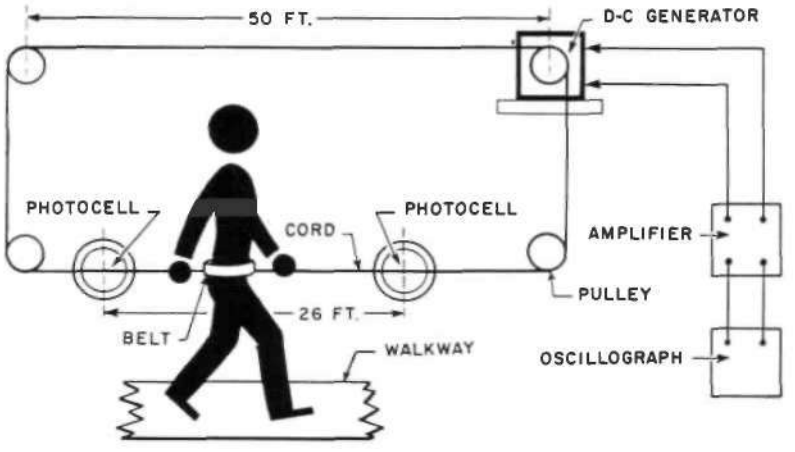

Fig. 2. Schematic diagram of the tachograph, a system for recording linear velocity. The subject wears a lightweight belt, to which is attached a fine cable that turns the rotor of a direct-current generator. Voltage produced by the generator is proportional to the velocity of the subject.

AVERAGE STRIDE LENGTH

Prior to Realignment of Prostheses: 17.0 in.
After Realignment of Prostheses: 19.4 in.

SMOOTHNESS OF GAIT

In addition to measuring velocity, the tachogram reflected other elements of the gait pattern. Thus the smoother wave forms recorded after realignment of the prostheses (Fig. 3) indicate less lurching and jerkiness in the gait pattern.

ANTEROPOSTERIOR AND VERTICAL DISPLACEMENTS

No significant differences were observed in the displacement of the head, elbow, hip, and knee after realignment of the sockets. However, the ankle displacement curve (Fig. 4) indicated a more rhythmic oscillation of greater amplitude after the realignment. This motion reflects more normal timing and range of knee flexion.

KNEE FLEXION

Knee flexion at toe-off and during the swing phase prior to realignment of the sockets was variable and at times very limited. After realignment of the sockets, the extent of knee flexion at toe-off and during the swing phase was more consistent and generally of more normal magnitude.

Knee Flexion at Toe-Off in Degrees	Maximum Knee Flexion during Swing Phase in Degrees
Before Realignment	
27.5	51.0
4.5	5.5
41.0	41.0
10.0	13.5
22.0	25.0
After Realignment	
30.0	30.0
38.0	44.5
33.0	39.5
44.0	47.0
43.0	51.0
31.0	31.0

FLOOR REACTION FORCES

In view of the variability of the patient's performance on the four runs, vertical load and fore-and-aft shear forces do not show consistent differences. Nevertheless, reference to Figure 5 indicates that:

The patient applied his full body weight to the prostheses faster after the sockets were realigned.

Before Realignment *Time in Seconds*		After Realignment *Time in Seconds*	
.300		.260	
.463		.175	
2).763		2).435	
Mean	.381	Mean	.218

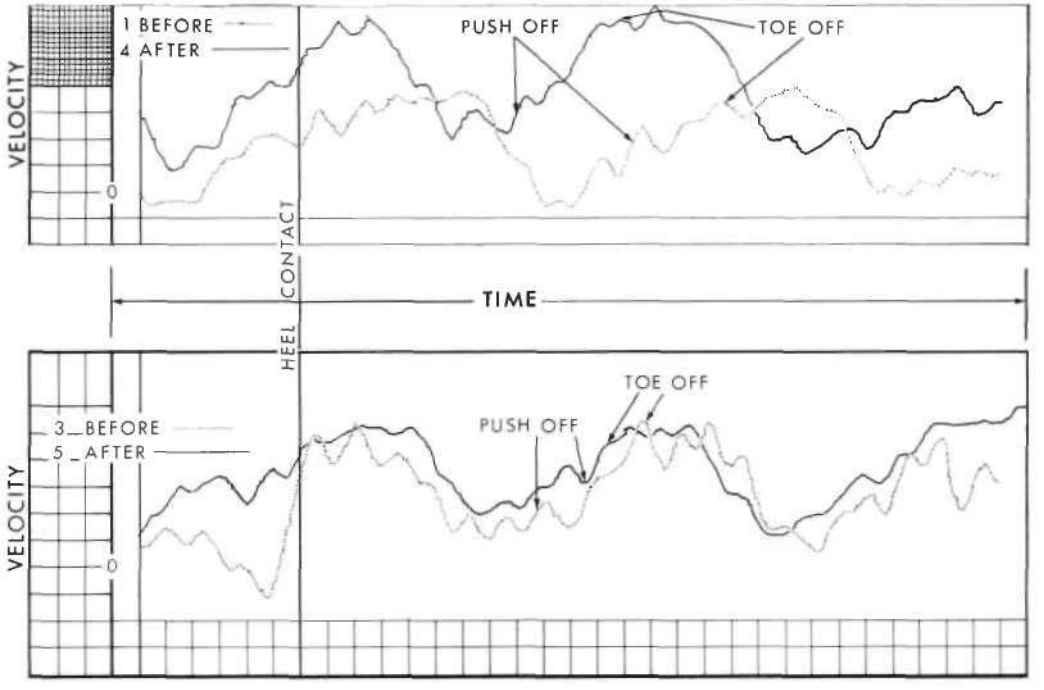

Fig. 3. Tachograph recordings. Run No. 1 and run No. 3 were recorded on May 15, 1963, prior to realignment of prostheses; run No. 4 and run No. 5 on May 24, 1963, after realignment.

Full body weight was applied to the prostheses in a smoother, less jerky fashion, as indicated by a diminution of the oscillations in the patterns representing performance after realignment.

The smaller amplitude of the oscillations in the vertical load curves after realignment indicates decreased lurching in the stance phase and perhaps a smoother initiation of the swing phase on the contralateral side.

The fore-and-aft shear load curves indicate greater horizontal forces after push-off with the realigned sockets. Moreover, the increased magnitude of the aft shear loads after toe-off before realignment indicates a greater degree of toe drag.

MOTION-PICTURE ANALYSIS

Motion pictures were made of the patient prior to and after realignment of the sockets. Analysis of the gait patterns indicated the following positive changes:

Somewhat less anteroposterior pelvic lurch,
More symmetrical arm swing.
Somewhat longer step length.
Narrower walking base.
Easier initiation of the swing phase with increased hip flexion.

Analysis of the motion pictures did not bring out any significant improvement in stability. However, this may have been masked by the obviously improved mobility.

SUMMARY

The performance of an above-knee, bilateral amputee in level walking with two suction sockets and two Hydra-Cadence knee units was compared before and after increasing initial hip flexion approximately 10 deg. Before realignment, he had worn the assembly three or four months. However, the second evaluation was conducted on the same day as the realignment; consequently, the comparison does not represent a reliable index to the significance of the change. The observations

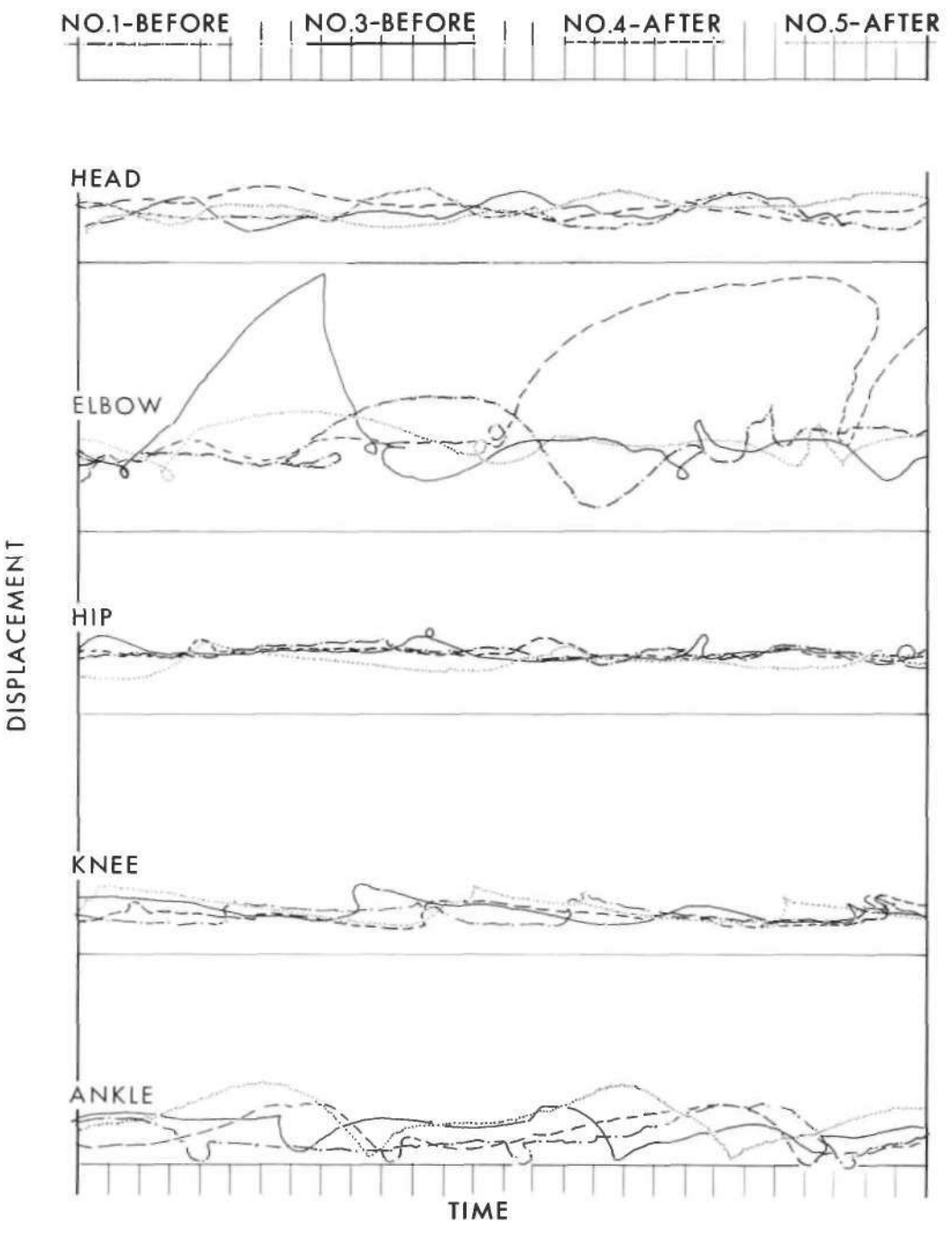

Fig. 4. Pathways of targeted points on the amputee during ambulation, as determined by interrupted-light photography.

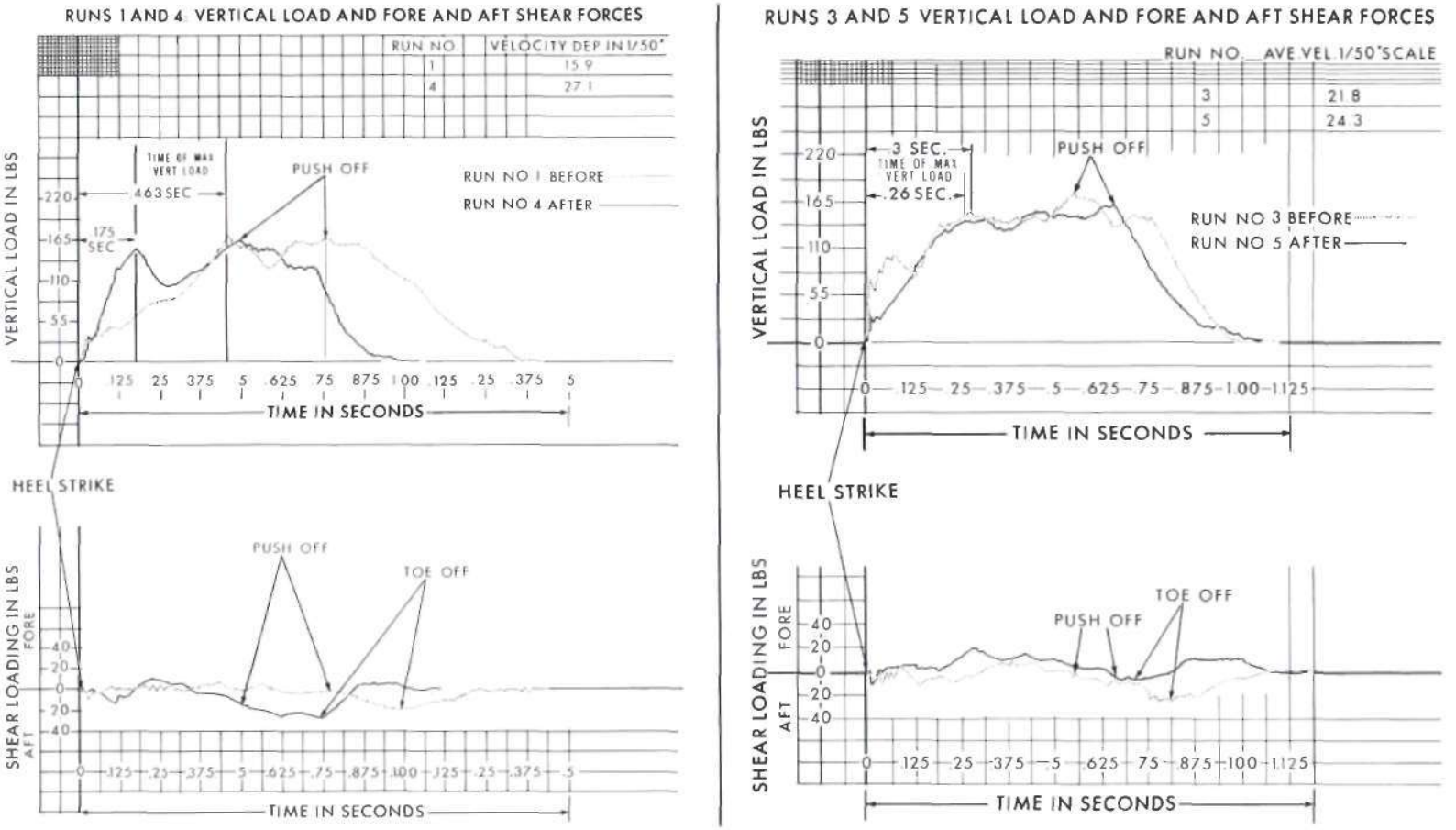

Fig. 5. Force-plate data. Vertical forces applied by the subject to the force plate during the stance phase are shown in the upper curves. Less time was required to apply the full body weight to the prosthesis after realignment. Fore-and-aft shear forces shown in the lower curves indicate the pattern of push-off and toe-off.

disclose only immediate reactions; another evaluation after at least three months of wear should provide a more conclusive analysis.

In general, the patient's performance revealed marked variations from run to run, making it difficult to select a truly representative performance for each test condition. For this reason, "before" and "after" data describing performance during the runs have been presented.

The increased initial hip flexion was undertaken to increase the amputee's range and strength in hip extension. Analysis of the data disclosed mild improvements in:

Stability.
Velocity and stride length.
Smoothness of gait pattern.
Initiating the swing phase by increased push-off forces.

The only significant change which could be identified in the symmetry of the motions of body segments was a more normal ankle displacement, reflecting improved knee flexion in the swing phase.

A follow-up inquiry on August 20, 1963, disclosed that the patient, who was employed in a summer camp, was wearing his prostheses daily. Because of the hilly terrain where he was working, he was using two crutches rather than the two canes previously used. Despite his comments that the limbs were heavy and he wanted to have the socket fit re-checked, he regularly wore the prostheses from 8:00 a.m. to 11:00 p.m. daily and did considerable walking.

This experience illustrates a tendency toward excessive concern for stability when fitting and aligning prostheses for above-knee, bilateral amputees, thereby imposing needless functional limitation.

In this particular case, more than 10 deg. of initial hip flexion could have been tolerated without significant loss of stability. However, even the increase of 10 deg., the maximum in view of stump length and cosmetic requirements, had several beneficial effects on the patient's performance.

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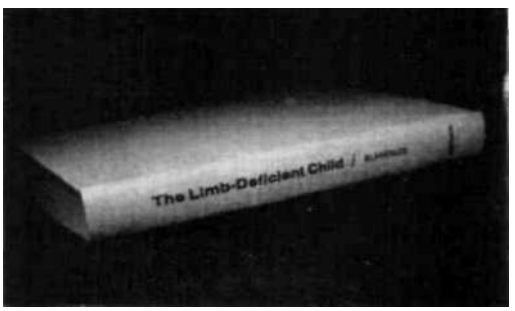
The Limb-Deficient Child, a Review

THE LIMB-DEFICIENT CHILD, edited by Berton Blakeslee, University of California Press, Berkeley 4, California, August 1963. 391 pages. Price: $8.50



The Limb-Deficient Child is important as the first comprehensive summary of modern techniques in the relatively new field of child prosthetics. For until recent years, the consensus was that prosthetic fitting could wait "until the child is older"—an opinion based on the generally unsatisfactory attempts to care for the child amputee as if he were simply a small adult. The presentation made in *The Limb-Deficient Child* is based on the experience of the Child Amputee Prosthetics Project of the University of California at Los Angeles. The Project was started in 1955 and is supported by grants from the United States Department of Health, Education, and Welfare.

Dr. Milo B. Brooks, who is the Medical Director of the Project, various members of the Project staff, and other persons closely associated with the Project are the contributors to *The Limb-Deficient Child.* The nine chapters of the book cover the role of the medical director, orthopedic considerations, psychosocial problems, preprosthetic evaluations, preprosthetic therapy, child prosthesis design and fitting, training, training the upper-extremity amputee, and lower-extremity training. There are numerous illustrations, the appendix contains various evaluation charts developed at the Child Amputee Prosthetics Project, and there is an index.

Chapter I, "The Role of the Medical Director," describes the type of information desired from the referring physician and parents, stressing social information concerning the family organization, the child's general physical condition, and the type of amputation presented. A number of charts depict the normal development of children, with heights and weights for given ages. There is some discussion of the growth and development of limb-deficient children, the problems of limb dominance, and psychological adjustment. The etiology of congenital limb deficiencies is briefly discussed, and statistics are presented on cases studied at the Project. The thalidomide syndrome is briefly mentioned.

Chapter II, "Orthopedic Considerations," discusses the relative importance of orthopedic management, the utilization of plaster-of-Paris cast techniques for correction, the use of braces, indications for surgical interference, the problem of scars, and the functional range of joints. Although very brief, the discussion on long bones, osteotomies, the problem of terminal overgrowth of long bones, neuromata, and the judgment and timing of surgical conversion of deficient extremities to more conventional types of stumps will be of interest to the orthopedist.

This reviewer, however, is not in agreement with the attempt made in the discussion of the development of limbs to assign dermatome relationships to the limb buds.

In general, this reviewer agrees with the brief classification of limb deficiencies, although it is incomplete from an anatomical standpoint. Perhaps future modifications may be in

order to produce a more universal nomenclature, understandable to all who are interested in the limb-deficient child. The classification is followed by the prosthetics management of the terminal transverse deficiencies from wrist disarticulation (acheiria) up to amelia or shoulder disarticulation.

Chapter III, "The Psychosocial Problems," gives a realistic discussion of parental guilt feelings and parental cooperation and emotional stability. There is discussion of the role of the physician in attempting to produce an environment of cooperation by the parents, an environment that is essential for success in treating the child amputee. The problems confronting the prosthetics team during the child's preadolescent and adolescent years are discussed, and the role of the social worker is clearly defined. This is an important chapter in the book.

Chapter IV, "Preprosthetic Evaluations," discusses in detail the roles of the occupational therapist and the physical therapist. Reference is made to *The First Five Years of Life,* by Arnold Gesell and others, and it is highly desirable that therapists be well acquainted with this work. Chapter IV briefly describes the progress of motor kinesthetic development from the infant to the toddler. Techniques for determining the range of motion and the functional needs of the child are analyzed carefully. The chapter discusses the self-care needs of the child and relates them to the type of prosthesis indicated.

In Chapter V, "Preprosthetic Therapy," the principles of joint motion, the correction of contractures, techniques of bandaging for shrinkage, the proper use of crutches, and skin care are elucidated and beautifully illustrated by photography.

Chapter VI, "Child Prosthesis Design and Fitting," presents the important consideration of the growth of the child as contrasted to the adult. Materials for prostheses, such as plaster and polyester and epoxy resins, are discussed. The choice of terminal devices appropriate to the age and size of the child is clearly stated and well illustrated. Techniques for harnessing are demonstrated by photography. In addition, there are shown nonstandard types of prostheses for fitting upper-extremity phocomelic children. Unusual methods for operating elbow locks, by the phocomelic limb, buried in the humeral section of the prosthesis, are given special attention. The problems of upper-extremity amelia, both unilateral and bilateral, are discussed and shown in photographs, including cable systems and the various methods of hook-ups for the transmission of power. The problem of fitting a multihandicapped child is covered, together with some of the frustrating problems of finding power for terminal-device operation that is adequate in terms of the amount of energy expended. Stages of fitting lower-extremity amelic children from a small stationary bucket up to two prostheses are shown.

In Chapter VII, "The Training Period," the training of the limb-deficient child is stressed, and rightly so. The child must know what the prosthesis will do for him. The chapter also emphasizes that one cannot go beyond the child's capabilities or his kinesthetic development for his years. One must not expect too much too soon in the avenues of function. There is a practical and well-illustrated discussion of clothing needs and modifications for ease of application. Illustrations also show how to reduce friction from the system through proper alignment of the cable-control assembly. Techniques to be employed by the unilateral and the bilateral amputee in applying and removing the prosthesis are excellently illustrated. The lower extremities are dealt with briefly with respect to the fitting of the socket, proper application—especially the fitting of a suction socket—and the problems involved with a patellar-tendon-bearing prosthesis and bilateral lower-extremity prostheses.

Chapter VIII, "Training the Upper-Extremity Amputee," is well illustrated and goes into considerable detail. The environmental situation is discussed, and the necessary equipment is illustrated. In this reviewer's mind, there is some question about the discussion of training infants, because it is debatable whether one actually trains an infant or simply exposes him to experience in motor fields. There is discussion of the desirability of the presence of parents during training periods. Techniques for activating the components in stages by the young child are clearly presented, and action

photographs show the functional capabilities of youngsters of various ages, both unilateral and bilateral types. Activities (aids to daily living) are well documented and very practical. This chapter should be especially interesting to occupational therapists.

Chapter IX, "Training the Lower-Extremity Amputee," is much shorter than the preceding chapter. It gives a brief description of the progress of a youngster from infancy to an erect standing posture. Three phases of training are discussed with respect to the lower-extremity amputee. Comfort, fit, and skin tolerance are important during the first phase, with frequent inspection of the skin and prosthesis alignment. Independent ambulation is achieved during the second phase. During the third phase, faster ambulation, stair climbing, and walking up and down ramps and over uneven ground are mastered. This training is clearly illustrated by excellent photographs.

Judging by its title, one would expect *The Limb-Deficient Child* to be a textbook on all facets of the child amputee. It is not such a text. It is a well-written presentation of the experiences of the Child Amputee Prosthetics Project of the University of California at Los Angeles. The problems of the limb-deficient child are much more far-reaching than this volume indicates.

But the book is important as the first of its kind and should serve as a reference for physical and occupational therapists and for prosthetists. It is a clear and very adequately illustrated narrative, with excellent photographs of children in action during their training periods, and photographs of prostheses. Harnessing patterns and cable operations are clearly depicted. There is much material here that should be of great assistance to therapists and prosthetists, particularly those who have broad experience with adult amputees. For with this text they can translate their past experience into the area of child amputees, especially those with congenitally malformed limbs.

CHARLES H. FRANTZ, M.D.[1]

[1] Medical Co-Director, Area Child Amputee Program, Michigan Crippled Children Commission; Chairman, Subcommittee on Child Prosthetics Problems, CPRD, NAS-NRC, Washington, D. C.

News and Notes

Changes in CPRD Membership

With some exceptions due to expediency and special circumstances, the membership of the Committee on Prosthetics Research and Development is rotational. The appointments to CPRD, which are normally for a three-year period, are made by the Chairman of the Division of Engineering and Industrial Research, subject to the approval of the President of the National Academy of Sciences.

June 30, 1963, marked the end of the CPRD fiscal year and also marked the completion of the terms of service of two members of the Committee: Dr. Charles O. Bechtol and Dr. Sidney Fishman. Both, however, will continue to be active in CPRD affairs—Dr. Bechtol as a member of the Subcommittee on Evaluation, and Dr. Fishman as a member of the Subcommittee on Child Prosthetics Problems. Moreover, both Dr. Bechtol and Dr. Fishman will continue to carry on their other important activities connected with the over-all program.

New members appointed to CPRD as of July 1, 1963, are: Dr. John Lyman, Head of the Biotechnology Laboratory, Department of Engineering, UCLA; Dr. Robert W. Mann, Professor of Mechanical Engineering, Massachusetts Institute of Technology; and Dr. Robert G. Thompson, Associate Professor of Orthopedic Surgery, Northwestern University. Thus the total membership of CPRD has been increased from 13 to 14.

Activities of CPRD Subcommittee on Design and Development

By arranging frequent meetings of small groups of persons directly concerned at the working level with the design and development of prosthetic and orthotic devices, the Subcommittee on Design and Development of the Committee on Prosthetics Research and Development is responsible for an active interchange of information and ideas between the various groups engaged in design and development, the provision of leadership in attacking critical problems, the evaluation of new ideas and suggestions from the standpoint of engineering feasibility, and the encouragement of competent designers.

The following members of the Subcommittee have been assigned as chairmen of workshop panels as follows: Colin A. McLaurin, Chairman of Panel on Upper-Extremity Components; Dr. Fred Leonard, Chairman of Panel on Upper-Extremity Fitting, Harnessing, and Power Transmission; Charles W. Radcliffe, Chairman of Panel on Lower-Extremity Components; Anthony Staros, Chairman of Panel on Lower-Extremity Fitting; Dr. John Lyman, Chairman of Panel on External Power in Prosthetics and Orthotics.

Convened with CPRD approval as part of the action of the Subcommittee on Design and Development, a Workshop Panel on Lower-Extremity Fitting met under the chairmanship of Anthony Staros in Orlando, Fla., on April 24, 25, and 26, 1963. Jack Caldwell, Henry F. Gardner, J. Morgan Greene, Fred Hampton, Herbert Kramer, Dr. Newton McCollough, Edward W. Snygg, Howard R. Thranhardt, and A. Bennett Wilson, Jr., participated in the meeting. Topics covered included above-knee sockets, flexible sockets, adjustable sockets, cosmesis of lower-extremity prostheses, below-knee sockets, socket porosity, the feasibility of a pneumatic leg, alignment devices, knee-bearing sockets, sockets for Syme's amputation, sockets for amputation through the foot, and hip-disarticulation sockets.

Convened with CPRD approval as part of the action of the Subcommittee on Design and Development, a Workshop Panel on Terminal Devices met under the chairmanship of Mr. McLaurin in Washington, D. C, on April 18 and 19, 1963. Peter Kaiser, Hector W. Kay, Edward A. Kiessling, Gilbert M. Motis, Victor T. Riblett, and Carl Sumida participated in the meeting. Although authorized to consider problems related to upper-extremity components in general, the panel limited its consideration to terminal devices, because the Conference on Design of Upper-Extremity and Knee-Bearing Prostheses held in Chicago in March 1962 had indicated that the greatest needs lie in this area. In conclusion, each member of the panel gave an informal indication of the course of action he would follow, with a view toward reporting progress at a subsequent meeting of the panel.

Meeting of CPRD Subcommittee on Evaluation

The second meeting of the Subcommittee on Evaluation of CPRD was held in Warm Springs, Ga., on May 10, 1963. All the members—Herbert R. Lissner, Chairman; Dr. Charles O. Bechtol, Dr. Robert L. Bennett, Dr. Verne T. Inman, Colin A. McLaurin, and Bert Titus—were present. In addition, the meeting was attended by Dr. Sidney Fishman, A. Bennett Wilson, Jr., and James R. Kingham.

The chief purpose of the meeting was to consider the problem of evaluation of orthotic devices. The Subcommittee considered that the following orthotic devices and techniques are probably ready for evaluation: the VAPC below-knee brace with PTB cuff, the UCLA long leg brace, the Georgia Warm Springs forefoot correction device, the NYU technique for measuring the amount of tibial torsion necessary for correction of varus or valgus, the Georgia Warm Springs hinged back brace, the Baylor University plastic hand splints, and the University of Michigan feeder. Dr. Fishman outlined a clinical testing procedure, and it was the consensus of the Subcommittee that such a procedure should be set in motion.

The Chairman of the Subcommittee enumerated several specific objectives to be accomplished over a period of time by the Subcommittee. First, the Subcommittee should accept and seek out items for evaluation. Second, the Subcommittee should publish a list of all items that have been evaluated, so that the information will reach practicing physicians who might not be aware of these items. Third, in addition to compiling a list of existing devices, there should be an up-to-date listing of needed orthotic devices. Fourth, by the inclusion of psychological questions in questionnaires to be completed by patients being fitted with orthotic devices, an effort should be made to determine in a general way whether individual patients are disposed to be easy to please or difficult to please, thus making it possible to appraise a particular patient's acceptance or rejection of a device.

The Chairman considered that the evaluation of a device could be made in three general areas: materials, comfort, and adequacy as a biological substitute. The suggestion was also made that a helpful specific analysis could be made by assigning numerical ratings in each of the following categories: cosmetic appearance, durability, reliability, ease of operation, ease of application, simplicity of sequence operation, comfort, weight, function, initial cost and cost of maintenance, and education for maintenance and use. It was thought that such numerical ratings would be helpful, because low ratings would indicate specific areas in which improvements should be made.

Dr. Fishman gave the Subcommittee a status report on prosthetic devices undergoing tests by NYU Adult Prosthetic Studies. Included were the AIPR pneumatic prostheses, the Miinster techniques for fitting upper-extremity sockets, the Kingsley Flexi-Cage Socket, NU disc-friction units, the APRL half-cycle elbow, and the APRL shoulder joint.

Changes in CPEI Membership

With the beginning of the new Fiscal Year on July 1, 1963, certain changes in the composition of the Committee on Prosthetics Education and Information became effective. Dr. William J. Erdman, II, Chairman of the Department of Physical Medicine and Rehabilitation at the University of Pennsylvania School of Medicine, who has chairmanned the Advisory Committee on Prosthetics in Pennsylvania, was appointed a member of CPEI. W. Frank Harmon, of Atlanta, Ga., who has ably represented the interests of orthotics on CPEI since its organization in 1958, completed his term of service on June 30, 1963. This discipline will be represented during the coming year by Charles W. Rosenquist, of the Columbus Orthopaedic Appliances Company in Columbus, O. Mr. Rosenquist has been active on the national scene in educational affairs relating to the training of orthotists. He has served as a Director of Region V of the American Orthotics and Prosthetics Association, and is presently a member of the Committee on Credentials of the American Board for Certification in Orthotics and Prosthetics. Charles L. Eby, Director of the Bureau of Vocational Rehabilitation of the State of Pennsylvania, retired from CPEI on June 30, 1963, having served since 1959. It was at Mr. Eby's invita-

lion that CPEI organized the Advisory Committee on Prosthetics in Pennsylvania to work with the staff of his Bureau to improve prosthetic services in that state. This program has been very successful and can serve as a model for other states.

Meeting of CPEI Steering Committee

At a meeting of the Steering Committee of the Committee on Prosthetics Education and Information in New York City on May 17, 1963, the chairmen of the subcommittees reviewed the activities of their respective groups since the annual meeting of CPEI in Phoenix in October 1962. Dr. J. Hamilton Allan, Chairman of the Subcommittee on Prosthetics in Medical Education, reported that the orientation prosthetics brochure, appropriate for senior medical students and the medical profession at large, would be ready to go to press when Fiscal Year 1964 funds become available. A second brochure, stressing the principles of amputation surgery, is in the planning stage and will be appropriate for all practicing physicians who have occasion to perform amputations. The subcommittee's slide collection has been materially increased in recent months. Dr. Roy M. Hoover, Chairman of the Subcommittee on Prosthetics Clinical Studies, stated that the participating prosthetics clinics had completed the study data forms on more than 400 cases. As a result of this trial test, certain modifications have been made in the forms. This study is broadening its clinical base by including additional amputee clinics. Miss Dorothy E. Baethke, Chairman of the Subcommittee on Prosthetics in Paramedical Education, briefly reviewed the results of a two-day meeting of her group that was held in Chicago on April 8 and 9, 1963. This meeting was reported in the Spring 1963 issue of *Artificial Limbs.*

The next meeting of CPEI will be held at the National Academy of Sciences in Washington, D.C., on October 26, 1963.

Panel on Lower-Extremity Prosthetics in Dallas

The Committee on Prosthetics Education and Information, with the cooperation of the University Council on Orthotic and Prosthetic Education (UCOPE), sponsored a three-hour panel discussion on *Recent Developments in Lower-Extremity Prosthetics* at the Congress of Physical Medicine and Rehabilitation held in Dallas, Tex., August 25-30, 1963. Dr. William J. Erdman, II, served as moderator. The participants included Dr. Sam C. Colachis, Jr., Assistant Professor of Physical Medicine, University of California at Los Angeles; Dr. Allen S. Russek, Associate Professor of Physical Medicine, New York University; Dr. Raymond J. Pellicore, Assistant Clinical Professor of Orthopedic Surgery, University of Illinois; H. Blair Hanger, Assistant Director, Prosthetic-Orthotic Education, Northwestern University; and Dr. J. Warren Perry, Assistant Chief of the Division of Training, Vocational Rehabilitation Administration.

Prosthetics-Orthotics Education

For the academic year 1963-1964, the Vocational Rehabilitation Administration of the Department of Health, Education, and Welfare has announced that short-term courses in prosthetics and orthotics for physicians, surgeons, therapists, prosthetists, orthotists, rehabilitation counselors, and other rehabilitation personnel will again be offered at the three major training centers for this instruction: the University of California at Los Angeles, New York University, and Northwestern University. Continuation grants were also made to Rancho Los Amigos for its training program in orthotics, to the Institute for Crippled and Disabled in New York City for a course in prosthetics and orthotics at the technician's level, and to Woodrow Wilson Rehabilitation Center, in cooperation with the University of Virginia Medical School, for the continuation of its orientation course in prosthetics and orthotics for rehabilitation counselors in Region III. (Region III comprises Kentucky, Maryland, North Carolina, Virginia, West Virginia, the District of Columbia, Puerto Rico, and the Virgin Islands.) The undergraduate program at New York University, a recipient of a VRA training grant, will award the first long-term traineeships for junior students, who will be members of the first graduating class in 1965 in the degree program in the field of prosthetics and orthotics.

Participants in UCLA semester course in prosthetics and orthotics, June 1963. Back row: Dr. Miles 11. Anderson, Director, UCLA Prosthetics-Orthotics Education; John J. Bray, Associate Director; Pat Marer, James R. Fenton, James Hennessy, Donald F. Cohvell, Instructor. Front row: William F. Sinclair, Paul T, Lindbergh, Gordon P. Thanos.

Prosthetics-Orthotics Education at UCLA

A semester program in prosthetics and orthotics is offered by the Prosthetics-Orthotics Education Program of the UCLA Medical School. The purpose of this program is to provide the equivalent of one full year of college-level instruction in this professional field for qualified young men who are presently in or wish to enter prosthetics and orthotics.

The program is intensive, with a combination of 350 hours of lectures and recitations, 650 hours of laboratory work, and 400 hours of clinical practice scheduled over a period of 30 weeks. One unit of credit is earned by either one hour of lecture and recitation and two hours of outside study each week for 15 weeks, or by three hours of laboratory work requiring no outside study for the same number of weeks. On this basis, the semester program student completes 23 units of lectures and recitations and 14 units of laboratory work for a total of 37 units. This is the equivalent of two regular semesters of university work of 18 units per semester. The 400 hours of supervised clinical practice in which the students have the opportunity to work with physicians, nurses, and therapists, in rehabilitating orthopedicallv handicapped patients are required, but do not yield credits.

Traineeship grants are available from V.RA to assist qualified candidates for the semester program in prosthetics and orthotics. Each application for such assistance is evaluated on the basis of the information on educational and professional experience shown. Since the number of traineeships is limited to six, the six best-qualified applicants are selected from those applying.

Selection of students for the semester program is based on educational background and work experience. Applicants who have a baccalaureate degree and one year or more of shop and laboratory experience in prosthetics or orthotics, or both, are given first priority. Second are those with the baccalaureate degree only, followed by those with an associate

of arts degree and one year or more of shop and laboratory experience in prosthetics or orthotics, or both.

Students planning college programs with the goal of ultimately entering the field of prosthetics and orthotics should major in one of the life sciences, as the courses in that area would be most applicable later when studying the subject matter in the specialty of artificial limbs and braces.

The class schedule for students in the UCLA semester program for the Spring Semester, 1964, is as follows:

January 6-24	
Below-Knee Prosthetics	150 hours
January 27-February 7	
Supervised Clinical Practice	80 hours
February 10-March 6	
Above-Knee Prosthetics	200 hours
March 9-20	
Supervised Clinical Practice	80 hours
March 23-April 10	
Functional Long Leg Bracing	150 hours
April 13-17	
Supervised Clinical Practice	40 hours
April 20-24	
Child-Amputee Prosthetics	50 hours
April 27-May 15	
Hip-Disarticulation Prosthetics	150 hours
May 18-29	
Supervised Clinical Practice	80 hours
June 1-19	
Upper-Extremity Prosthetics	150 hours
June 22-July 3	
Supervised Clinical Practice	80 hours
July 6-24	
Functional Bracing of the Upper Extremities	150 hours
July 27-31	
Supervised Clinical Practice	40 hours
Total lecture, recitation, and laboratory instruction	1,000 hours
Total supervised clinical practice	400 hours
Total lecture-recitation instruction	350 hours
Total laboratory instruction	650 hours

During the 1963-1964 academic year, the UCLA Prosthetics Education Program is offering a new two-week course for physicians and therapists which covers the major fields of upper- and lower-extremity prosthetics, upper- and lower-extremity orthotics, and spinal orthotics.

This new course is designed to provide a thorough refresher on the basic principles of these fields, plus new material on all the newest techniques and devices. Those who have taken previous courses at UCLA will find ample information on all the latest advances in prosthetics, such as the total-contact plastic socket, hydraulically controlled prosthetic units, the patellar-tendon-bearing below-knee prosthesis, the new functional long leg brace, and the use of porous laminates for sockets.

The basic framework of the course will include the principles of evaluation of the patient, prescription, fitting, fabrication, training, components, and biomechanics. In addition, there will be special class sessions covering dermatology, normal human locomotion, congenital anomalies, child-amputee prosthetics, and the treatment of special cases and problems. The two-week session will include an all-day field trip to Rancho Los Amigos Respiratory Center for special presentations on devices for the so-called totally disabled.

As always, this new UCLA course will include ample demonstrations and laboratory practice with patients. Completion of the two-week course will be the equivalent of attendance at all the courses in prosthetics and orthotics presently offered at UCLA for physicians and therapists.

This new comprehensive course is being presented in response to requests from the Veterans Administration, from various medical societies, and from the faculties of several of the nation's larger teaching institutions. It is believed that the course will be of value to orthopedic surgeons, specialists in physical medicine and rehabilitation, traumatologists, general surgeons, neurosurgeons, industrial surgeons, specialists in geriatrics, and pediatricians.

Information concerning UCLA instructional offerings in prosthetics and orthotics, together with application forms, can be obtained from Dr. Miles H. Anderson, Director, Prosthetics-Orthotics Education, Medical Center B4-229, University of California, Los Angeles 24, Calif.

Listed below is a schedule of the courses offered during the 1963-1964 academic year:

Prosthetists

Total-Contact Above-Knee Socket Technique—Sept. 23-27; Nov. 18-22; Dec. 9-13.

Below-Knee Prosthetics—Jan. 6-24.
Above-Knee Prosthetics—Feb. 10-Mar. 6.
Hip-Disarticulation Prosthetics—Apr. 27-May 15.
Upper-Extremity Prosthetics—June 1-19.

Orthotists

Functional Long Leg Bracing—Oct. 14-Xov. 1; Mar. 23 -Apr. 10.
Functional Bracing of the Upper Extremities—July 6-24.

Therapists

Prosthetics-Orthotics—Oct. 14-25; Dec. 2-13; Feb. 10-21; Apr. 6-17.

Physicians

Prosthetics-Orthotics—Oct. 14-25; Dec. 2-13; Feb. 10-21; Apr. 6-17.

Rehabilitation Personnel

Prosthetic-Orthotic Rehabilitation—Nov. 18 22; Jan. 6-10; Mar. 9-13; May 18-22.

Prosthetics Clinic Teams

Management of the Child Amputee—Apr. 20-24.

In addition to their regular teaching duties, members of the UCLA Prosthetics-Orthotics Education faculty have been engaged in a number of related activities.

Bernard Strohm, a member of the instructional staff, read a paper and showed a motion picture on the UCLA Functional Long Leg Brace at the Ninth World Congress of the International Society for Rehabilitation of the Disabled and at the Sixth International Prosthetics Course, both of which were held in Copenhagen, Denmark, during the summer of 1963.

The UCLA brace emplo\ s a free-swinging knee, alignment stability, and hydraulic ankle control, and uses a thigh shell made from a mold developed through the use of the VAPC cast-taking machine designed for making above-knee sockets. The brace was developed by John J. Bray, Associate Director of the UCLA Prosthetics-Orthotics Education Program, with the assistance of Charles Scott, of the United States Manufacturing Co., Glendale, Calif.

Dr. Sam Colachis, Assistant Professor of Physical Medicine and Instructor in the Prosthetics-Orthotics Education Program at

Power shovel scoops up first load of earth at groundbreaking ceremony for UCLA Rehabilitation Center. Left to right: Dr. Ralph Worden, Welton Becket, Dean Sherman Mellinkoff, Vice-Chancellor William G. Young, Associate Dean John Field, Lawrence Frank, Zeb Gullidge, Mary E. Switzer, and Dr. Stafford Warren. UCLA Prosthetics-Orthotics Education will be among the programs conducted at the Center upon its completion.

UCLA, gave a talk on *Hydraulics in Above-Knee Prosthetics* at the Congress of Physical Medicine and Rehabilitation in Dallas, Tex., during August 1963. In connection with his presentation, Dr. Colachis had a number of amputees demonstrate above-knee prostheses equipped with the Hydra-Cadence hydraulic unit.

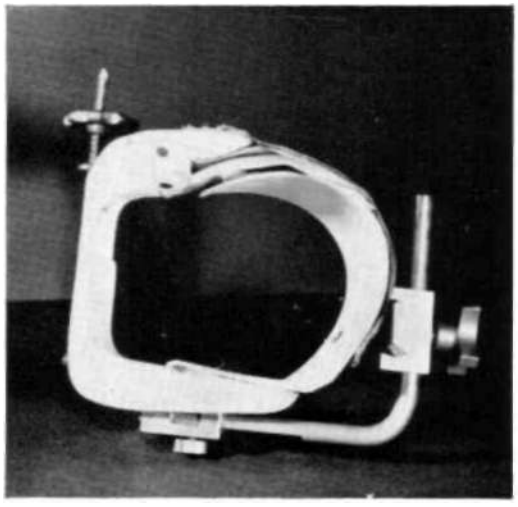
Prosthetics-Orthotics Education al NYU

New York University's Post-Graduate Medical School offered its first courses in prosthetics and orthotics in March 1956, some seven years ago.

Since then, surprisingly large numbers of students have taken time from their professional practices to attend one (and in some cases, two or three) of the courses. Including the 1962-1963 academic year, total student registration has been more than 3,000, as follows:

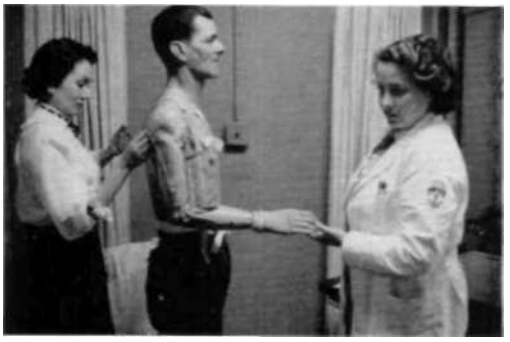
Physicians and Surgeons	1,068
Therapists	935
Prosthetists	642
Rehabilitation Counselors	321
Orthotists	82
	3,048

Students have come from 43 states, the District of Columbia, and 40 foreign countries.



Top view of NYU casting brim for total-contact, above-knee socket.

Mr. Richard Lehneis, NYU Prosthetics-Orthotics Education, explains the importance of proper alignment in a lower-extremity brace



Therapists gain actual experience in check-out procedures,

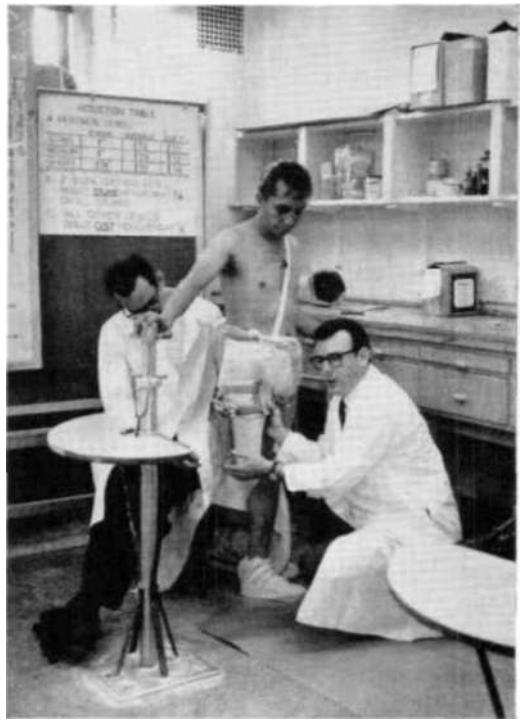
This widespread, continuing high level of interest has stimulated NYU to expand the scope of its educational program in prosthetics and orthotics. In the early years, courses limited to upper-extremity and above-knee prosthetics were offered to physicians, therapists, and prosthetists. Later, instruction was extended to include below-knee prosthetics, and additional courses were developed for a fourth professional worker, the rehabilitation counselor.

More recently, and again in response to continuing interest and need, a comprehensive instructional program for orthotists was introduced in the field of lower-extremity orthotics.

In addition to the short-term intensive courses offered by the Post-Graduate Medical School, NYU has inaugurated the first undergraduate curriculum leading to the degree of Bachelor of Science in Prosthetics and Orthotics. This degree program, offered by the School of Education, is designed to meet the growing demand for professionally trained prosthetists and orthotists throughout the United States and overseas.

The first graduates of this curriculum, in June 1965, will have had not only a broad educational experience but also thorough training in both the theoretical and practical aspects of prosthetics and orthotics.

During the 1963-1964 academic year, courses in lower-extremity orthotics for physicians and surgeons and for therapists will be included in the teaching program for the first time. While much still remains to be accomplished in the areas of upper-extremity and spinal orthotics, these courses will round out the program in lower-extremity orthotics.



Demonstration of stump-casting techniques.

Clinic team prepares to evaluate a patellar-tendon-bearing, below-knee prosthesis.

Another major new development is the presentation of courses for prosthetists in total-contact, plastic, above-knee sockets. This recent advance in lower-extremity prosthetics has aroused considerable interest. The courses will demonstrate several methods of casting, fabricating, and fitting total-contact sockets, but will emphasize the recently developed NYU Flexible Casting-Brim.

Besides these relatively new additions to the curriculum, the NYU Prosthetics and Orthotics Program will continue to offer the familiar intensive, basic courses in upper- and lower-extremity prosthetics.

A limited number of traineeships are available through the Vocational Rehabilitation Administration to persons for whom attendance at a course would be a financial hardship. Information and application forms can be obtained from Dr. Sidney Fishman, Coordinator, Prosthetics and Orthotics, New York University, 342 East 26th St., New-York 10, N. Y.

Listed below is a schedule of the courses offered during the 1963-1964 academic year:

Physicians and Surgeons

Lower-Extremity Prosthetics—Sept. 9-14; Dec. 2-7; Feb. 3-8; May 11-16.
Lower-Extremity Orthotics—Oct. 28-Nov. 1; Jan. 13-17; Apr. 27-May 1.
Upper-Extremity Prosthetics—Nov. 18-22; Apr. 6-10.

Prosthetists

Below-Knee Prosthetics—Sept. 9-27; Feb. 3-21.
Total-Contact Above-Knee Prostheses—Oct. 14-19; Oct. 21-26; Mar, 2-7; Mar. 9-14; June 8-13.
Above-Knee Prosthetics—Dec. 2-20; May 11-29.
Upper-Extremity Prosthetics—Fitting and Harnessing—Mar. 30-Apr. 10.

Therapists

Lower-Extremity Prosthetics—Sept. 16-27; Dec. 9-20; Feb. 10-21; May 18-29.
Upper-Extremity Prosthetics—Nov 11-22; Mar. 30-Apr. 10.
Lower-Extremity Orthotics—Jan. 13-17; Apr. 27-May 1.

Orthotisls

Lower-Extremitv Orthotics—Jan. 6-17; Apr. 20-May 1.

Rehabilitation Counselors

Prosthetics and Orthotics—Mar. 2-7; Mar. 9-13; June 8-12.

Prosthetics-Orthotics Education at NU

The academic year 1963-1964 is Northwestern University's fifth year of classes in Prosthetic-Orthotic Education. Offerings include a new residency training program, the first regularly scheduled course in spinal orthotics, and continuation of two special courses, *Management of the Juvenile Amputee* and *Business and Administrative Procedures.*

Five sections of *Total-Contact Plastic-Socket Techniques* are scheduled in order to meet the demands of prosthetists in the Middle West. Instruction includes the techniques developed by the VA Prosthetics Center and the University of California at Berkeley.

In response to the interest in prosthetics and orthotics education courses on the part of increasing numbers of resident physicians, an effort has been made to systematize their enrollment. As a result, it is estimated that more than 160 residents will attend courses during the academic year 1963-1964.

Principles of Spinal Orthotics, a course designed to orient the orthotist in the current practice of the art of spinal bracing, has been revised to meet more accurately the needs of students. The first regular section is scheduled for January 1964.

As in 1962-1963, Northwestern will offer two sections of *Management of the Juvenile*

Lecture on biomechanics, Prosthetic-Orthotic Education, Northwestern University.

Amputee. The course, open to physicians, therapists, and prosthetists, will emphasize medical and therapeutic techniques, as well as biomechanics and harnessing problems connected with the management of the juvenile amputee.

Northwestern University School of Business will present a one-week course in business and administrative procedures. Open to owners, managers, employees, and suppliers of prosthetics and orthotics facilities, the course emphasizes accounting, business law, and administration.

Northwestern will continue to offer to prosthetists separate courses in above-knee prosthetics, below-knee prosthetics, and special prostheses. Courses in both lower- and upper-extremity prosthetics will continue to be offered to therapists. During 1963-1964, the course for rehabilitation counselors will also be open to medical social workers and registered nurses who are working in rehabilitation centers.

Inquiries concerning instructional offerings by Northwestern University in prosthetics and orthotics should be addressed to Dr. Jack B. Armold, Director, Prosthetic-Orthotic Education, Northwestern University Medical School, 401 East Ohio St., Chicago 11, Ill.

Listed below is a schedule of the courses offered during the 1963-1964 academic year:

Prosthetists

Total-Contact Plastic-Socket Techniques—Sept. 16-21; Sept. 23-28; Feb. 24-29; Apr. 6-11; Apr. 20-25.
Above-Knee Prosthetics—Oct. 7-Nov. 1.
Management of the Juvenile Amputee—Dec. 2-5; May 11-14.
Below-Knee Prosthetics—Mar. 9-27.
Fitting and Fabrication of Special Prostheses—May 18-June 5.

Managers of Facilities

Business and Administrative Procedures—Oct. 14-18.

Therapists

Lower-Extremity Prosthetics—Oct. 28-Nov. 1; Mar. 23-27; Apr. 27-May 1; June 1-5; June 8-12.
Management of the Juvenile Amputee—Dec. 2-5; May 11-14.
Upper-Extremity Prosthetics—Feb. 3-7; Feb. 17-21.

Physicians and Surgeons

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Upper-Extremity Prosthetics—Feb. 3-7; Feb. 17-21.

Rehabilitation Personnel

Orientation in Prosthetics and Orthotics—Nov. 11-15; Dec. 9-13; Jan. 6-10; Apr. 13-17; June 22-26.

Orthotists

Principles of Spinal Orthotics—Jan. 13-17.

International Meetings

Copenhagen

At the request of the International Society for Rehabilitation of the Disabled, the Committee on Prosthetics Research and Development sponsored a trip to Europe during the summer of 1963 by A. Bennett Wilson, Jr., Technical Director of CPRD, and Howard R. Thranhardt, of J. E. Hanger, Inc., Atlanta, Ga. The purpose of the trip was to participate in a series of three meetings held in Copenhagen: the International Experts Meeting in Prosthetics, June 17-21; the Ninth World Congress of the International Society for Rehabilitation of the Disabled, June 22-28; and the Sixth International Prosthetics Course, June 30-July 5. In addition, research facilities and manufacturing establishments were visited in England and Germany.

Summing up their observations, Mr. Wilson and Mr. Thranhardt said that American practices in prosthetics are being adopted throughout the world; that a number of countries, among them Sweden and Canada, are now initiating research programs; that there still exists a need for a more effective program for dissemination of information; that the German and Polish techniques of amputation should be evaluated thoroughly in the United States; and that the French technique of fitting patellar-tendon-bearing prostheses should also be evaluated.

Other persons from the United States who participated in the meetings sponsored by ISRD were: Dr. Eugene F. Murphy, Chief of the Research and Development Division of the VA Prosthetic and Sensory Aids Service; Dr. Jacquelin Perry, of Rancho Los Amigos;

Sixth International Prosthetics Course, Copenhagen, Denmark, June 30-July 5, 1963. Participants assembled by the steps of the Orthopaedic Hospital in Copenhagen.

Dr. Allen S. Russek, Chief Orthopedist at the NYU Institute of Physical Medicine and Rehabilitation; Anthony Staros, Chief of the VA Prosthetics Center; Bernard R. Strohm, of the UCLA Medical Center; William A. Tosberg, Technical Director of Prosthetics Services at the NYU Medical Center; Joseph E. Traub, Director of Prosthetic-Orthotic Laboratories at the University of Washington in Seattle; and Donald V. Wilson, Secretary-General of the International Society for Rehabilitation of the Disabled.

The Subcommittee on Prosthetics in Paramedical Education of the Committee on Prosthetics Education and Information was represented at the Fourth International Congress of the World Confederation for Physical Therapy during June 1963 by Miss Dorothy Baethke, Chairman of the Subcommittee, Mrs. Florence Linduff, and Mrs. Barbara Friz, Staff Officer of CPEI. The Congress was held in Copenhagen, the location of the initial meeting in 1951.

At one of the general sessions, Miss Baethke, who is Director of Physical Therapy at the University of Pennsylvania, presented a paper entitled *New Knowledge in the Management of Amputee Patients,* in which she discussed educational programs and their role in communicating to the field the developments in prosthetics research.

Gait Analysis, a film produced by the faculty and staff of Prosthetic-Orthotic Education at Northwestern University, was one of three American films shown at the Film Program during the Congress.

Vienna and The Hague

A number of persons well known for their contributions to the Artificial Limb Program participated in meetings at Vienna and The Hague during September 1963.

At a symposium on embryonic malformations, in Vienna on September 5, 1963, Dr. Charles H. Frantz, Medical Co-Director of the Area Child Amputee Program of the Michigan Crippled Children Commission, made a presentation on *Clinical Aspects of Phocomelia and Related Malformations;* Colin A. McLaurin, Project Director of the Prosthetic Research and Training Program at the Ontario Crippled Children's Centre, made a presentation on *Prosthetic Advances* and showed a motion picture entitled *An Electric Arm Programmed for Feeding;* and Dr. Arthur J. Lesser, Director of the Division of Health Services of the Children's Bureau, Department of Health, Education, and Welfare, made a presentation on *Congenital Malformations from*

the Point of View of Public Health and Prevention. The symposium was part of the program of the Congress of the International Society of Orthopaedic Surgery and Traumatology, September 1-5, 1963.

The Third International Conference on Human Genetics at The Hague was followed immediately by a meeting sponsored by the Association for the Aid of Crippled Children on September 11, 12, and 13, 1963, during which Dr. Frantz made a presentation on *Research Needs in Orthopedic Surgery,* and Dr. Sidney Fishman, of Prosthetic and Orthotic Research at New York University, made a presentation on *Behavioral and Psychological Reactions of Amputees.* Mr. McLaurin participated in a panel discussion on recent advances in prosthetics.

Prosthetics in Alaska

Dr. Harold W. Glattly, Executive Secretary of the Committee on Prosthetics Education and Information, was an invited guest at the Governor's Institute on Vocational Rehabilitation held at the University of Alaska in Fairbanks, August 12-14, 1963. All federal and state agencies concerned with the rehabilitation of the handicapped were represented at the conference. Of especial interest to the participants was the management of amputees. The rate of amputation in Alaska is relatively high due to cold injury and accidents. Since the untimely death two years ago of Mr. Rogers of the Alaska Orthopedic Appliances Company in Anchorage, no prosthetics services have been available in the state. All amputees must go to Seattle or Tacoma for the fitting and servicing of their appliances. Not only is this situation unsatisfactory from the standpoint of the patient, but the cost of providing adequate services by this means is almost prohibitive.

Steps were taken at the Institute to make it attractive for a prosthetist to open a facility in Alaska and toward the organization of a prosthetics clinic team that would serve all federal and state agencies.

It was pointed out by certain of the conferees that some conventional prosthetic components are unsuitable for use in Alaska because of the extreme winter cold. A plea was made for a research program to develop components that are more suitable for the environment.

UCOPE Sponsors Panel on Orthotics and Prosthetics

Orthotics and Prosthetics was the subject of a panel discussion sponsored by the University Council on Orthotic and Prosthetic Education at one of the general sessions of the annual conference of the American Physical Therapy Association, held in New York City during May 1963.

The physical therapist members of the panel, representing the three prosthetic-orthotic schools, included Bernard Strohm, University of California at Los Angeles; Joan Erbach, New York University; and Charles Fryer, Northwestern University. Dr. J. Warren Perry, Assistant Chief of the Division of Training, Vocational Rehabilitation Administration, was also a participant. Dr. Sidney Fishman of New York University was the panel moderator.

This program was instigated by the CPEI Subcommittee on Prosthetics in Paramedical Education in response to many requests from physical therapists who want to keep up to date in the field of prosthetics and orthotics.

Dr. Eugene F. Murphy Honored by FBA

The Federal Business Association of New York recently conferred its highly regarded 1963 Civilian Award for Outstanding Federal Service on Dr. Eugene F. Murphy, Chief of the Research and Development Division of the VA Prosthetic and Sensory Aids Service.

Dr. Murphy was selected for his "outstanding national and international contributions in the development and improvement of prosthetic and sensory aids for the physically handicapped."

The presentation to Dr. Murphy was made by Dr. Robert E. Stewart, Director of the VA Prosthetic and Sensory Aids Service, at a luncheon meeting of the Federal Business Association at Fort Hamilton, N. Y. Dr. Stewart praised Dr. Murphy's contributions to the field of prosthetics, citing him as one of the outstanding men in this important specialty and stating that the United States

stands first among the nations of the world in this field.

Dr. Murphy's efforts in behalf of the disabled have had an international impact. Researchers from 40 countries have visited and consulted with Dr. Murphy on prosthetics problems. In 1954 he was selected as one of a dozen world-wide experts to participate in a World Health Organization Conference on Prosthetics. He was the first recipient of a Fulbright Lecture-ship in Prosthetics in 1957-1958. With the Society and Home for Cripples in Copenhagen as his headquarters, he rendered invaluable services to the Danish prosthetics program. In 1961 he received the Silver Medal of the City of Paris for his work as a member of the Committee on Prostheses, Braces, and Technical Aids of the International Society for Rehabilitation of the Disabled.

Dr. Robert E. Stewart, Director of the VA Prosthetic and Sensory Aids Service, presents 1963 Civilian Award for Outstanding Federal Service to Dr. Eugene F. Murphy, Chief of the Research and Development Division of the Prosthetic and Sensory Aids Service, as Arthur Miller, Regional Administrator of the General Services Administration, looks on.

Dr. Murphy is a native of Syracuse, N. Y. He contracted polio at the age of 11, which left him with severe involvement of his arms and legs. His determination and motivation to overcome the restrictions imposed by his disability resulted in steady progress from the use of a wheel chair and brace, to crutches, and finally to the use of orthopedic shoes and canes. In the performance of his duties, which require him to be away from the office about one-third of the time, he travels by all the usual means of public transportation.

Dr. Murphy received his M.E. degree from Cornell University in 1935, his M.M.E. degree from Syracuse University in 1937, and his Ph.D. from the Illinois Institute of Technology in 1948. He taught engineering at Syracuse University, the Illinois Institute of Technology, and the University of California at Berkeley. Prior to joining VA, Dr. Murphy served as Staff Engineer with the Committee on Artificial Limbs of the National Academy of Sciences—National Research Council. He was also an Advisory Fellow on Bracing Research with the Mellon Institute for Industrial Research.

Mr. Colin A. McLaurin Now at Ontario Crippled Children's Centre

Mr. McLaurin, who is well known for his many valuable personal contributions to the field of prosthetics, has recently accepted an appointment as Project Director of the Prosthetic Research and Training Program at the Ontario Crippled Children's Centre, 350 Rumsey Road, Toronto, Canada.

Mr. McLaurin, who holds the degree of Bachelor of Applied Science from the University of Toronto, was formerly the Project Director at the Northwestern University Prosthetics Research Center in Chicago.

The research program at Toronto will be directed toward the development of improved devices and fitting principles for child amputees. Although it is intended that prosthetics training will be provided at the Ontario Crippled Children's Centre, no definite plans have been formed as yet.

The program at the center in Toronto will work in cooperation with similar centers at Montreal and Winnipeg, and Mr. McLaurin will continue in his associations with CPRD, of which he is a member. He also serves as Chairman of the Subcommittee on Design and Development of CPRD and as a member of the Subcommittee on Evaluation of CPRD.

New Director of AMBRL

Lieutenant Colonel Peter M. Margetis has been named Director of the U. S. Army Medical Biomechanical Research Laboratory (formerly the U. S. Army Prosthetics Research Laboratory) at Walter Reed Army Medical Center, Washington, D. C. Colonel Margetis, one-time Assistant Chief of the Department of

Dental Research, Walter Reed Army Institute of Research, was transferred to AMBRL after serving for six years as Chief of the Dental Research Branch, U. S. Army Medical Research and Development Command.

Colonel Margetis received a Bachelor of Arts degree from the University of Wisconsin in 1939 and a Doctor of Dental Surgery degree from Marquette University in 1943. He was assigned for three years to the Dental Materials Research Section of the National Bureau of Standards concurrent with a two-year assignment to Georgetown University, where he received a Master of Science in Dental Materials. He is presently a member of the Executive Committee of the Dental Materials Group of the International Association for Dental Research and the Army representative of the Dental Materials Specifications Committee of the same group. He is the consultant on dental materials to the Assistant Surgeon General and Chief of the Dental Corps, Office of the Surgeon General, Department of the Army. He serves as a guest lecturer on dental materials at the U. S. Army Institute of Dental Research and has published a number of articles on dental materials. He is also a member of the American Dental Association and a Fellow of the American College of Dentists.

Conference on Engineering in Medicine

A Conference on Engineering in Medicine was held under the auspices of the Engineering Foundation at Proctor Academy in Andover, N. H., August 19-23, 1963.

Co-Chairmen of the Conference were Dr. Hans H. Zinsser, of the College of Physicians and Surgeons at Columbia University, and Renato Contini, Research Coordinator of Special Projects at the College of Engineering of New York University.

The Conference, which brought together engineering educators, engineering scientists engaged in some aspect of medical engineering, and representatives of medical science, explored the role of the engineer in medicine and medical research and how he could be trained to fulfill this role.

Major topics considered at the Conference were: Education in Biomedical Engineering, Operations Research and Systems Analysis, Biomedicine in Mechanical Engineering, and Biomedicine in Chemical Engineering.

In addition to Mr. Contini, a number of other persons long associated with the prosthetics and orthotics research program took an active part in the Conference. Among the participants were Dean L. M. K. Boelter, of the University of California at Los Angeles; Herbert R. Lissner, Coordinator of the Biomechanics Research Center at Wayne State

Conference on Engineering in Medicine, Proctor Academy, Andover, N. H., August 19-23, 1963.

University, who is a member of CPRD; Dr. Fred Leonard, Scientific Director of the Army Medical Biomechanical Research Laboratory; Dr. Eugene F. Murphy, Chief of the Research and Development Division of the VA Prosthetic and Sensory Aids Service; Charles W. Radcliffe, of the Department of Engineering of the University of California at Berkeley; Thomas Sheridan, of Massachusetts Institute of Technology; and Dr. Robert W. Mann, of Massachusetts Institute of Technology, who is a member of CPRD.

West German Publication on Care of Congenially Handicapped Children

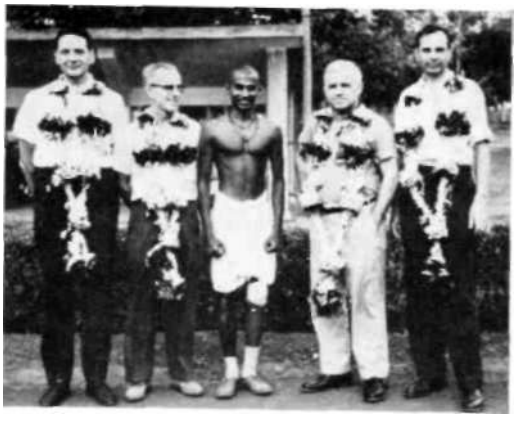
The German Association for the Rehabilitation of the Handicapped has recently issued a 64-page publication in English which deals with the management and care of young children with severe congenital limb deformities. The publication is entitled *Information on Measures for Rehabilitation of Children with Dysmelia.* Major articles in the publication are *Prosthetic Possibilities at Baby-Age,* by Dr. O. Hepp; *The Fitting of Children with Arm Prostheses,* by Dr. W. Wigand; *Pneumatic Arm Prostheses for Children* and *Provision of Active Prostheses for Armless Babies in the Second Year of Life,* both by Dr. E. Marquardt; *Information on Standard Prostheses for Armless Children,* by Dr. K. Lindemann and Dr. E. Marquardt; and *Indications for Early Treatment of Children with Dysmelia,* by Dr. E. Marquardt.

Requests for copies of the publication should be addressed to: Deutsche Vereinigung fur die Rehabilitation Behinderter, Zechnerweg la, Heidelberg-Schlierbach, West Germany.

Visit to India by Prosthetics Team

Upon the recommendation of Dr. Howard A. Rusk, the concurrence of the Surgeon General of the Army, and by invitation of the Government of Tndia, a four-man prosthetics team visited India during June 1963 to study the status of current prosthetics practice, to make recommendations for expediting the production of prostheses, and to teach the application of the most modern materials and methods in fitting prosthetic devices.

The team—consisting of Colonel John Butchkosky, former Director of the Army Prosthetics Research Laboratory; Mr. Ivan Dillee, a prosthetist at New York University; Dr. Fred Leonard, Scientific Director of the Army Medical Biomechanical Research Laboratory; and Mr. Colin A. McLaurin, Project Director of the Northwestern University Prosthetics Research Center—made site visits to the Tirath Ram Shah Charity Hospital in New Delhi, the All India Institute for Rehabilitation in Bombay, and the Armed Forces Artificial Limb Centre in Poona.



Members of prosthetics team—Dr. Fred Leonard, Mr. Ivan Dillee, Colonel John Butchkosky, and Mr. Colin A. McLaurin—receive warm welcome in India.

At the Tirath Ram Shah Hospital in New Delhi, Dr. B. S. Kohli, an orthopedic surgeon, has set up an amputee clinic and a limbshop. Plastic limbs are fabricated, and Dr. Kohli is manufacturing prosthetic components such as elbows and hooks on a limited scale. In Bombay, Dr. M. V. Sant, an orthopedic surgeon, is in charge of a modern rehabilitation center consisting of sections for patient examination and physical therapy as well as wings devoted to the manufacture of prosthetic components and to the fabrication of braces. Mr. T. P. Mirajkar, a mechanical engineer, and Mr. K. V. Venkatranan, a prosthetist, supervise limb and brace manufacture. Dr. Kohli, Mr. Mirajkar, and Mr. Venkatranan have studied at prosthetics schools and at various Government and industrial facilities in the United States.

The Armed Forces Artificial Limb Centre is

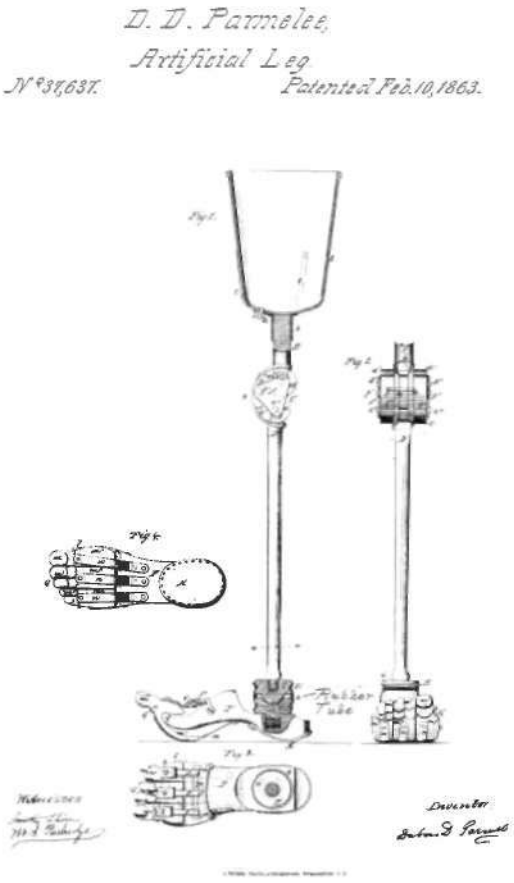
directed by Lieutenant Colonel L. K. Ananthanarayanan, who is an orthopedic surgeon. The center was established in 1944, with the help and advice of experts from the British Ministry of Health's Limb Fitting Centre in Roehampton, England. It has spacious workshops and rehabilitation and administrative buildings. The limb manufacture techniques and the components used are similar to those to be found in Roehampton.

The team spent considerable time at the center, analyzing and collating time and motion records, uncovering materials and personnel resources, and in teaching and engineering services. The results of this work will be presented in a report to be published in the near future.

In all places, the prosthetics team found a very high level of perceptive interest, willing cooperation, and enthusiastic participation.

Patents, Patients, and Patience

Not only does the year 1963 mark the centennial of our sponsoring body, the National Academy of Sciences, but—from the viewpoint of prosthetics—it is especially memorable as the centennial of the issuance of United States Patent No. 37,637 to Dubois D. Parmelee of New York City on "Improvement in Artificial Legs." Parmelee stated that part of his invention "consists in the fastening of such bucket to the stump by means of atmospheric pressure. . . ."



This concept, now known as the suction socket, has had great influence on prosthetics, not only as a technique but also as a stimulus for prosthetics education and for formation of clinic teams, and as a goad forcing research in

biomechanics, alignment principles, and dermatological problems of amputees. Its value, though, was not immediately appreciated in Parmelee's time. Presumably the problems of developing it to a practical level worthy of routine clinical use were too great, not only during the Civil War but on the occasions of many later attempts. Though patents were granted on various modifications and details, none of the known attempts before the 1930's attained routine success on substantial numbers of patients.[1]

Parmelee described a process for forming the socket which was, he stated, "similar to that by which dentists form plates of hard rubber to conform perfectly to the roof of the mouth to be held there by atmospheric pressure. A form or mold of the stump is prepared in wax or plaster-of-paris. . . . Into this mold plaster-of-paris or fusible metal is cast, and thereby a perfect fac-simile or form of the natural stump is obtained. Around this form a sheet of india-rubber ... is tightly wound . . . . . and vulcanized. . . . Instead ... a hollow cone of vulcanite is formed . . . heated to 212° Fahrenheit. . . and forced over the form of the stump and allowed to cool upon it."

Apparently Parmelee desired a socket which *exactly* fitted the patient's stump, made with materials available in his time. In recent years laminates of cloth and thermosetting resins, sheets of thermoplastic materials for blow molding, and conical preforms of thermoplastic materials have been used with varying success. The real questions probably are the exactness of the cast and subsequent model, or the degree of modification deliberately introduced. One may suspect that exact casts of stumps have *seemed* to fail because they did *not* represent the working stump. Some swelling may well have been present when the cast was taken after the bare stump had been left below the torso and unsupported for some minutes before taking the cast; even with precision techniques, the socket would only fit the initially engorged stump. Shortly, in use, the surplus fluid would be pumped out by muscle activity and piston action of the bone within a confining envelope of fascia as well as outer wall. Then the stump might well become loose, sinking painfully during stance or withdrawing disastrously during swing.

Later limbfitters have been substantially if not wholly unanimous in their goal of *reducing* the cast, the model of the stump, and the socket below the circumferences and diameters of the stump, especially in the upper third. (See, for example, the instructions even in the manuals of the last fifteen years.) Yet one may strongly suspect, from available accounts of known difficulties, that excessive zeal in obtaining a tight fit assured against accidental loss of the socket during walking but indirectly caused later rejection of the socket

[1] The history of the suction socket has been sketched repeatedly in the three editions of *The Suction Socket Above-Knee Artificial Leg,* published by the University of California at Berkeley, and in "Status of the Above-Knee Suction Socket in the United States," by Chester C. Haddan and Atha Thomas, *Artificial Limbs,* May 1954.

because of medical complications from outright constriction in the worst cases and, more commonly, edema, discoloration, or ultimate breakdown of the distal end of the stump, as described by Levy in *Artificial Limbs* Spring 1956. Indirectly, the numerous early failures appear to have resulted from attempts of each successive inventor to work alone, without that teamwork which we now consider routine.

Though Parmelee's description is not very clear, and his illustration may merely be schematic, one may legitimately wonder if he also invented the total-contact socket. He simply states that "The bucket *A* is provided with a small faucet, *a,* inserted in its under side. . . ." He was willing to place "a dry sponge, cotton, wool, or small bag of fused chloride of calcium ... at the bottom," though, so there may normally have been some space, particularly if his hollow cone method were used.

The suction socket with precise fit to the stump, whether for an above-knee prosthesis as illustrated or for arms or below-knee prostheses as mentioned, was only one feature of Parmelee's patent. A later reissue has claims on the method of making the bucket by molding a plastic substance. The original patent also discusses a special polycentric knee construction, aiming at *low* friction, and individual segments or cantilever springs representing metatarsals and toes. He also used a ball-and-socket ankle joint.

The New York City directories of the period May 1, 1862, through May 1, 1873, list Parmelee as a "chemist," probably the equivalent of an apothecary or druggist, originally with an office on lower Broadway and a home on 41st Street, apparently a few doors from Fifth Avenue in an area which was then quite far uptown, next to the Croton Reservoir on the site of the present New York Public Library. Later he was listed on 34th Street, opposite the present location of Macy's Department Store. He is not listed after 1873.

A descendent of a Parmelee, Mrs. Dorothy H. Smallwood of Washington, D. C, has made a hobby of gathering information on some 10,000 members of the family, with a variety of forms for spelling the name. It appears fairly certain that our hero, Dubois Duncombe Parmelee, was born August 15, 1829, at Fairfield, Connecticut, the son of Ezra and Mary Duncombe Parmelee. He married Rosina Gloward in New York City on October 7, 1857; apparently they had no children. He died in New York April 15, 1897.

He evidently joined the American Institute of the City of New York, an eminent and venerable scientific society which still exists, on August 1, 1861, and he was listed as an annual member in the membership list of January 2, 1868, with profession given as Practical Chemist. A distant relative, in writing to Mrs. Smallwood, commented that Dr. Du Bois *[sic]* D. Parmelee was active in the American Institute.

Some years ago I had the pleasure of studying at the National Archives in

Washington the original hand-written correspondence between Parmelee and the Patent Office. In his day the Patent Office acted fairly promptly: Parmelee filed late in 1862, and the patent was issued February 10, 1863. The state of the art was then rather simple, and Patent Office actions were correspondingly straightforward.

Patents, because they are readily available at small cost even a century after issuance, have historical and educational aspects long after the protection aspect has expired. It is illuminating to reexamine patents of Parmelee and his contemporaries. Sometimes an old concept, like holding the socket in place by means of atmospheric pressure, can be revived with dramatic success. The current efforts on plastic sockets and on casting techniques may well have major impacts on speed of fitting, comfort for patients, and economics. Even Parmelee's suggestion of a pylon leg with flexible cosmetic covering is still surprisingly current.

Patients have been helped by the ideas of old patents now in the public domain. While imagination, sustained effort, and patience are needed, modern research methods should be able to compress the time scale. Will our descendants be forced to wait a century to benefit from germs of good ideas disclosed in current literature?

EUGENE F. MURPHY