Spring 1967

Artificial Limbs

A Review of Current Developments

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Artificial Limbs

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EDITORIAL BOARD

Surgeons and Sockets

ANTHONY STAROS, M.S.M.E.[1]

An apt, alliterative appellation for this introduction to the Spring 1967 issue of ARTIFICIAL LIMBS might have been *Wilson's Way with Words*, for the writings of A. Bennett Wilson, Jr., Executive Director of the Committee on Prosthetics Research and Development, comprise much of the issue. Mr. Wilson's literary talents are documented—and acknowledged—but the primary concern of this editorial is with surgeons and prostheses.

Mr. Wilson has set himself a continuing task. The difference between *Limb Prosthetics Today* and *Limb Prosthetics—1967* is four productive years of the Research Program. Many new items are covered. But the Program can be expected to continue to produce significant developments that should be made known to the world, so that four years hence that which is published as representing the state of the art in 1967 will require updating.

Comprehensive summaries of prosthetics technology are an essential part of an efficient information-dissemination system. Typical articles reporting developments in prosthetics research assist the day-to-day practitioner with technical details of design, fabrication, and fitting. They serve an important purpose. But also needed is comprehensive, accurate, nontechnical information in a form that is readily understandable to amputees and their families and the large number of clinicians who are too busy to digest all the detail underlying prosthesis design. The summary coverage is appropriate; as one would attempt to highlight important and even complex matters for a busy Board of Directors, so must there be occasional briefings for those concerned with prosthetics. Not only busy clinicians but equally busy and technically deprived administrators currently or newly responsible for prosthetics programs in the United States and abroad can also obtain an excellent overview from Mr. Wilson's offering. For those surgeons who have never attempted to gain such an overview—and, unfortunately, there are too many—this article represents a real opportunity.

Significant developments of recent years are reported in the other two articles of this issue. The total-contact concept represents a major contribution to improved socket design. Founded upon the very sound principles of the quadrilateral and PTB sockets, total-contact sockets became accepted

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early in this decade. Beneficial results, particularly in patient satisfaction, have certainly accrued.

Dr. Georg Bakalim of Finland has conducted an interesting survey. Especially stimulating were the replies to an inquiry about skiing. "Only" 23 of the group surveyed (more than 15 per cent) tried to ski with their new prostheses. The Finns are a hardy people.

Also noted are the problems of perspiration (in Finland!). But the advantages of the total-contact principles are brought out quite clearly from the survey. It is refreshing to see surveys of this type conducted on the products of the North American Research Program; even if the results had been less favorable, such follow-ups are welcome. The Finnish survey exemplifies a very desirable evaluation in what may now properly be called the International Program.

Dr. Bakalim points out that the problems that do occur may be attributable in large part to factors other than use of the total-contact principles. How true! The importance of careful attention by the prosthetist and the significance of stump hygiene would be replicated in surveys of fittings elsewhere in the world. But perspiration in Finland!

Total contact means total support of tissues. Support and control forces are present all over the stump; some are low, and some are necessarily high. But all tissue is subjected to pressure. Various external portions of the body can take higher pressures than others, and there is a time dependency. There may also be ambient temperature effects on the response of skin and tissue to pressure. Moreover, not only the forces applied perpendicular to the surface but shearing force must also be considered in the stump-socket interface. It is gratifying to report that studies of the forces acting on the stump are under way at several projects. Eventually, more will be known about the interface between stump and socket in current types of socket fittings. Also needed is a better understanding of the effects of force application on skin and tissue, with due consideration to other variables such as time.

It would be gratifying to report innovations in surgery, also. Total contact, with uniformly low pressures distally, is the present prosthetic answer for stumps resulting from "conventional" amputation surgery. Myoplasty and "tension myodesis" may permit higher pressures to be applied distally, reducing further the proximal share of the load and accruing less constriction in fit. Bone plugs and osteoplastic procedures may permit major changes in pressure distributions on stumps. Total contact will, nevertheless, still be needed, but the distribution of the forces required at the interface will be a function of surgical results and of the reaction of tissue to pressure.

Recent concepts of lower-extremity amputee management, as described in Mr. Wilson's second article, present some unanswered questions. A multipart technique produces a certain result, in this case apparently positive. The several *major* parts of this procedure are the surgery, the rigid dressing, and early weight-bearing and ambulation.

There are various hypotheses as to which part is the most essential, and even about which element of a particular part is significant. There appears to be general agreement, based upon nothing more than "clinical" or "professional" judgments, that the rigid dressing is the most important part. The greatest significance, many state, is in the reduction and control of edema. Other advantages cited are reduction in pain, acceleration and improvement in healing, reduced time in the hospital, and—most significantly—the possibility that many more knee joints can be preserved in amputation surgery on cases with peripheral vascular disease.

Clinical data indicate that the immediate postsurgical fitting procedure provides some of these advantages. Precisely which elements or subelements are truly significant is not entirely clear.

Is the control of edema related to the reduction of pain?

Is early weight-bearing and ambulation related to success in cases with marginal circulation?

Is the control of edema related to improvement in circulation?

From these several causes and their effect on circulation, can more knees be saved?

Are there disadvantages to immobilization of the knee, as most techniques prescribe for the below-knee amputee?

Does mobility of the knee improve circulation and in turn reduce edema?

Does the "tension myodesis" method affect the effectiveness of circulation?

Does an immediate prosthetic experience foster an amputee's sense of well-being and feeling of early recovery?

Are the habits of walking disturbed minimally by immediate fittings?

What effects do variations in the design of rigid dressings have on the control of edema?

How significant to success is the special attention now being given by the surgeon in this procedure?

These and other questions on the significance of the new concepts in the management of lower-extremity amputees still remain. It would be most gratifying if talented researchers could be encouraged to explore the physiological and psychosocial aspects of this revolutionary approach to surgical-prosthetics treatment. Surely, some new ideas would accrue.

More research is needed on socket design for the lower-extremity amputee. Total-contact concepts are beneficial but no cause for complacency. Surgical experimentation and parallel studies of pressures and their effects on tissues should be encouraged to develop even better fitting concepts, short of direct skeletal attachment. There is no more logical place to begin than in conjunction with research on the immediate postsurgical prosthetics fitting procedure.

If nothing else, the introduction of immediate postsurgical fitting procedures has stimulated the interest and concern of surgeons in prosthetics management. Now their possible interest in related research problems is commended to their attention.

Limb Prosthetics—1967

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

Because of the large demand for reprints of "Limb Prosthetics Today" *which originally appeared in the Autumn 1963 issue of ARTIFICIAL LIMBS, the article has been revised to reflect the numerous advances that have been introduced into limb prosthetics since 1963. To distinguish this revision from the original we have chosen the title* "Limb Prosthetics—1967."

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, 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

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.

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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.

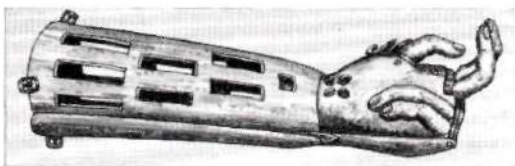

Fig. 3. Alt-Ruppin Hand (circa 1400). The thumb is rigid; the fingers move in pairs and are sprung by the buttons at the base of the palm; the wrist is hinged. Putti, V., *Chir. d. org. di movimento*, 1924–25.

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 Paré, 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. Paré, 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 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.

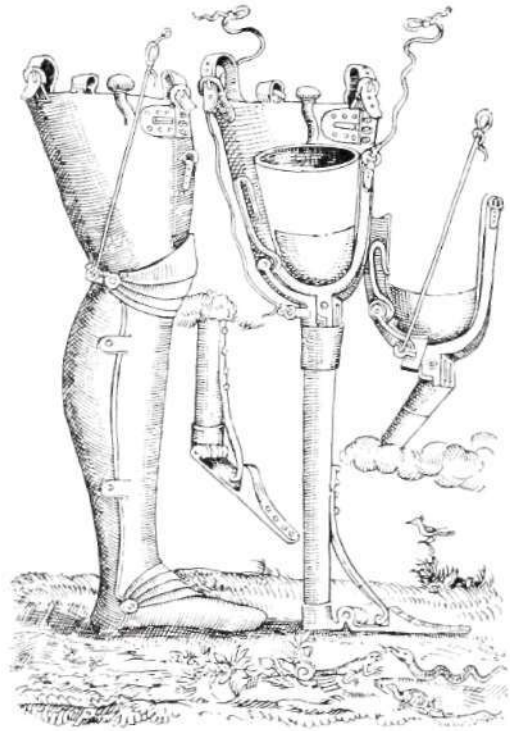

Fig. 4. Artificial leg invented by Ambroise Paré (middle sixteenth century). From Paré, A., *Oeuvres Completes*, Paris, 1840. From the copy in the National Library of Medicine.

After Paré'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

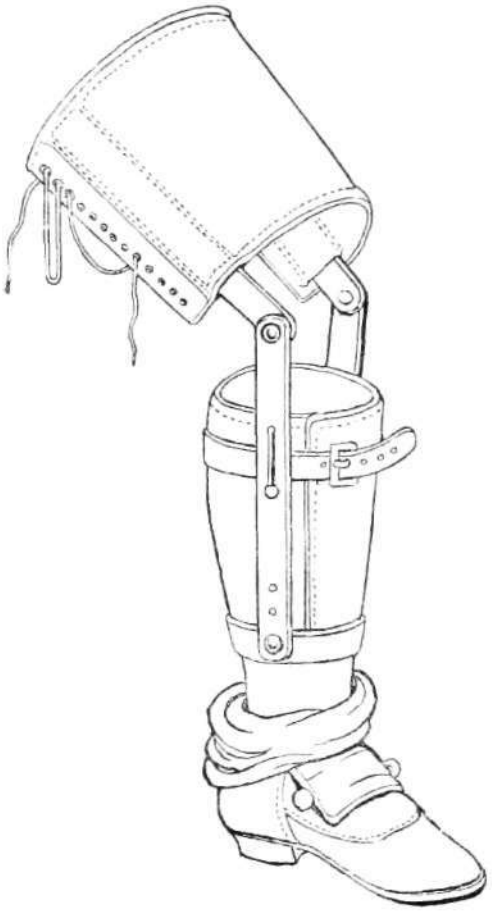

Fig. 5. Verduin Leg (1696). From MacDonald, J., *Am. J. Surg.*, 1905.

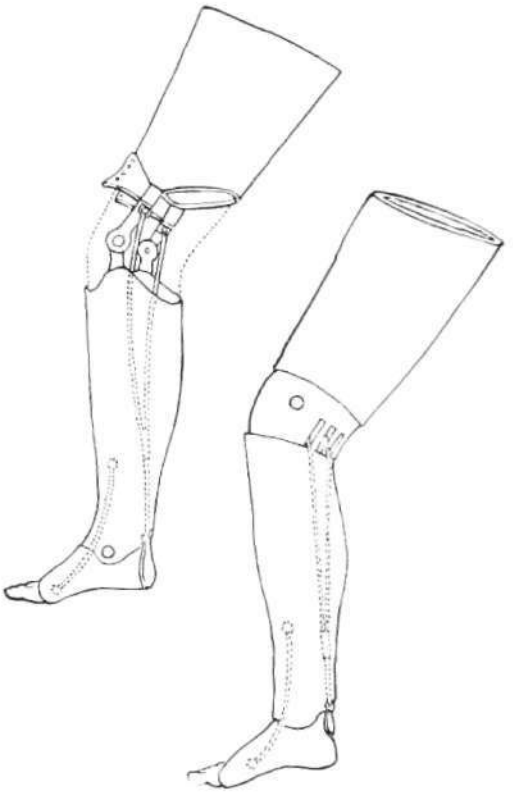

Fig. 6. Anglesea Leg (1800). Below knee at left, above knee at right. Knee, ankle, and foot are articulated. From Bigg, H. H., *Orthopraxy*, 1877.

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 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 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 Thomas and Haddan (*17*), 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 (*7*). 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 (*12*). Devices and techniques based on fundamental data have materially changed the practice of prosthetics during the past 15 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 30 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 overall program is coordinated by the Committee on Prosthetics Research and Development of the National Academy of Sciences—National Academy of Engineering.

In England and Europe, research in artificial limbs was resumed after World War II at Queen Mary's Hospital, Roehampton, London, by the Ministry of Health, and a new program was initiated in West Germany by the government. Also, a program was started in Russia. The so-called "Thalidomide Tragedy" of 1959–1960 gave incentive for governments to support research, and now there are effective programs in Canada, Denmark, Holland, Scotland, and Sweden, and the studies in England and Germany have been greatly expanded. Under Public Law 480 the United States supports prosthetics research in India, Israel, Poland, and Yugoslavia.

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,[2] this organization consists of some 500 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 in Orthotics and Prosthetics, Inc.,[3] 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, Inc.

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

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[3] Suite 130, 919-18th St., N.W., Washington, D.C. 20006.

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 5,787 physicians, 3,962 therapists, and 2,000 prosthetists have been enrolled in these courses during the period 1953 through 1967.

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 July 1965 the 89th Congress passed Public Law 89-97, the Medicare bill, which includes provision for artificial limbs at essentially no cost for persons 65 years of age and over. The bill also assists individual states in providing artificial limbs for persons who are medically indigent at any age. A number of states have enacted legislation to take advantage of the offer by the federal government.

In addition to the 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 the misuse of power tools also account for many amputations.

Improved medical and surgical procedures introduced in recent years have resulted in the preservation of many limbs that would have been amputated. Infection, once a cause of a high fraction of amputations, can usually be controlled by use of antibiotics. Newer methods of vessel and nerve suturing make it possible to save limbs that would have had to be amputated some years ago. Highly qualified sur-

gical teams have demonstrated during the last few years that it is possible to replace a completely severed limb.

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 body. 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.

"Thalidomide babies" born between 1958 and 1961 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.

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 two-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.

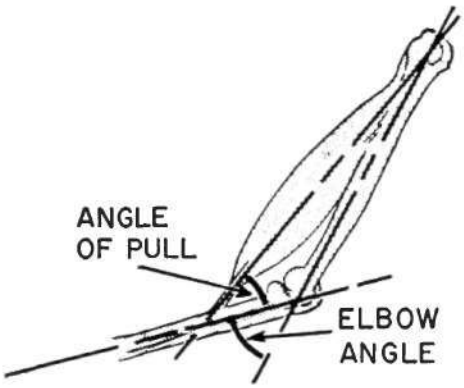


Fig. 8. Schematic drawing of muscular action on skeletal system. The motion shown here is flexion, or bending, of the elbow.

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. The general rule in selecting the site of amputation is to save all length that is medically possible.

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) (*2, 14*). 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

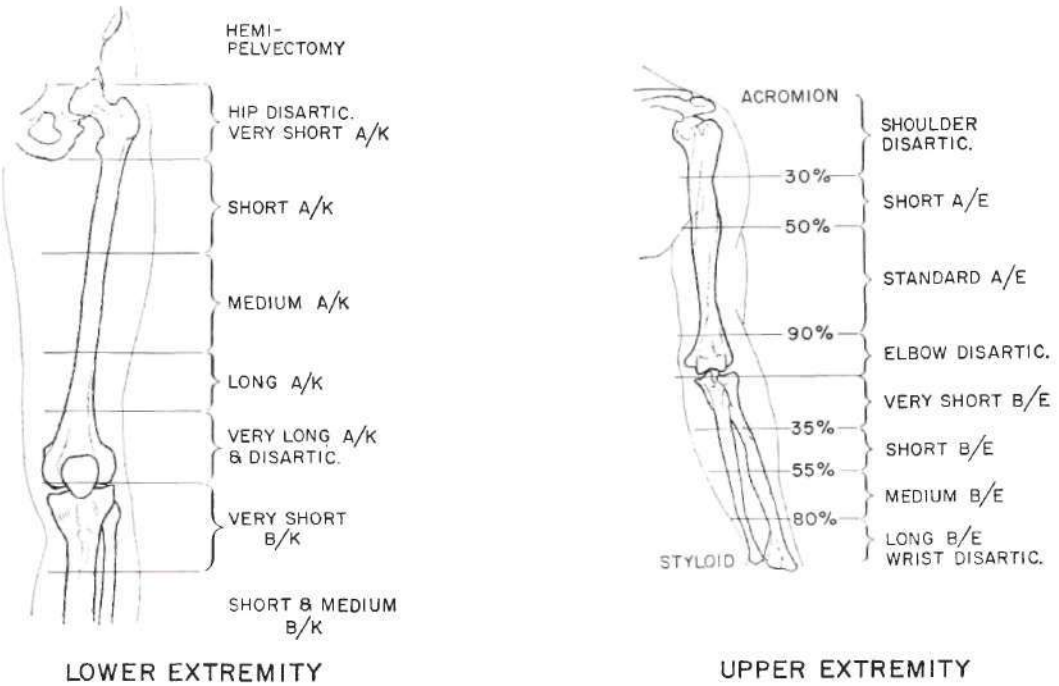


Fig. 9. Classification of amputation by level.

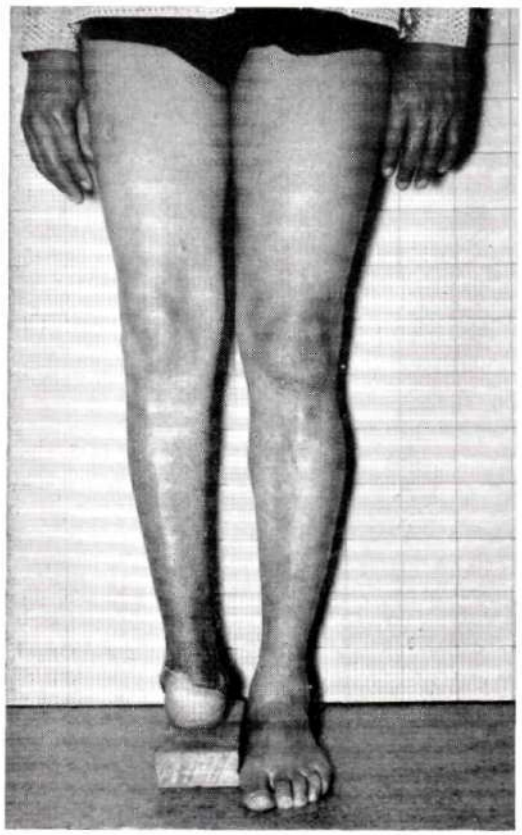


Fig. 10. Excellent Syme stump.

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 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, excellent prostheses can be provided the knee-disarticulation case.

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.

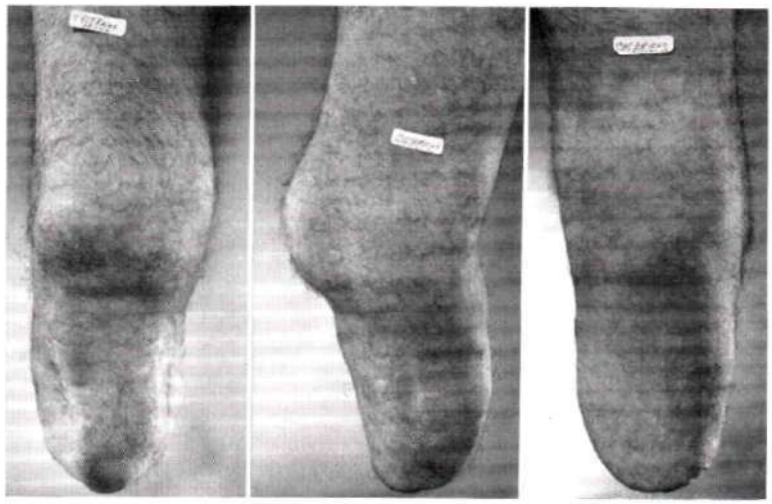


Fig. 11. Typical, well-formed, right below-knee stump. *Courtesy Veterans Administration Prosthetics Center.*

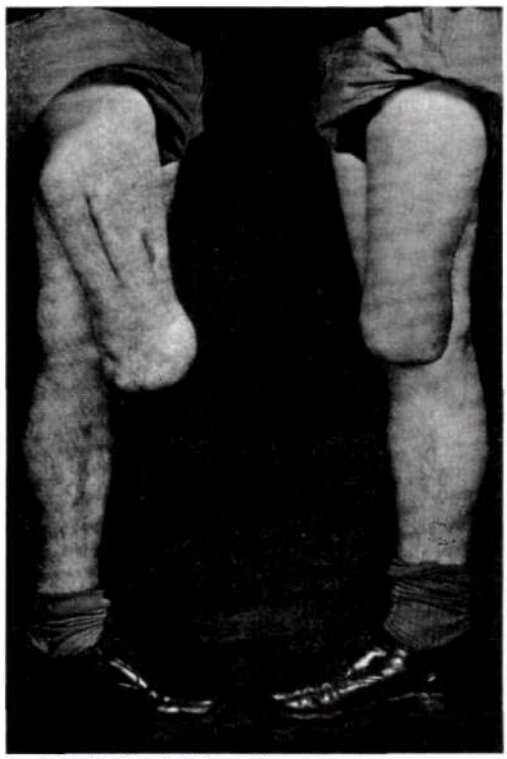


Fig. 12. Typical knee-disarticulation stumps.

Above-Knee Amputations

Amputations through the thigh are among the most common (Fig. 13). Because of the high pressures exerted on the soft tissues by the cut end of the bone, 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 (*1*). Both types of stump 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 re-

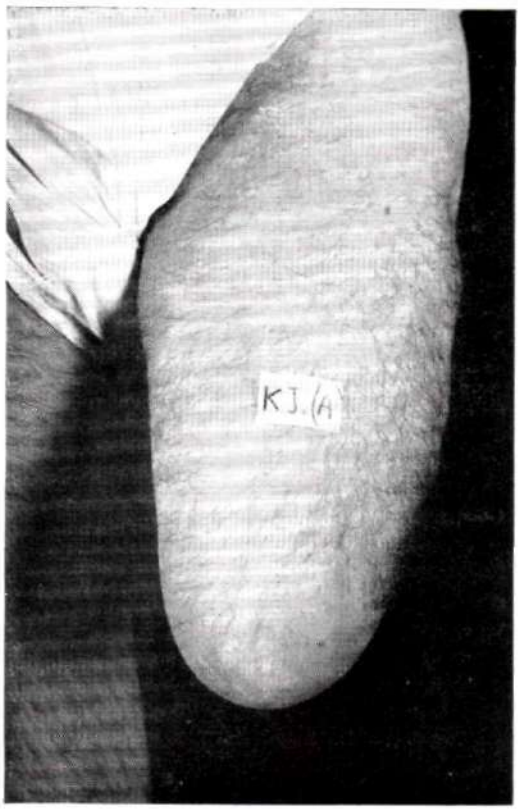


Fig. 13. Typical, well-formed above-knee stump. *Courtesy Veterans Administration Prosthetics Center.*

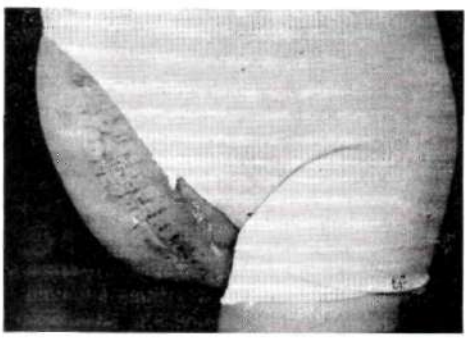


Fig. 14. Patient with true hip-disarticulation amputation.

sult 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,

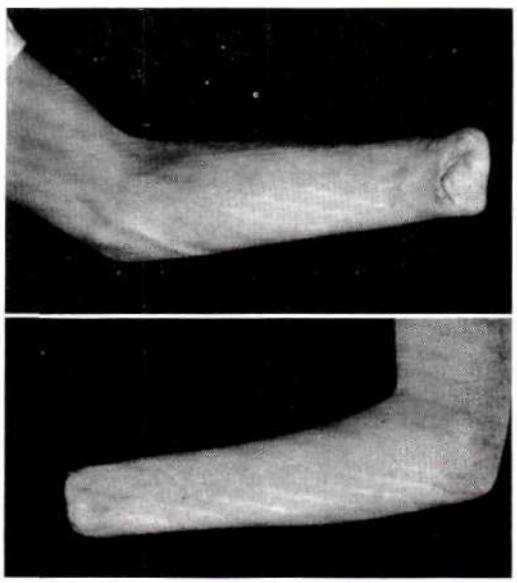


Fig. 15. A good wrist-disarticulation stump.

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.

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,

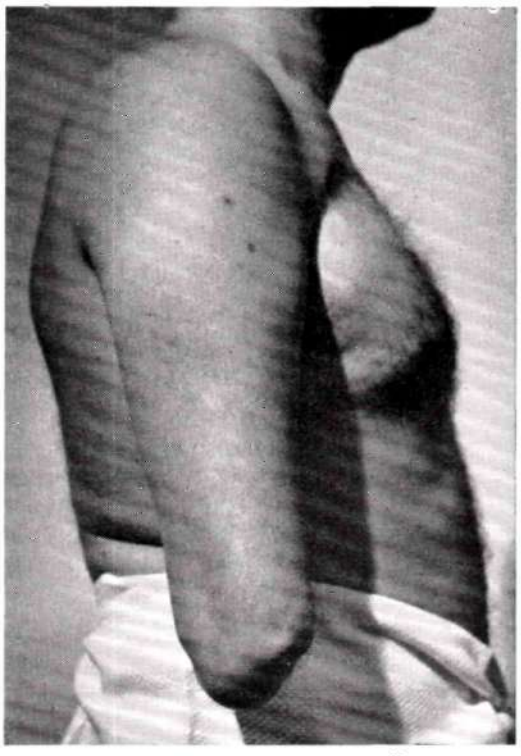


Fig. 16. Amputation through the elbow.

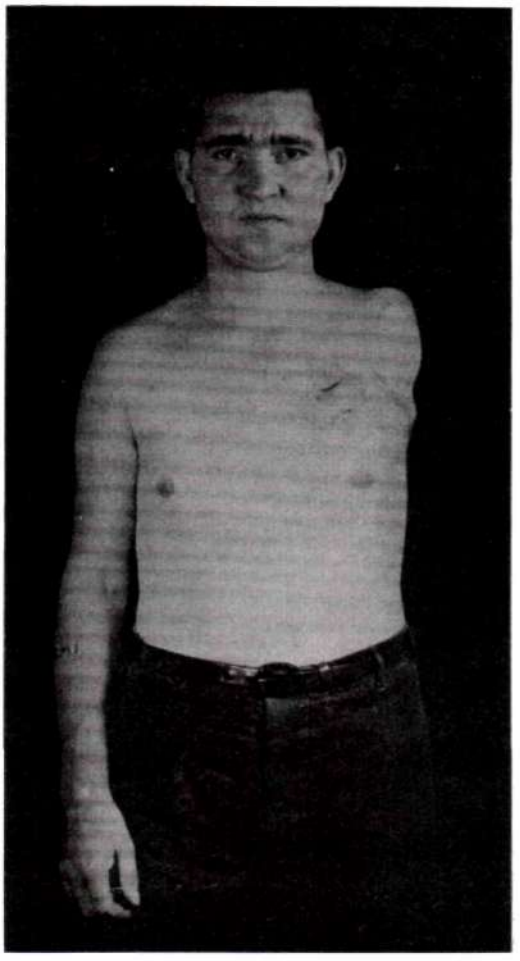


Fig. 17. A true shoulder disarticulation.

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.

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.

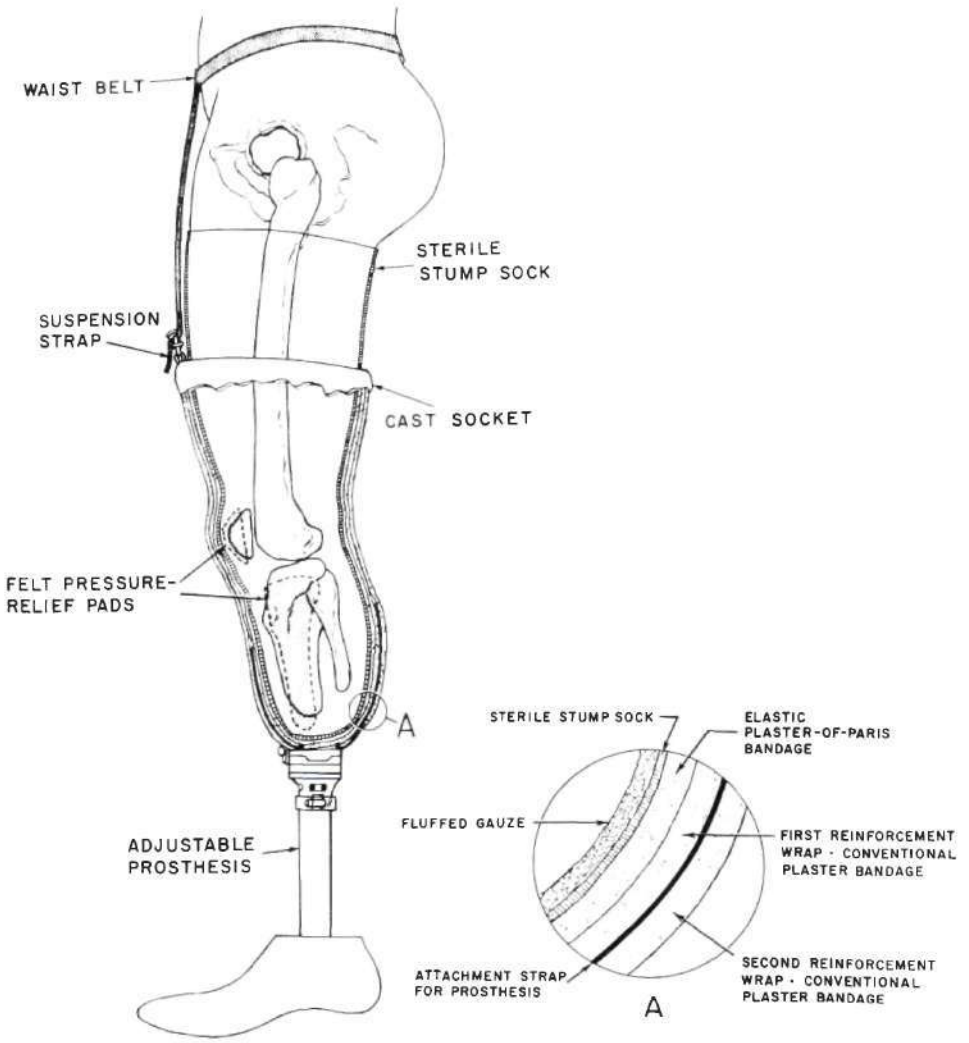


Fig. 18. Schematic cross section showing most of the elements of the application of a prosthesis to a below-knee amputee immediately after surgery. The suture line, silk dressing, and drain are not shown for the sake of clarity. View "A" is an enlarged schematic section of the cast socket, prosthetic unit attachment straps, stump sock, and fluffed gauze at the distal portion of the stump. The fluffed gauze does not extend beyond the area indicated.

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.

It has been generally agreed through the years that the earlier a patient could be fitted the easier would be the rehabilitation process. However, until a few years ago, virtually no patients were provided with a prosthesis before six weeks after amputation, and such cases were rare, the average time probably being closer to four months.

With the advent of improved cast-taking methods, and temporary legs in which alignment can be easily adjusted, Duke University, about 1960, began an experiment to determine the earliest practical time after surgery for providing amputees with limbs. By 1963 it had been shown clearly that it was not only practical but desirable to fit a temporary, but well-fitted, limb as soon as the sutures were removed some two to three weeks after surgery. In 1963 Dr. Marian Weiss of Poland, in an address in Copenhagen, reported success with fitting amputees immediately after surgery while the patient was still anesthetized, and beginning ambulation training the day after (*19*). Dr. Weiss's work stimulated similar work in this country, notably at the University of California, San Francisco; the Oakland Naval Hospital; Prosthetics Research Study, Seattle, Washington; Duke University; the University of Miami; Marquette University; and New York University. Results with over 400 patients of all types have shown immediate postsurgical fitting of prostheses to be the method of choice when possible. Healing seems to be accelerated, postsurgical pain is greatly alleviated, contractures are prevented from developing, phantom pain seems to be virtually nonexistent, less psychological problems seem to ensue, and patients are returned to work or home at a much earlier date than seemed possible only a few years ago.

The procedure consists essentially of providing a rigid plaster dressing over the stump which serves as a socket, and the use of an adjustable leg which can be removed and reinstalled easily (Fig. 18) (*6*). The cast-socket is left in place for 10 to 12 days during which ambulation is encouraged. At the end of this time the cast-socket is removed, the stitches are usually taken out, and a new cast-socket is provided immediately. The original prosthetic unit is replaced and realigned. The second cast-socket is left in place for eight to ten days at which time a new cast can be taken for the permanent, or definitive, prosthesis.

Special courses in immediate postsurgical fitting and early fitting are being offered to qualified prosthetics clinic teams by Northwestern University, the University of California at Los Angeles, and New York University.

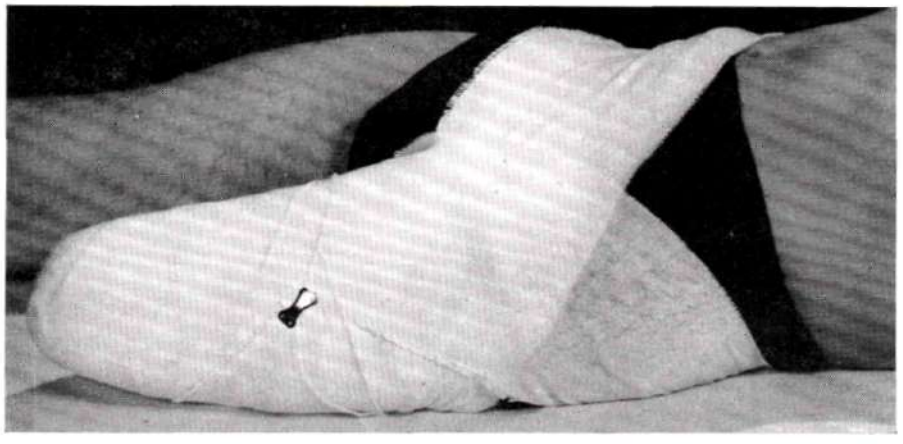


Fig. 19. Compression wrap for above-knee amputation. The wrap of elastic bandage aids in shrinking the stump.

CONTRACTURES

When immediate postsurgical fitting is employed there is little opportunity for contractures to develop. When these procedures are not used, it is most important to avoid the development of muscle contractures. They 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. 19) 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. Wheelchairs 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. 20).

THE PHANTOM SENSATION

After amputation the patient almost always has the sensation that the missing part is still present. 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 (*8*).

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. Plastic laminates so popular in small-boat construction form the basis for construction of most artificial limbs. Some artificial legs are made of wood, and occasionally leather is used for sockets, but the trend is toward the plastic laminates. They 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

Fig. 20. Actions to be avoided by lower-extremity amputees during the immediate postoperative period.

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).

A number of devices have been introduced in recent years to aid the prosthetist in obtaining accurate casts rapidly (*11*). Most use an apparatus that permits the patient to absorb some of the weight-bearing load through the affected side while the cast is being formed (Fig. 22).

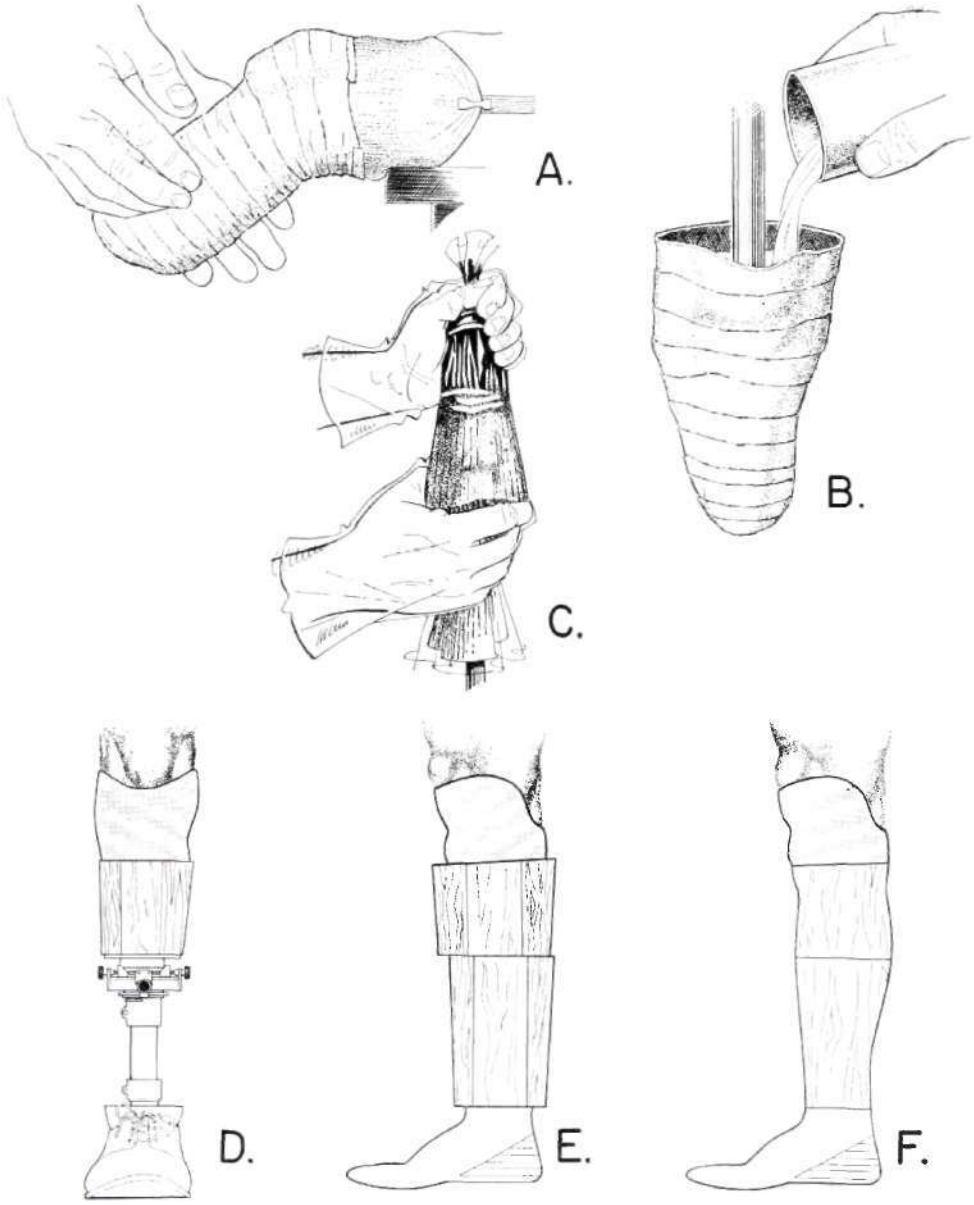


Fig. 21. Steps in the fabrication of a plastic prosthesis for a below-knee amputation. *A*, Taking the plaster cast of the stump; *B*, pouring plaster in the cast to obtain model of the stump; *C*, introducing plastic resin into fabric pulled over the model to form the plastic-laminate socket; *D*, the 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.

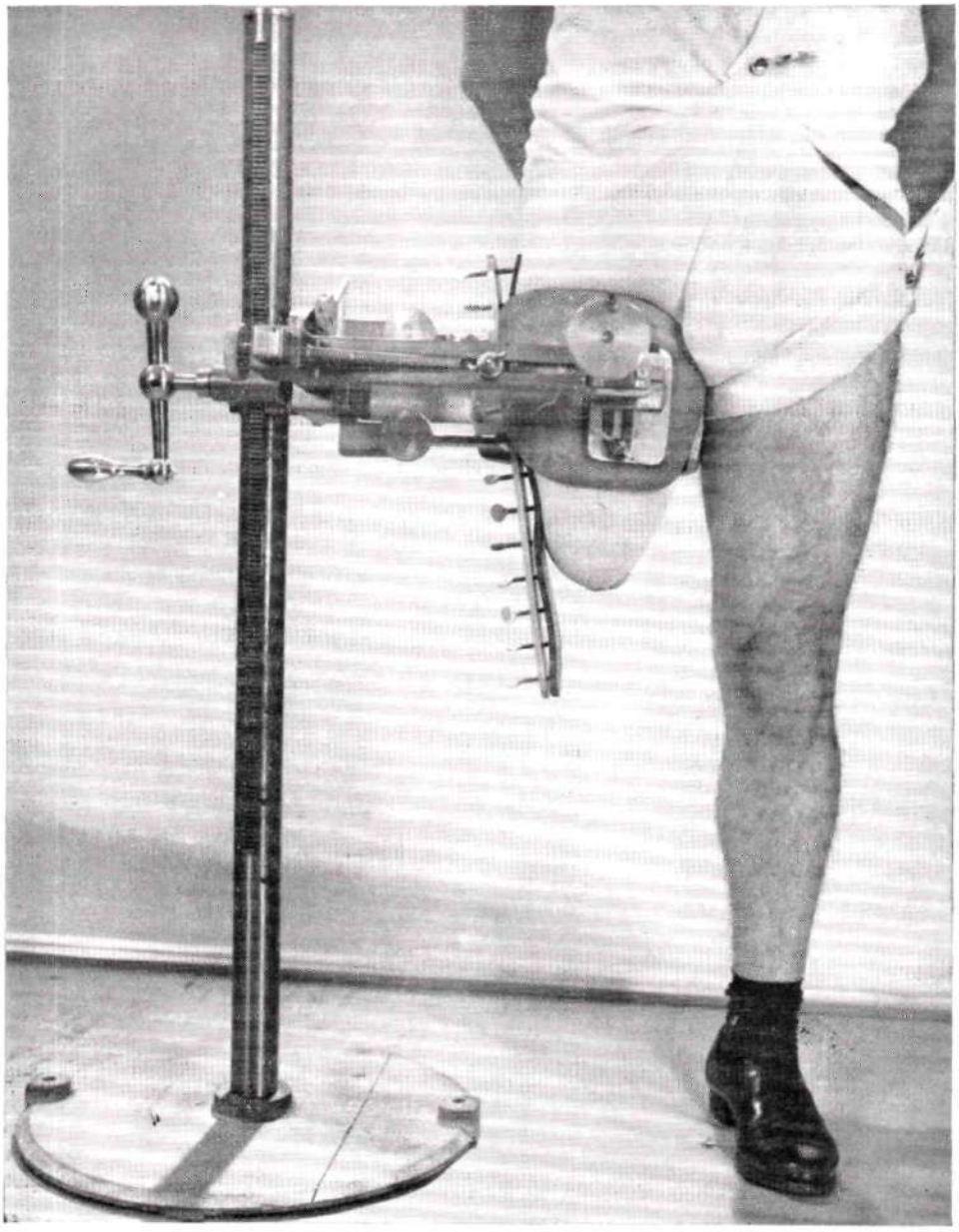
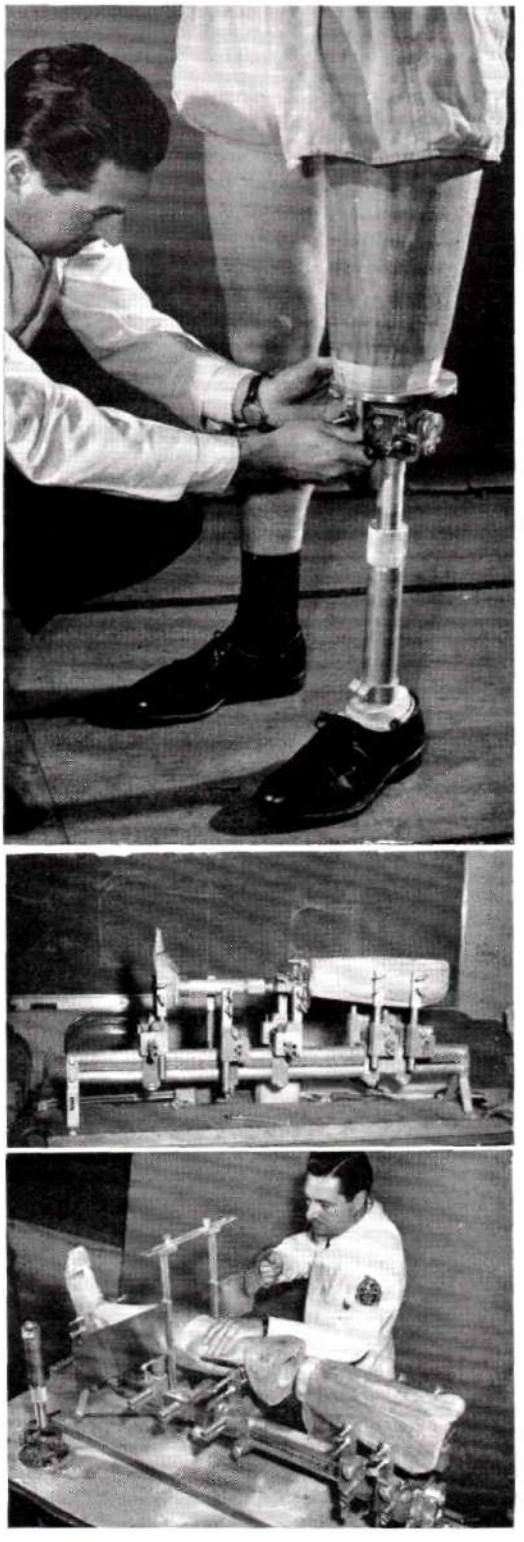


Fig. 22. Special jig developed by the Veterans Administraton Prosthetics Center to facilitate casting above-knee stumps.

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. 23). 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.

An even more refined procedure uses the "Staros-Gardner" coupling (Fig. 24) (*15*). Not only is the need for the alignment jig eliminated but in the case of above-knee fittings the alignment adjustments can be made with the knee unit that is to be used permanently, an important factor when sophisticated knee units are used because the present adjustable leg is available with only a single-axis, constant-friction joint.

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 of the stump and the floor made it extremely difficult to provide for ankle motion needed.

Fig. 23. 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.

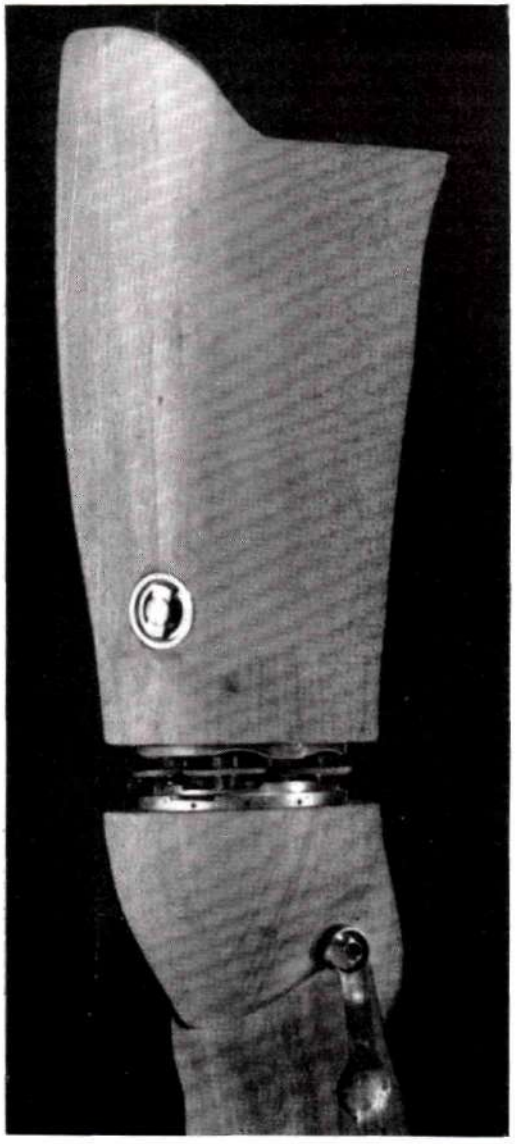


Fig. 24. Adjustable coupling used for alignment of artificial legs. This unit was designed by the Veterans Administration Prosthetics Center and is suitable for below-knee as well as above-knee legs.

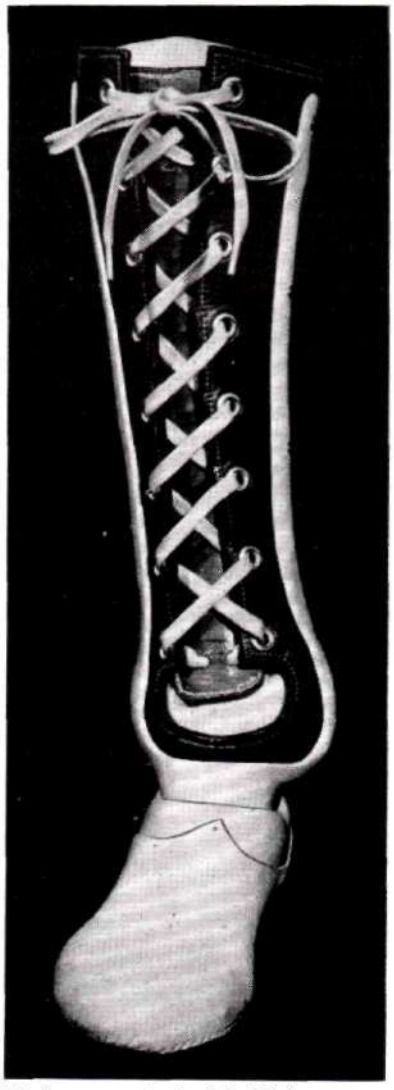


Fig. 25. Syme prosthesis with side bars mounted on medial and lateral aspects of the shank. This type of construction has been virtually replaced by plastic laminates.

Most Syme prostheses were of leather reinforced with steel side bars resulting in an ungainly appearance (Fig. 25). 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. 26) (*2*).

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

Fig. 26. The Syme prosthesis adopted by the Canadian Department of Veterans Affairs. The posterior opening extends the length of the shank.

American version (Fig. 27), a window-type 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. 28). 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 as the patellar-tendon-bearing (PTB) below-knee prosthesis (Fig. 29). In the PTB prosthesis no lacer and side hinges are used,

Fig. 27. Two views of the Canadian-type Syme prosthesis as modified by the Veterans Administration Prosthetics Center.

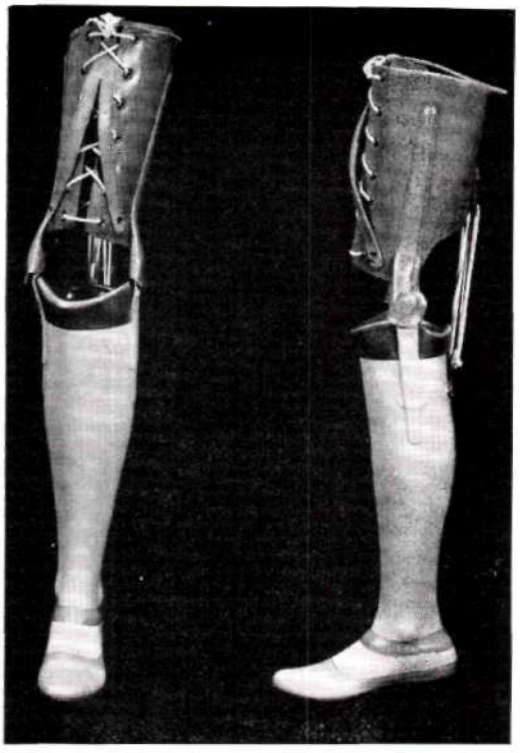


Fig. 28. Below-knee prosthesis with wood socket-shank, thigh corset, and steel side bars. *Courtesy Veterans Administration Prosthetics Center.*

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 (*3, 10*). 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.

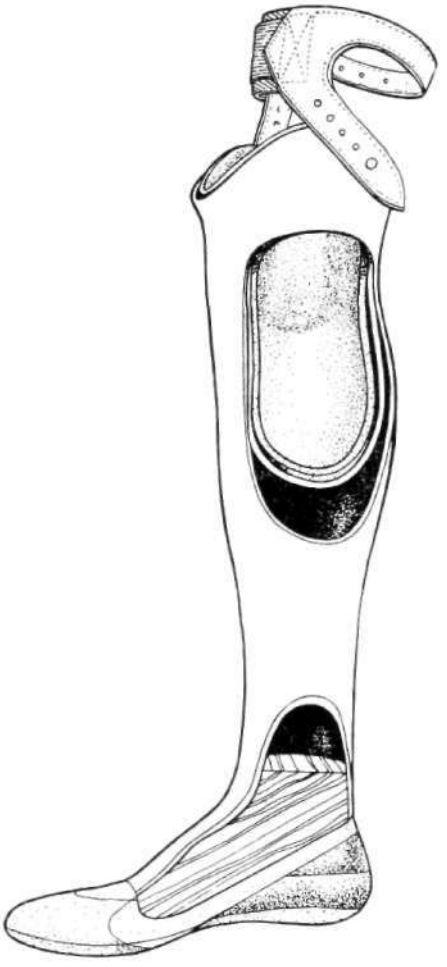


Fig. 29. Cutaway view of the patellar-tendon-bearing leg for below-knee amputees.

After the socket has been made, it is installed on a special adjustable leg (Fig. 30) so that the prosthetist can try various alignment combinations with ease. When both prosthetist and patient are satisfied, the leg is completed utilizing 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.

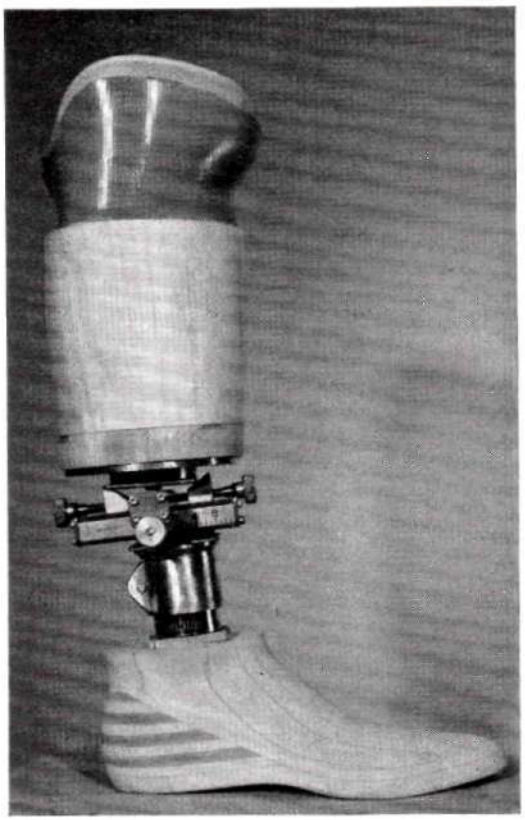


Fig. 30. Trial below-knee adjustable leg.

Stumps as short as two and one-half inches 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.

Several simplified adjustable shanks have been made available recently expressly for use in the immediate postsurgical fitting technique (Fig. 31). Straps are provided for lamination into the plaster cast-socket. Provisions are incorporated for adjustability in all planes. The shank and foot can be connected to and disconnected from the socket easily and quickly. Although these units were designed for temporary use, they are sturdy enough for use on a permanent basis. A natural appearance can be obtained by using plastic cosmetic covers.

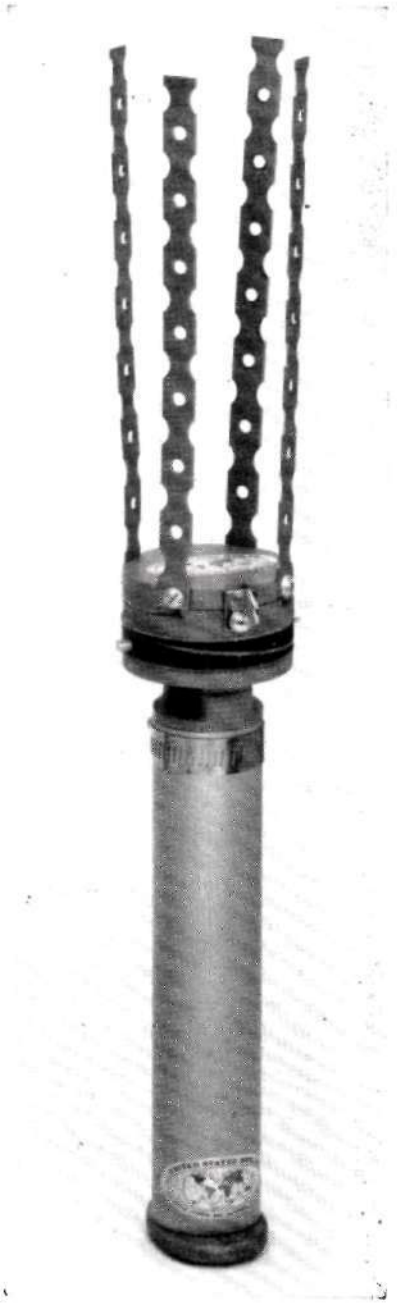


Fig. 31. Prosthetic unit designed especially for fitting below-knee cases immediately after surgery. The stainless steel straps are laminated into the plaster socket. All parts below the top plate are easily removed without affecting alignment. A SACH foot is normally used with this device. Although designed for temporary use, this device can form part of a "permanent" prosthesis.

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. 32). The length of the knee-disarticulation and supracondylar stump makes it difficult 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. Some prosthetists have installed commercially available piston-type hydraulic swing-phase control units, but this requires extreme care to achieve the proper result.

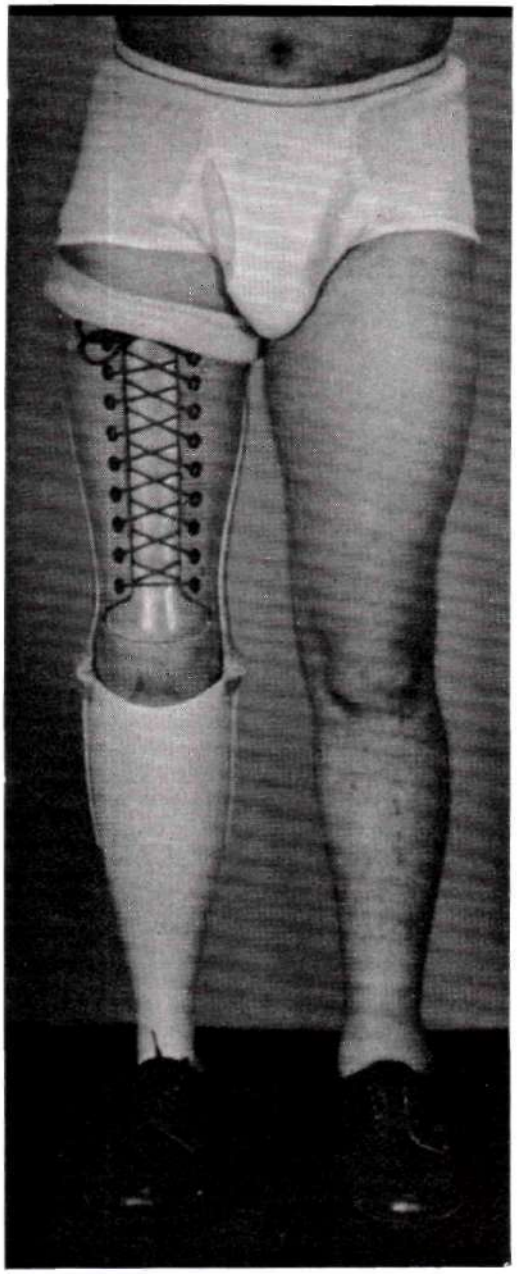


Fig. 32. Typical knee-disarticulation prosthesis.

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.

In recent years a number of hydraulic units have been made available for control of the shank during the swing phase. Among them are the DuPaCo, the Henschke-Mauch Model "B" (Fig. 33), and the Hydra-Knee. These units are all of the piston-cylinder-type, provide for swing-phase control only, and are designed so that they can be incorporated into the more conventional leg structures. The Hydra-Cadence leg (Fig. 34), a complete knee-shin-foot unit, in addition to providing swing-phase control hydraulically, uses the hydraulic system to control ankle action in concert with

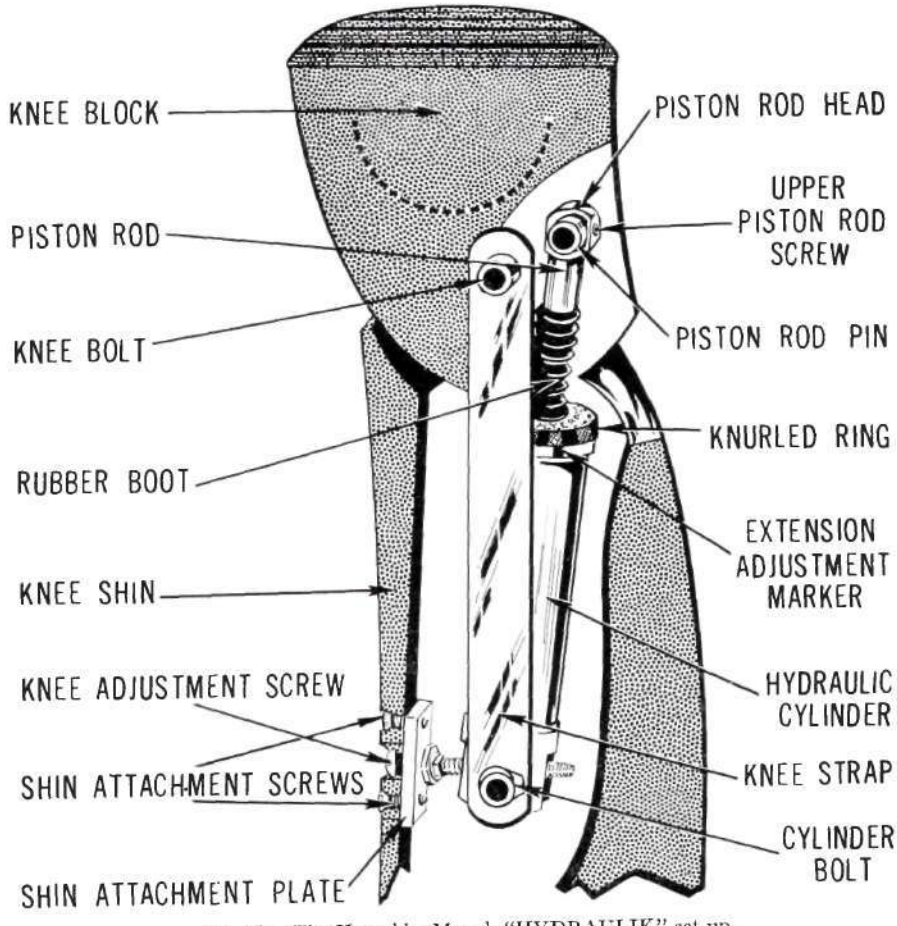


Fig. 33. The Henschke-Mauch "HYDRAULIK" set-up.

knee motion. After the knee is flexed 20 deg., the toe of the foot is lifted as the knee is flexed further, thereby giving more clearance between the foot and the floor as the leg swings through.

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.

When an automatic brake is indicated, the Bock, the "Vari-Gait" 100, and the Mortensen knee units (Fig. 35) 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.

A promising stance-phase control unit currently being evaluated is the Henschke-Mauch Model "A" hydraulic unit. The Model "A" unit contains the same swing-phase control device as the Model "B" and provides a braking action about the knee when there is a tendency to buckle. The braking action is brought about by the attitude of a pendulum which in turn is controlled by the inertia forces in the shank. The Model "A" and Model "B" units are interchangeable.

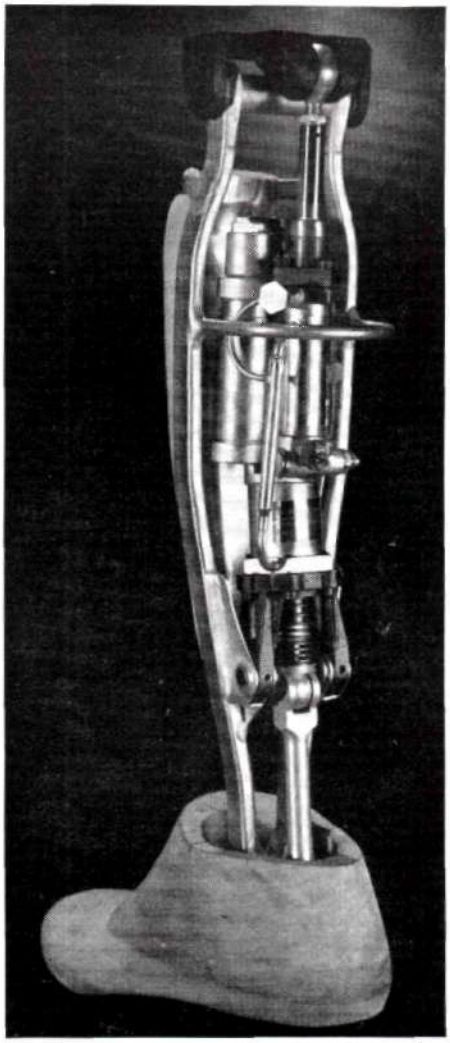


Fig. 34. The Hydra-Cadence Leg without cosmetic cover.

A number of methods for suspending the above-knee leg are available. For younger, healthy patients, the suction socket (Fig. 36*A*) has generally been 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 air 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. 36*B*), a light belt attached to the socket in such a way that there is very little restriction of 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. 36*C*). 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. 36) evolved, and now is virtually the standard for above-knee sockets regardless of 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

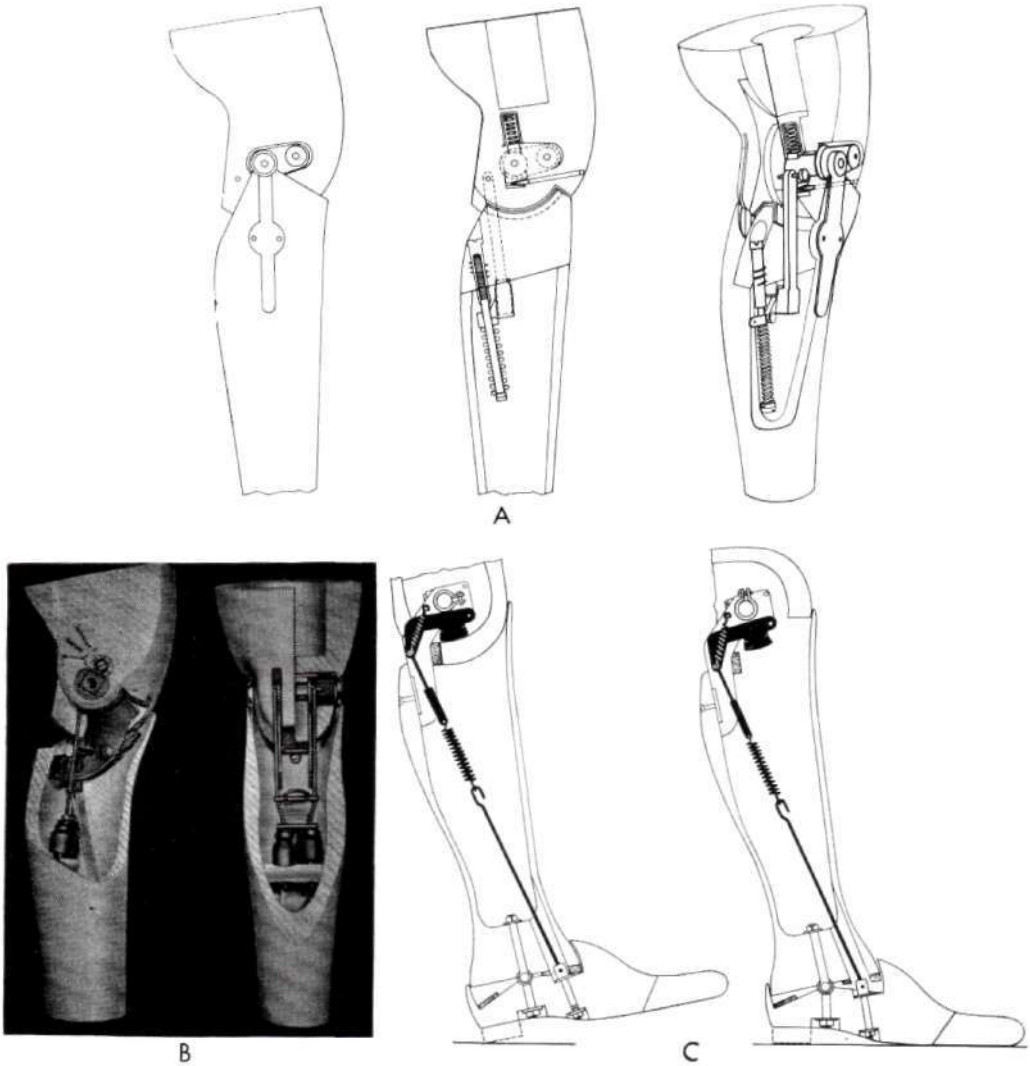


Fig. 35. Some examples of weight-actuated knee units. *A*, Bock "Safety-knee"; *B*, Vari-Gait knee; *C*, Mortensen leg.

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 (*9*) (Fig. 36*A*). As the name implies, the socket is in contact with the entire surface of the stump. In taking some pressure over the end of the stump, the pressure on the ischium area is reduced, thereby providing more comfort to the patient. It also appears that the pressure over the end of the stump helps circulation and improves proprioception. Today the total-contact socket is the method of choice for use by above-knee amputees.

In fitting the wooden above-knee prosthesis, the prosthetist carves the interior of the socket

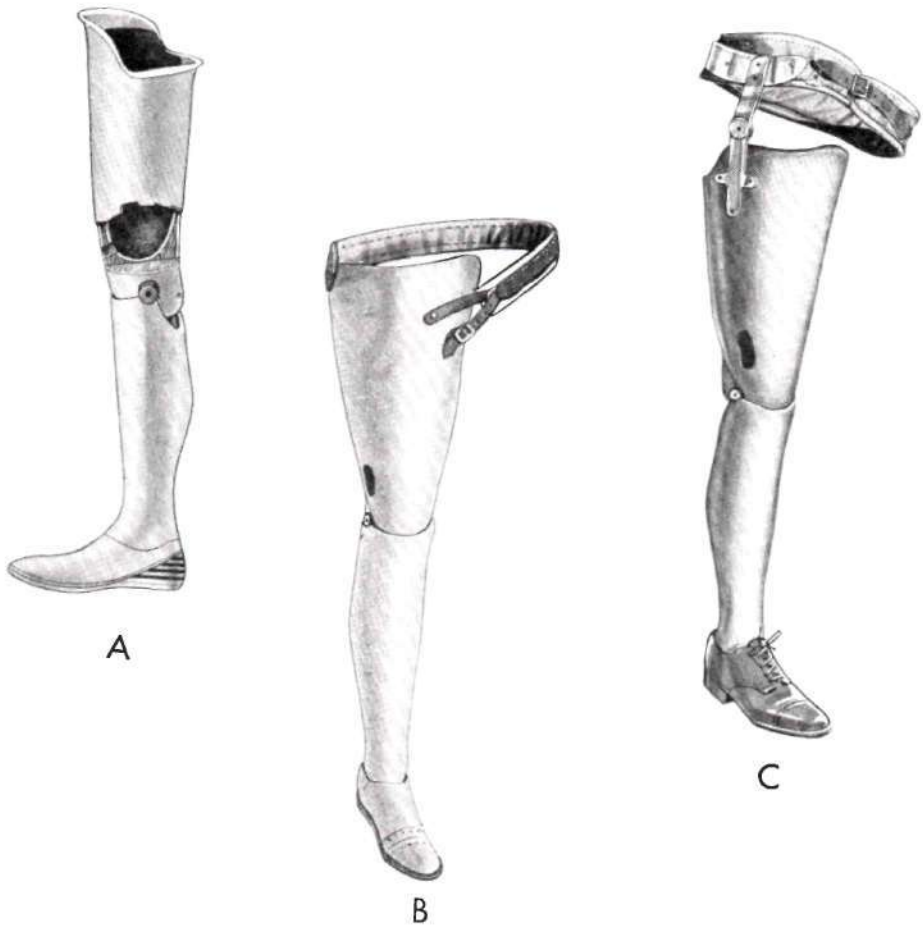


Fig. 36. Above-knee sockets and methods of suspension. *A*, Total-contact suction socket; *B*, above-knee leg with Silesian bandage for suspension; *C*, above-knee leg with pelvic belt for suspension. Most above-knee sockets have a quadrilateral-shaped upper portion as shown.

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. 22), and thus obtains a model of the stump over which the plastic socket can be formed.

Special adjustable pylon-type legs (Figs. 37 and 38) are available for fitting immediately after surgery, or use as a temporary leg. Provisions are made for all necessary adjustments, and a manually operated knee lock is provided for use by infirm patients.

Prostheses For Hip-Disarticulation And Hemipelvectomy Cases

A prosthesis (Fig. 39) 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

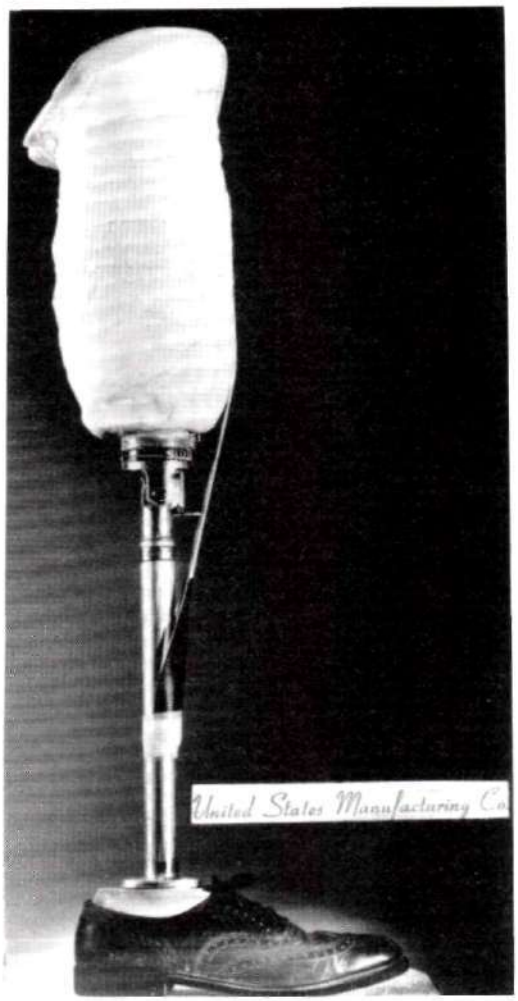


Fig. 37. Prosthetic unit designed especially for fitting above-knee cases immediately after surgery. The same principles used in the below-knee device (Fig. 31) are incorporated. In addition, mechanical friction about the "knee" axis and a mechanical "knee" lock are provided.

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

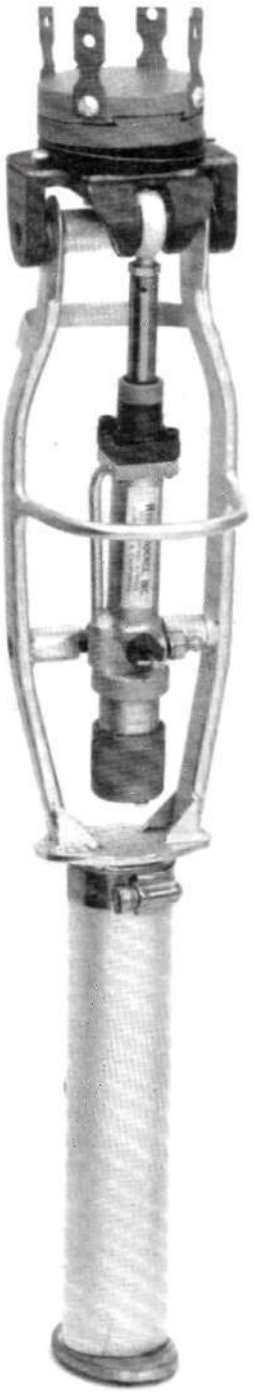


Fig. 38. Prosthetic unit designed especially for fitting above-knee cases immediately after surgery. This is essentially the same unit shown in Figure 37 except that hydraulic resistance instead of mechanical friction is provided about the knee joint.

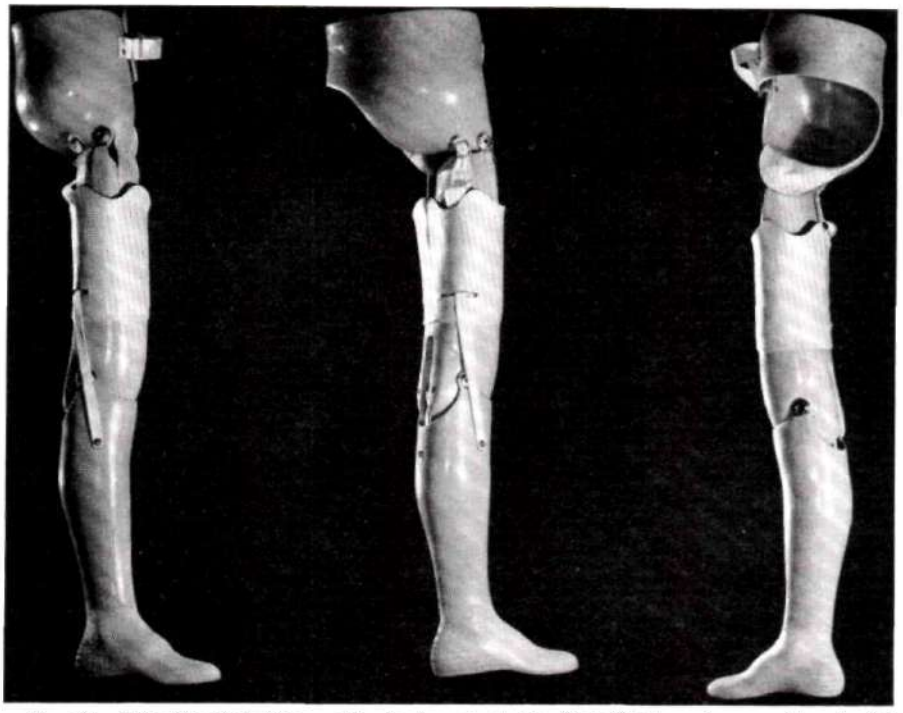


Fig. 39. Hip-disarticulation prosthesis, known as the Canadian-type because its principle was originally conceived by workers at the Department of Veterans Affairs of Canada.

design is altered to allow for the loss of part of the pelvis.

UPPER-EXTREMITY PROSTHESES (*16*)

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.

In recent years artificial arms powered by electricity have received considerable publicity. An artificial hand powered by electricity and controlled by electrical signals from muscles has been developed in Russia for below-elbow amputees. Versions of the Russian design are available in England and Canada. Similar devices have also been developed in Austria and Italy. However, the below-elbow patient, of all the types of upper-extremity amputees, is the least handicapped and therefore less in need of sophisticated devices. The devices are expensive and in their present state of development seem to offer no real advantage over the simpler conventional devices. The real need is for patients with amputations above the elbow and higher. Efforts to develop useful externally powered arms, both electrical and pneumatic, are being made in both the United States and abroad, especially in reference to severely handicapped children (13).

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 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 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 40 and 41.

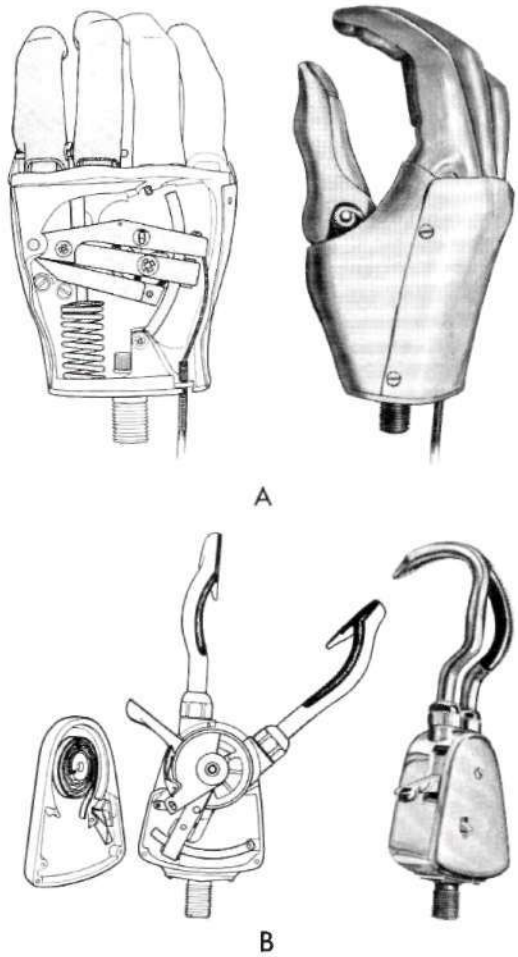


Fig. 40. Voluntary-closing terminal devices. *A*, APRL-Sierra Hand; left, cutaway view showing mechanism; right, assembled hand without cosmetic glove; *B*, APRL-Sierra Hook.

Prostheses For The Wrist-Disarticulation Case

One of the problems in fitting the wrist disarticulation in the past has been to keep the overall 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. 42).

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 fore-

Fig. 41. Voluntary-opening terminal devices. The wide range of models offered by the D. W. Dorrance Company includes sizes and designs for all ages.

arm, is usually fitted snugly to the entire stump, 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.

A wrist-flexion unit, which permits the terminal device to be tilted in toward the body

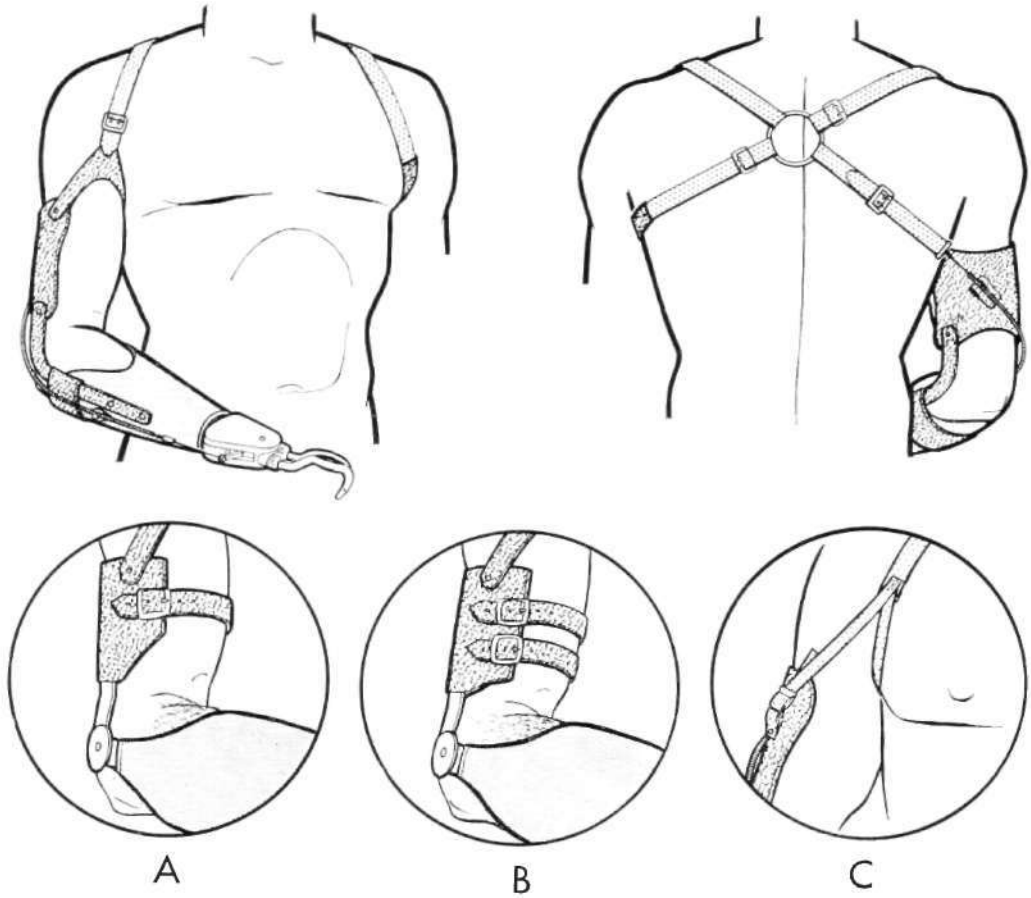


Fig. 42. Typical methods of fitting below-elbow amputees with medium to long stumps. Above, the figure-8, ring-type harness is most generally used. Where possible flexible leather hinges and open biceps cuff or pad are used. When more stability between socket and stump is required, rigid (metal) hinges 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.

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 Münster, 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. 43).

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. 44) 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 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 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-

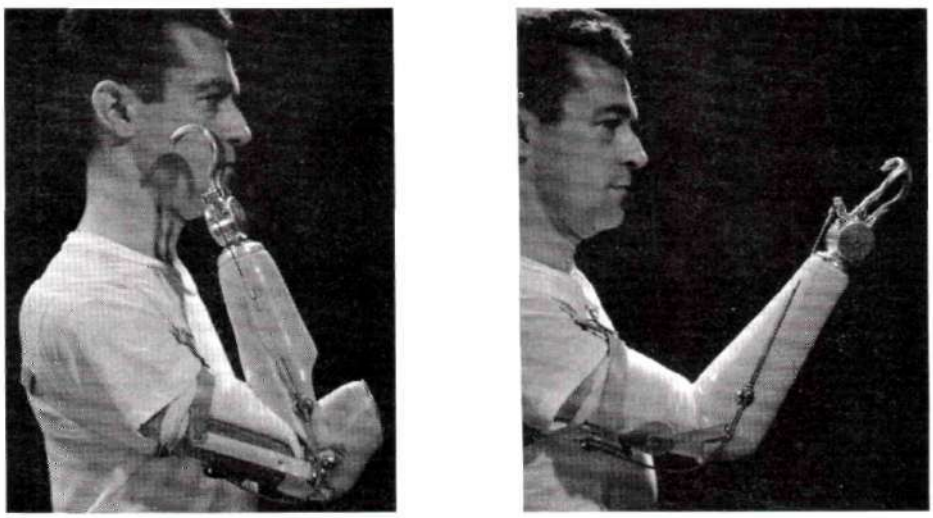


Fig. 43. Comparison of split socket and Münster-type fitting of short below-elbow case. *A*, Split socket and step-up hinge provides 140 deg. of forearm flexion; *B*, Münster-type fitting permits less forearm flexion but enables the amputee to carry considerably greater weight with flexed prosthesis unsupported by harness. *Courtesy New York University College of Engineering Prosthetic and Orthotic Research.*

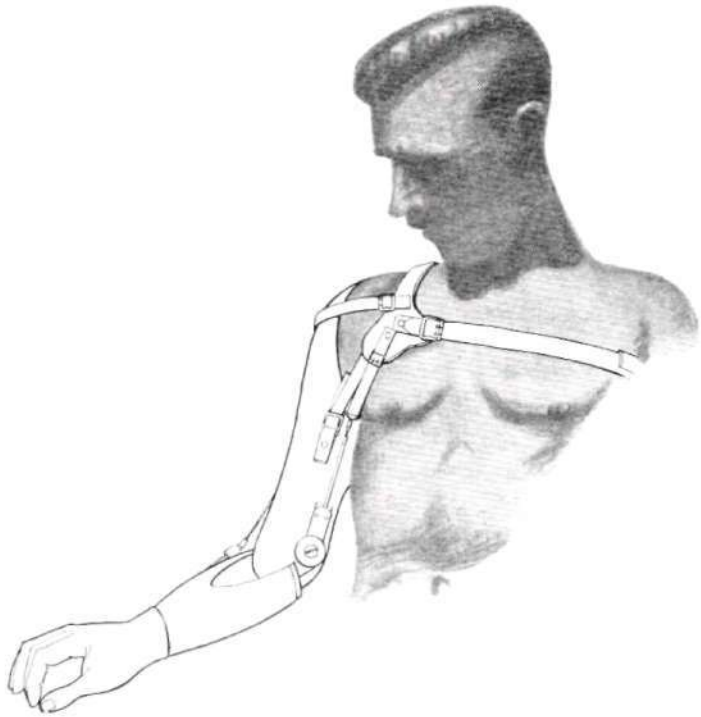


Fig. 44. Typical prosthesis for the elbow-disarticulation case. The chest-strap harness with shoulder saddle is shown here, but the above-elbow figure-eight is also used. See Figure 45.

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. 45).

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 to make available prostheses which provide a limited amount of function (Fig. 46). 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

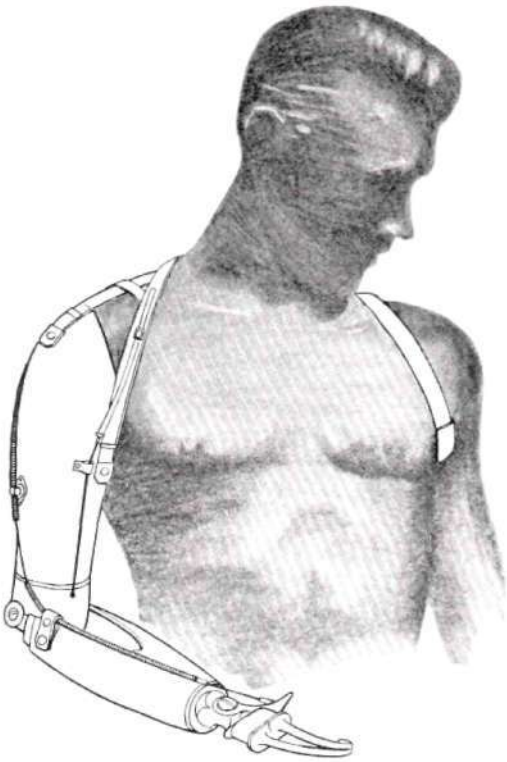


Fig. 45. Typical prosthesis for the above-elbow case. The figure-8 harness is shown here but the chest-strap harness with shoulder saddle may also be used. See Figure 44.

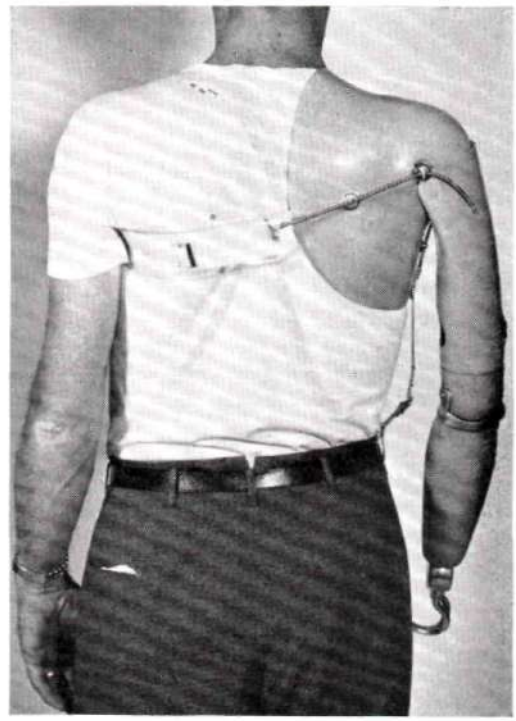


Fig. 46. Typical prosthesis for the shoulder-disarticulation case.

the general practice to combine the two (Fig. 47). 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. 48).

Learning to Use the Prosthesis

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

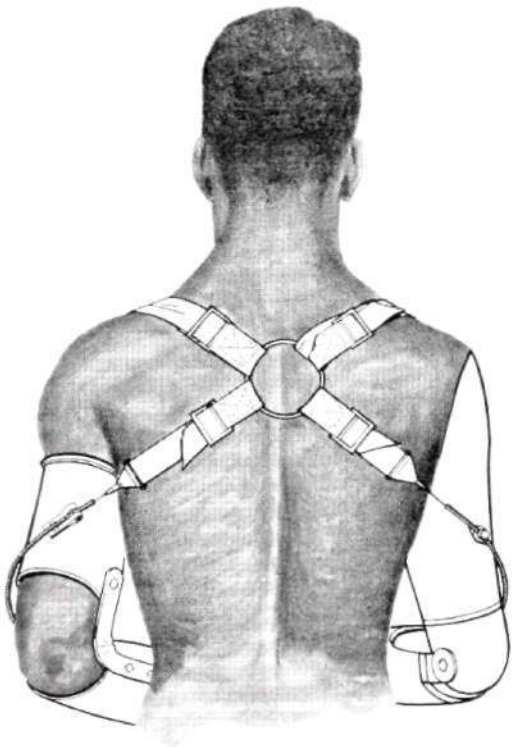


Fig. 47. Harness for the bilateral below-elbow/above-elbow case.

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 (*18*) is to enable him to walk as gracefully as possible. Training is begun as soon as the amputee is provided with a comfortable prosthesis. In the case of immediate post-surgical fitting (*6*), training is begun usually on the day following surgery and an adjustable leg is used. There is a growing tendency to train lower-extremity amputees on legs with adjustable features even though they have not been fitted immediately after surgery. Some other goals of training are to teach the patient proper methods of donning the prosthesis, caring for the stump, arising after a fall, and use of canes and crutches when necessary. The type of training will, of course, depend upon the level of amputation.

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. 49). 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 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. 50). 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.

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

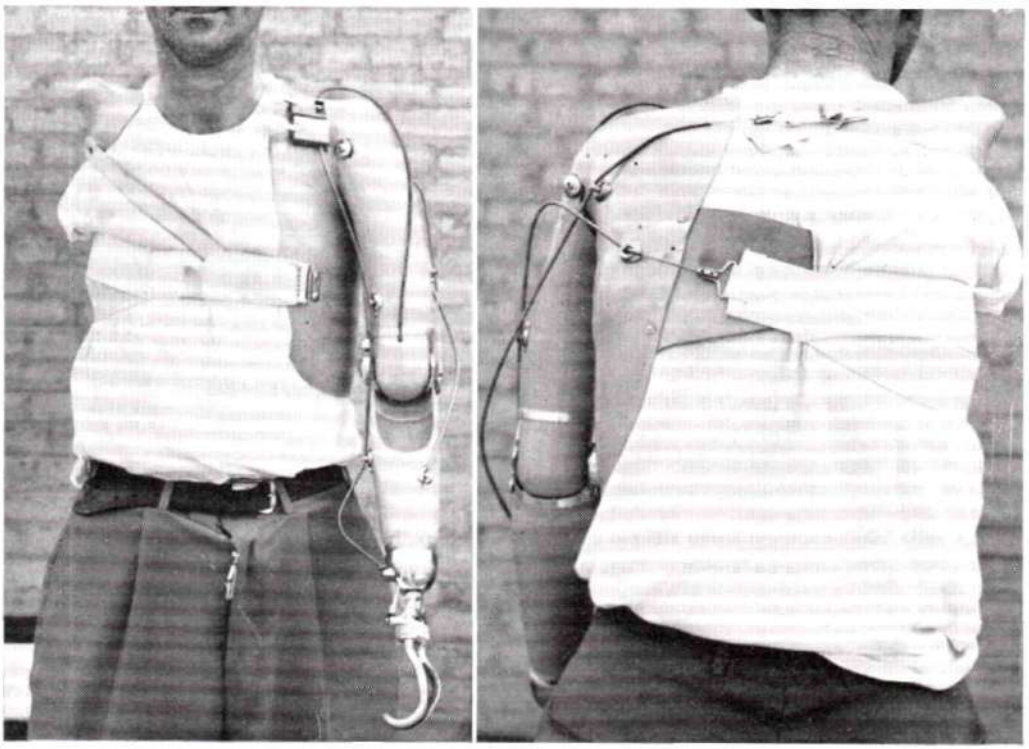


Fig. 48. Special harness arrangement for the bilateral shoulder-disarticulation case.

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.

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. 51).

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

Fig. 49. Above-knee patient being trained to walk by a physical therapist.

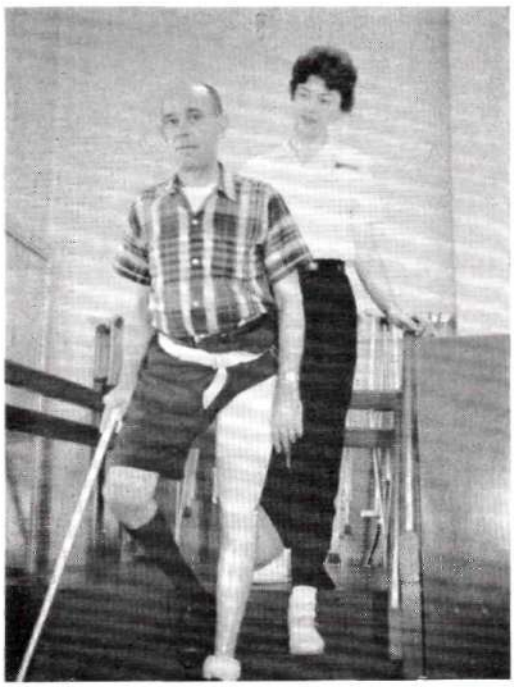


Fig. 50. Above-knee patient being taught correct use of cane.

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 bacterio-

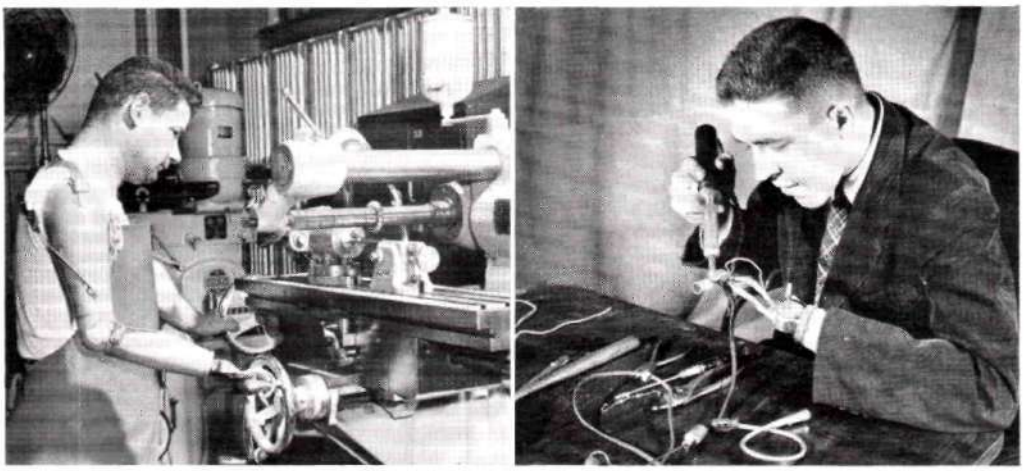


Fig. 51. Upper-extremity amputees performing vocational tasks.

static 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 52, 53, and 54, respectively. These illustrations first appeared in a booklet entitled "Industrial Amputee Rehabilitation," prepared by Dr. C. O. 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 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

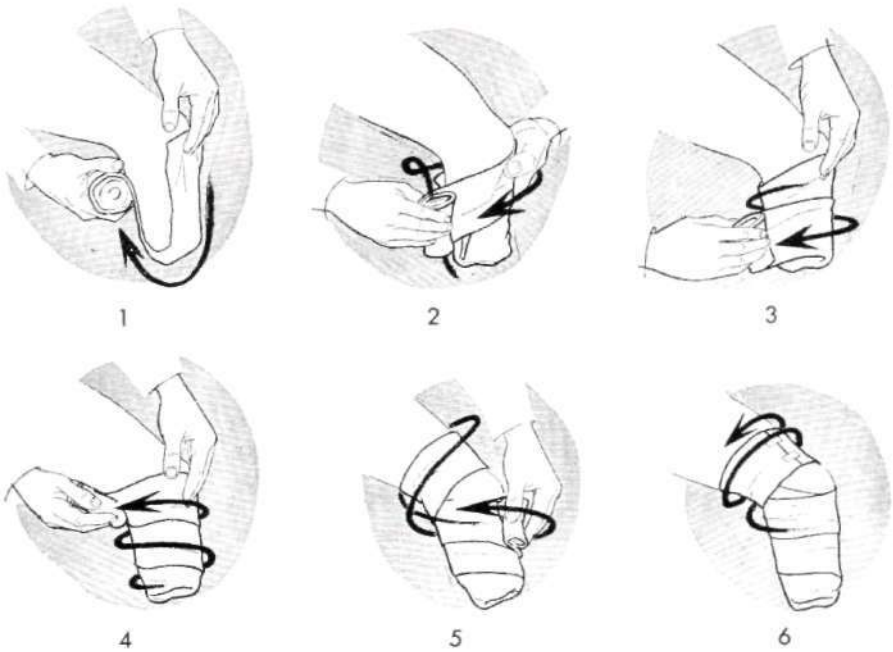


Fig. 52. Recommended method of applying elastic bandage to the below-knee stump. The bandage is wrapped tighter at the end of the stump than it is above.

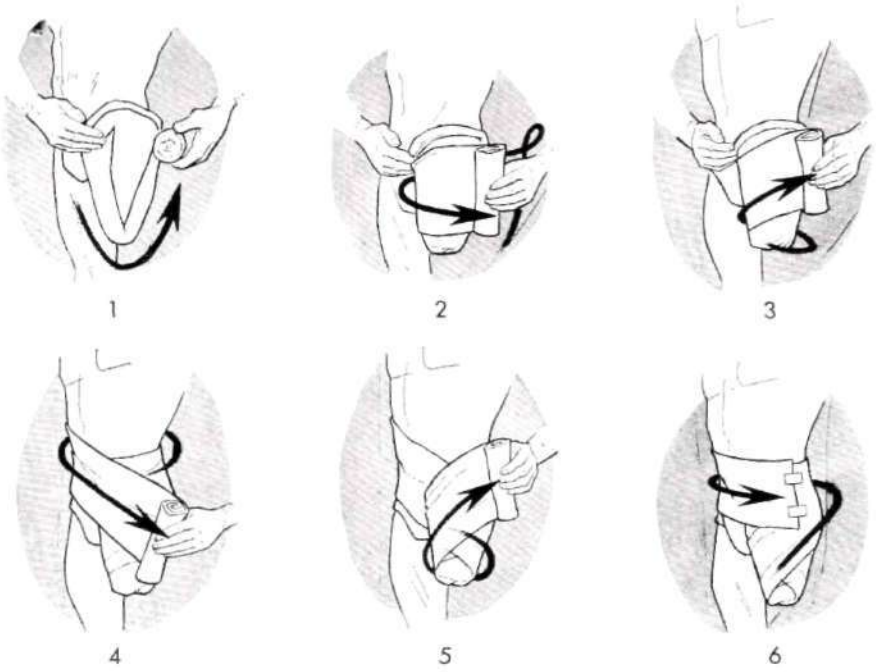


Fig. 53. Recommended method of applying elastic bandage to the above-knee stump. The stump is kept in a relaxed position, and the bandage is wrapped tighter at the end of the stump than it is above.

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

Special Considerations in Treatment of Child Amputees (5)

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. 55).

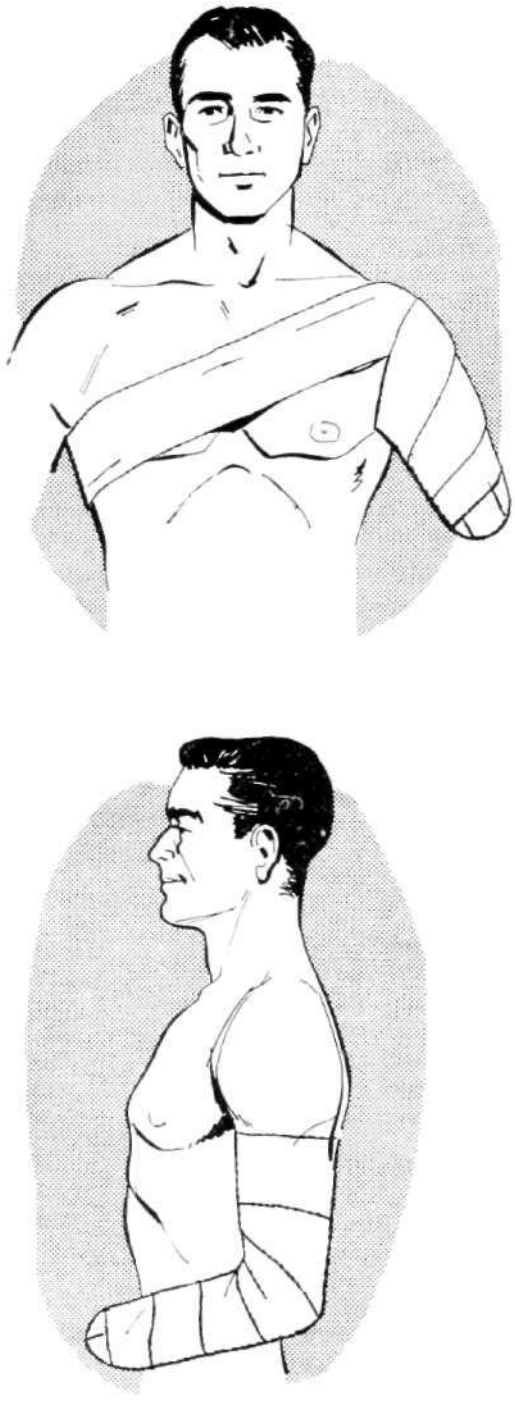


Fig. 54. Elastic bandages applied properly to upper-extremity stumps.

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 residents of states where such specialized services are not to be had. There is an agency in each state 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.

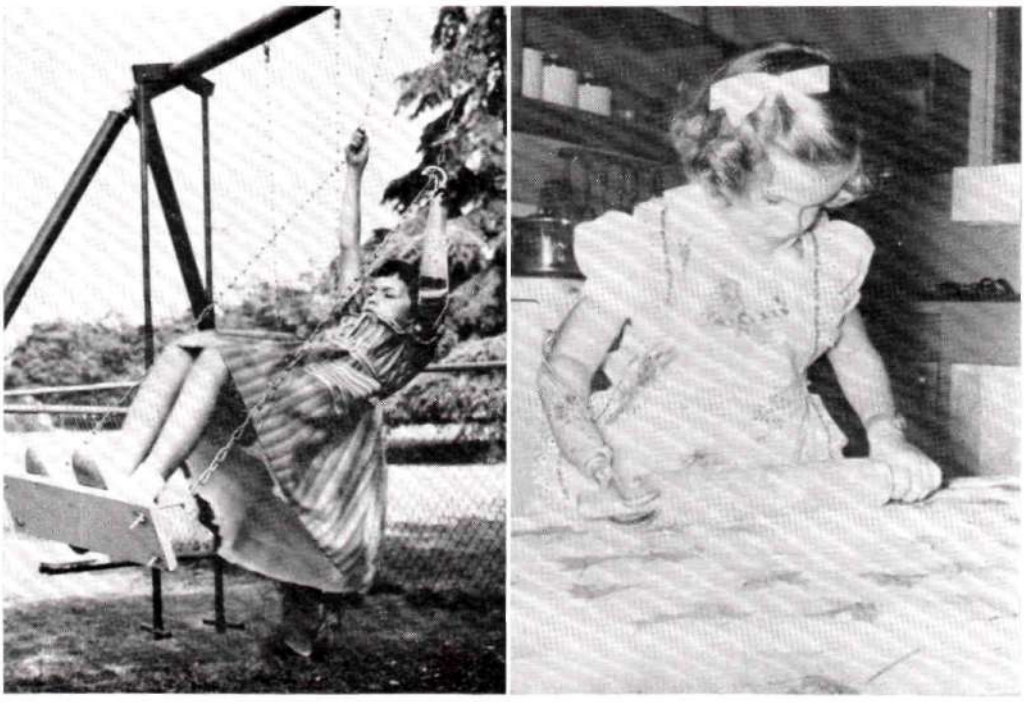


Fig. 55. Children with upper-extremity amputations performing two-handed activities.

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 37–39 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.

The patient should be fitted as soon as possible, to avoid such complications as the development of contractures. The availability of adjustable pylon-type legs and the use of plaster or plastic sockets now makes early fitting practical, and this approach is being adopted by more and more centers. Many geriatric patients have benefited from the immediate postsurgical fitting procedures.

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 (*4*)

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 military 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. Some of these programs 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, 828 Davis Street, Evanston, Ill. 60201.

LITERATURE CITED

1. Artificial Limbs, Autumn 1957.
2. Artificial Limbs, April 1961.
3. Artificial Limbs, June 1962.
4. Bechtol, Charles O., and George T. Aitken, *Cineplasty*, Chap. 12 in *Orthopaedic appliances atlas*, Vol. 2, J. W. Edwards, Ann Arbor, Mich., 1960.
5. Blakeslee, Berton, *The limb-deficient child*, University of California Press, 1963.
6. Burgess, Ernest M., Joseph E. Traub, and A. Bennett Wilson, Jr., *Immediate postsurgical prosthetics in the management of lower-extremity amputees*, Prosthetic and Sensory Aids Service, Veterans Administration, 1967.
7. Committee on Artificial Limbs, National Research Council, Washington, D.C., *Terminal research reports on artificial limbs*, covering the period from 1 April 1945 through 30 June 1947.
8. Feinstein, Bertram, James C. Luce, and John N. K. Langton, *The influence of phantom limbs*, Chap. 4 in Klopsteg and Wilson's *Human limbs and their substitutes*, McGraw-Hill, New York, 1954.
9. Foort, J., *Adjustable-brim fitting of the total-contact above-knee socket*, Biomechanics Laboratory, University of California (Berkeley and San Francisco), No. 50, March 1963.
10. Foort, James, *The patellar-tendon-bearing prosthesis for below-knee amputees, a review of technique and criteria*, Artificial Limbs, Spring 1965.
11. Hampton, Fred, *Suspension casting for below-knee, above-knee, and Syme's amputations*, Artificial Limbs, Autumn 1966.
12. Klopsteg, P. E., *The functions and activities of the Committee on Artificial Limbs of the National Research Council*, J. Bone & Joint Surg., *29:* 538–540, 1947.
13. National Academy of Sciences–National Research Council, *The control of external power in upper-extremity rehabilitation*, Publication 1352, 1966.
14. Sarmiento, Augusto, R. E. Gilmer, and A. Finnieston, *A new surgical-prosthetic approach to Syme's amputation, a preliminary report*, Artificial Limbs, Spring 1966.
15. Staros, Anthony, *Dynamic alignment of artificial limbs with the adjustable coupling*, Artificial Limbs, Spring 1963.
16. Taylor, Craig L., *Control design and prosthetic adaptations to biceps and pectoral cineplasty*, Chap. 12 in *Human limbs and their substitutes*, McGraw-Hill, New York, 1954.
17. Thomas, Atha, and Chester C. Haddan, *Amputation prosthesis*, Lippincott, Philadelphia, Pa., 1945.
18. Vultee, Frederick E., *Physical treatment and training of amputees*, Chap. 7 in *Orthopaedic appliances atlas*, Vol. 2, J. W. Edwards, Ann Arbor, Mich., 1960.
19. Weiss, Marian, *The prosthesis on the operating table from the neurophysiological point of view*, Report of Workshop Panel on Lower-Extremity Prosthetics Fitting, Committee on Prosthetics Research and Development, National Academy of Sciences, February 1966.

ADDITIONAL BIBLIOGRAPHY

1. American Academy of Orthopaedic Surgeons, *Orthopaedic appliances atlas*, Vol. 2, J. W. Edwards, Ann Arbor, Mich., 1960.
2. Batch, Joseph W., August W. Spittler, and James G. McFaddin, *Advantages of the knee disarticulation over amputations through the thigh*, J. Bone & Joint Surg., Boston, *36A:*921–930, October 1954.
3. Brunnstrom, Signe, *The lower extremity ampulee*, in Bierman and Licht's *Physical medicine in general practice*, Hoeber-Harper, New York, 1952.
4. DeLorme, Thomas, *Progressive resistive exercise*, Appleton and Co., New York, 1951.
5. Eisert, Otto, and O. W. Tester, *Dynamic exercises for lower extremity amputees*, Arch. Phys. Med. & Rehab., *25:*11, November 1954.
6. Kerr, Donald, and Signe Brunnstrom, *Training of the lower-extremity amputee*, Charles C Thomas, ed., Springfield, Ill., 1956.
7. Klopsteg, Paul E., Philip D. Wilson, *et al.*, *Human limbs and their substitutes*, McGraw-Hill, New York, 1954.
8. MacDonald, J., Jr., *History of artificial limbs*, Am. J. Surg., *19:*76–80, 1905.
9. University of California (Los Angeles), Department of Engineering, *Manual of upper extremity prosthetics*, 2nd ed., W. R. Santschi, ed., 1958.
10. University of California (Los Angeles), School of Medicine, Prosthetics Education Program, *Manual of above-knee prosthetics*, Miles H. Anderson and Raymond E. Sollars, eds., January 1, 1967.

New Concepts in the Management of Lower-Extremity Amputees

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FOR MANY years the acceptable practice in management of lower-extremity amputation after wound closure consisted of the application of a reinforced gauze dressing and the confinement of the patient to bed until the wound was healed. Fitting of a prosthesis was seldom attempted until edema was reduced to a more or less stable point by means of elastic bandages which had to be removed and reapplied at regular intervals during the day. Elaborate precautions had to be taken so that muscle contractures would not occur. With this method of treatment it was rare for a patient to be fitted less than six weeks after surgery, most patients requiring a much longer period (*1*).

The reluctance to fit patients before the stump was "stabilized" was, in a large part, due to the need for one or more socket replacements shortly after the initial fitting. A number of physicians advocated the use of temporary prostheses usually consisting of a plaster-of-Paris socket and a peg leg to hasten stabilization of the stump, but this practice never became widespread, probably because no adequate documentation was made of the various series that were reported, and many physicians realized that it was extremely difficult to obtain adequate fit and alignment with the techniques existing then.

The introduction of the patellar-tendon-bearing socket, total-contact sockets, new stump-casting techniques, adjustable legs, and plastic-laminate sockets led the Department of Orthopaedic Surgery, Duke University, to embark on a study to determine the earliest practical time for fitting. The project has demonstrated clearly that successful application of prostheses can be made as soon as it is safe to remove the sutures.

In the late fifties Berlemont of France (*2*, *3*) began providing patients with leg prostheses immediately upon completion of surgery and initiating ambulation training the following day. Berlemont's technique was modified somewhat by Weiss of Poland (*5*), who brought it to the attention of Americans in a lecture given at the Sixth International Prosthetics Course in Copenhagen in July 1963. A tour of the United States by Weiss later that year, sponsored by the Vocational Rehabilitation Administration and the Committee on Prosthetics Research and Development, stimulated sufficient interest at the University of California, San Francisco, and the U.S. Naval Hospital, Oakland, for these groups to experiment with the concepts reported by Weiss.

Initial results led the Veterans Administration to support an experimental program proposed by the Prosthetics Research Study of Seattle, Washington. Other groups, notably Duke University, the University of Miami, Marquette University, and a group in New York City centered around the Hospital for Joint Diseases, became interested and embarked on modest experimental programs.

Because there was not available any written or visual material covering European experience, each group approached the problem along somewhat different lines. From time to time through the efforts of the Committee on Prosthetics Research and Development and the University Council on Orthotic-Prosthetic Education, these groups were brought together for the purpose of exchang-

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ing ideas and coordinating the efforts of all involved. Meanwhile, the Vocational Rehabilitation Administration made it possible for a number of the research teams to visit Weiss. Experience with more than 400 cases has now been accumulated.

At its meeting January 20, 1967, which was preceded by a conference of research teams involved in immediate postsurgical fitting, UCOPE decided to offer courses in the technique to qualified teams.

The basic technique consists of the application of a nonadherent silk mesh dressing and fluffed gauze over the wound and a sterile stump sock and plaster-of-Paris cast (which is also the socket for the prosthesis) over the stump (Fig. 1). To the socket is attached an adjustable pylon-type prosthesis suitable for the level of amputation. Provisions are made for easy removal and reattachment of the prosthetic unit to prevent the prosthesis from being wrapped in the bedclothes and causing undue stresses on the stump. A drain is usually used.

The patient is encouraged to stand *between parallel bars or with the aid of a "walker"* about 24 hours after surgery if there are no physical or medical contraindications. The amount of weight-bearing and ambulation is increased daily and the patient is graduated to crutches, to canes, and to unaided walking as his physical condition permits. The drain is removed 48 hours after surgery, and the cast-socket is kept in place until time for removal of the stitches—some 10 to 14 days after surgery.

A new cast-socket is applied immediately, and the pylon-type prosthesis is replaced. The second cast is removed 8 to 10 days later when it is generally possible to make a cast for fabrication of a plastic socket.

The advantages of treating patients in this manner are a reduction in the formation of edema, a reduction in the incidence of pain, elimination of the formation of contraction, decreased hospitalization time, and less time lost from work. The technique appears to permit improved wound healing, and a number of investigators feel that in cases of amputations because of vascular disorders many more knee joints may be preserved than when conventional methods of treatment are used. In one series of a hundred cases, the average time between surgery and delivery of the "permanent" prosthesis was 28 days. The shortest time was 17 days (*4*).

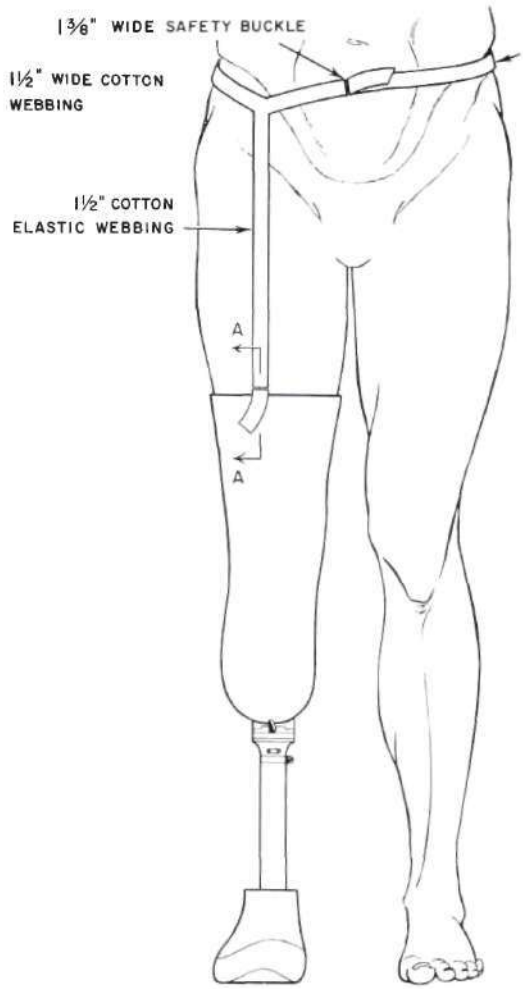

Fig. 1. An example of immediate postsurgical fitting of prosthesis to a below-knee amputee. Note the waist-belt suspension, the cast-socket carried above the knee, the pylon, and the foot. See also Figure 18 in *Limb Prosthetics—1967*, the preceding article in this issue.

Patients of all types and all ages have been treated successfully by fitting prostheses immediately after surgery. However, success depends upon many factors, and the technique should not be undertaken unless the team has a thorough understanding of proven methods. For this reason, courses are being offered at Northwestern University, the University of

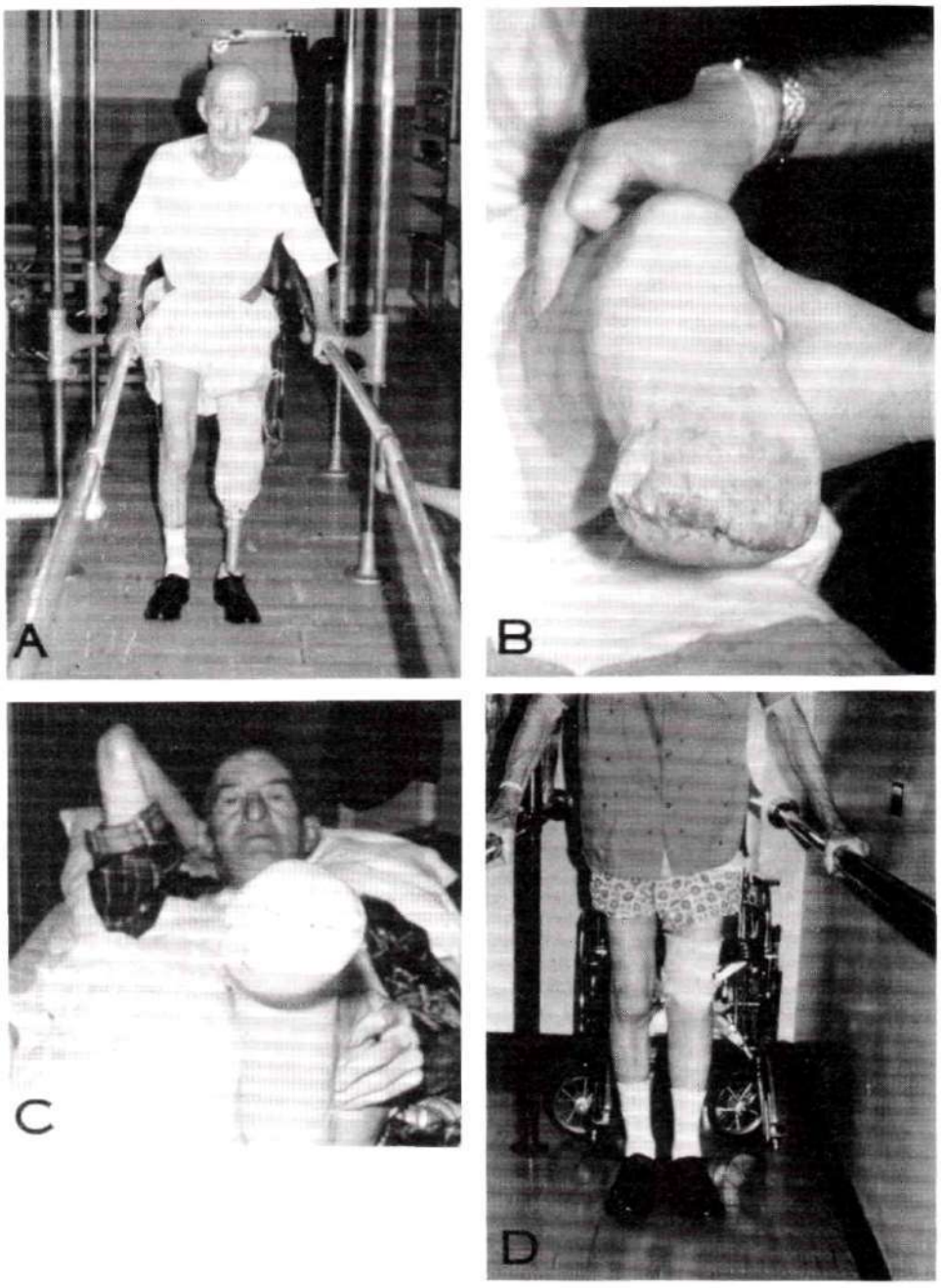

Fig. 2. Progress of 80-year-old patient whose leg was amputated because of vascular disease and diabetes. *A*, First day postoperative; *B*, seventh day postoperative; *C*, seventeenth day postoperative; *D*, twenty-sixth day postoperative.

California, Los Angeles, and New York University.

In spite of the success achieved by the research teams and others that have been trained by them, it is not clear why certain of the advantages accrue, and to what degree the various factors that enter into success are critical. Continued research is expected to answer these questions.

LITERATURE CITED

1. Alldredge, Rufus H., *The principles of amputation surgery*, Chap. 10 in Orthopaedic Appliances Atlas, Vol. 2, J. W. Edwards, Ann Arbor, Mich., 1960.
2. Berlemont, M., *Notre expérience de l'appareillage précoce des ampulés des membres inférieurs aux Établissements Hélio-Marins de Berck*, Annales de Médecine Physique, Tome IV, No. 4, Oct.–Nov.–Dec., 1961.
3. Berlemont, M., *L'appareillage des ampulés des membres inférieurs sur le table d'operations*, paper given at the International Congress of Physical Medicine, Paris, 1964.
4. Burgess, Ernest M., Joseph E. Traub, and A. Bennett Wilson, Jr., *Management of lower-extremity amputees using immediate postsurgical fitting techniques*, Prosthetic and Sensory Aids Service, U.S. Veterans Administration, 1967.
5. Weiss, Marian, *The prosthesis on the operating table from the neurophysiological point of view*, Report of Workshop Panel on Lower-Extremity Prosthetics Fitting, Committee on Prosthetics Research and Development, National Academy of Sciences, February 1966.

Experiences with the Total-Contact Prosthesis

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At the request of the Finnish Disabled Ex-Servicemen's Association, New York University arranged for a series of lectures on the fabrication of total-contact, above-knee sockets to be given in Helsinki in 1963. The lectures were intended for prosthetists and other interested persons. Since then some 300 prostheses of this type have been fabricated in Finland.

The total-contact socket (*1, 2*) is a further development of the conventional open-end socket. The proximal portion of a total-contact socket has the same contours as the corresponding portion of an open-end socket. The ischial seat, the relatively high anterior and lateral walls, the bulge into the femoral triangle, and the reliefs for the rectus femoris, for the adductor longus, and for the hamstring tendons are similar in both the open-end socket and the total-contact socket. The main difference is that the total-contact socket completely encases the stump, while the open-end socket, as its name implies, is open distally.

This means that, in the total-contact socket, the stump end is surrounded by a vacuum which keeps the prosthesis in position without a pelvic joint and belt. The total-contact socket is kept in place by its intimate fit around the stump. There is a moderate vacuum during swing phase. The intimate fit of the total-contact socket, which is made of plastic, has been designed with a view toward imitating the mechanism of the physiological pumping action performed by the muscles while walking. the patellar-tendon-bearing (PTB) prosthesis acts in a similar fashion. The pumping effect is accomplished by the amputee as he walks. In fact, a principal advantage of the total-contact socket is the mild, gentle counterpressure on the distal end of the stump during the stance phase. This positive pressure, alternating with the negative during the swing phase, improves circulation and reduces edema in the stump.

The total-contact socket is designed to reduce pressure on the stump proximally and increase the pressure distally. In cases where the diaphysis has been cut, the stump end never tolerates strong pressure. Therefore, pressure must be very carefully modified in each case.

Distally, the plastic socket is joined to a wooden knee. The shank, too, is made of wood, to which a SACH foot is attached. Plastic has certain advantages over other materials. It is readily washed with soap and water. The surface can be made very smooth and free from pores. The chief drawback is airtightness. Plastic does not permit an exchange of air. The result is perspiration, particularly in the summer. Sweat gradually breaks down the plastic. In winter plastic is cold. Sometimes there are allergic reactions to plastic.

In the Department of the State Supervisor of Prosthetic Services of the Ministry of Social Affairs, a follow-up study has been made of amputees fitted with total-contact prostheses. Initially, the amputees are given, for trial, prostheses which are not quite finished, although fit for wear. Some four to six weeks later the patients and their prostheses are examined at the Department of the State Supervisor, where the prostheses are approved or some modification or correction is prescribed. Only after this examination are the prostheses given their final finish. This applies to all prostheses paid for by the state. Six months after the patients have been fitted with their prostheses a questionnaire is sent to them, which they accomplish and return.

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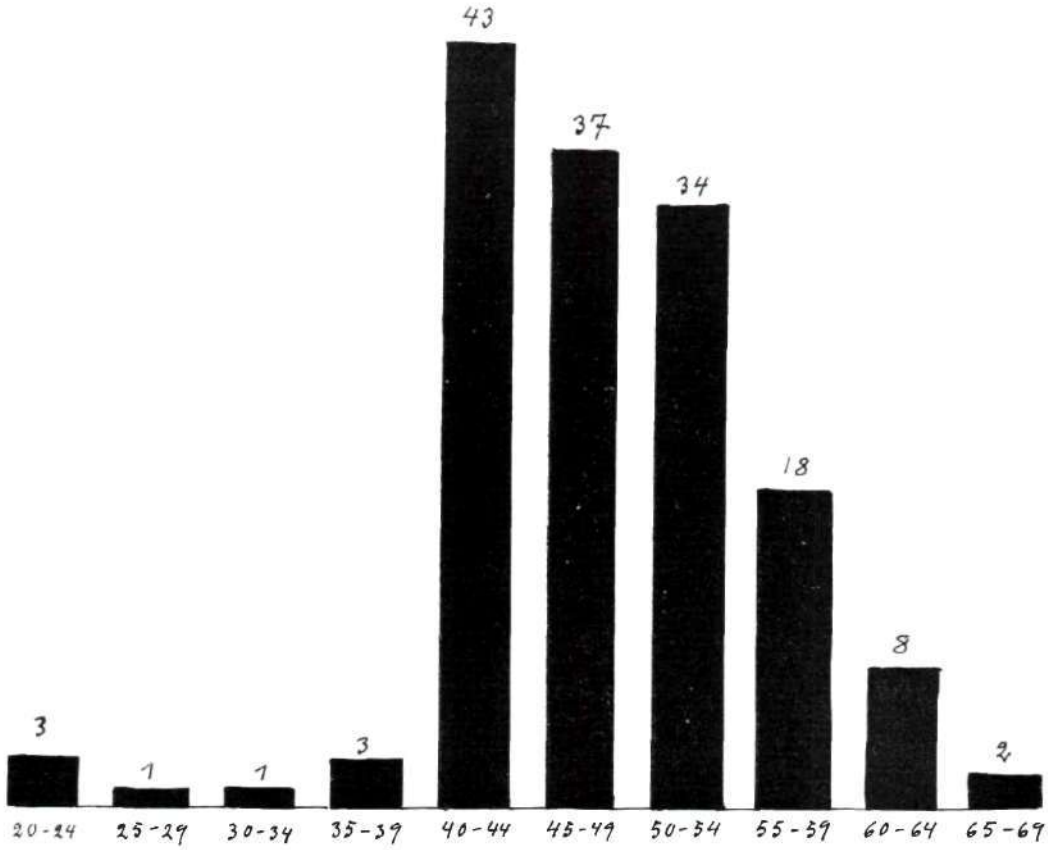


Fig. 1. Ages of the amputees when they were fitted with total-contact prostheses.

Record cards are kept for all amputees on which are entered notations concerning new prostheses, repairs, and modifications.

The present study covers 150 amputees fitted with total-contact prostheses. Of the amputees, 143 (95.3 per cent) were ex-servicemen and 7 (4.7 per cent) were insured civilians.

Figure 1, which shows the ages of the amputees, indicates that the age group of 40 to 54 years is the largest. The high mean age of the ex-servicemen is accounted for by the time that has elapsed since World War II. The series includes two cases from the Finnish civil war of 1918. The youngest amputee was 24, the oldest 67. Only one was a recent amputee. In principle, every above-knee amputee should be fitted with a total-contact prosthesis from the outset in order to become used to it as soon as possible. This would accelerate the remodeling of the stump. Still, the stump of a recent amputee is often tender and swollen for some time. The total-contact prosthesis demands much of the stump. Consequently, a recent amputee may need a new socket at frequent intervals.

Table 1 shows the occupations of the patients in the series. It is of major interest to ascertain whether the total-contact prosthesis can be worn while performing heavy labor of different kinds, particularly outdoors and at low temperatures. In northern Finland temperatures may be as low as -40 deg. C. Therefore, the occupations have been precisely specified. Whenever possible, amputees will usually choose labor that is not too heavy. The series includes 23 farmers (15.3 per cent), 1 lumberman, and 11 fitters. After World War II, retraining of invalids was arranged in the form of courses for watchmakers, storekeepers,

TABLE 1. THE OCCUPATIONS OF THE PATIENTS

Agriculturalist	1
Architect	1
Blacksmith	3
Bricklayer	1
Businessman	1
Carpenter	2
Chauffeur	2
Dental Mechanic	3
Disabled, retired	14
Doorkeeper	4
Elementary school teacher	3
Engineer	2
Farmer	23
Filer (machine shop)	3
Fisherman	1
Fitter	11
Gardener	1
Housewife	2
Lawyer	1
Lumberman	1
Managing Director	5
Noncommissioned officer	3
Office clerk	13
Outdoor man	1
Photographer	1
Shoemaker	5
Shopkeeper	3
Storekeeper	5
Student	2
Tailor	1
Teacher	5
Technician	2
Traveler	1
Turner	1
Unskilled worker	7
Upholsterer	1
Watchmaker	4
Welder	5
Unknown	5
Total	150

fitters, shoemakers, etc. These occupations appear in the table.

Figure 2 shows the lengths of the amputation stumps. The total-contact prosthesis has been worn successfully by amputees whose stumps measured only 10 cm to 15 cm. This series includes 10 such cases, but in two of these cases it became necessary to abandon the total-contact prosthesis. One of these patients received a conventional, wooden, open-end prosthesis; the other was fitted with a leather prosthesis. These cases (No. 8 and No. 9 in Table 2) will be discussed later.

Replies to the questionnaire are presented below:

1. *Have you worn your prosthesis regularly; if not, for how long have you worn it?* According to the replies, 108 (72 per cent) had worn their prostheses regularly, while 42 (28 per cent) had not been able to do so for a variety of reasons.

2. *Why have you not been able to wear your prosthesis regularly?* The replies were compared with the record cards, and causes were elicited as follows:

The knee joint in the prosthesis was too stiff.

In eight cases there was profuse perspiration and a repulsive odor.

In one case the prosthesis was too warm in the summer and too cold in the winter.

In one case the prosthesis was too cold in the winter.

In five cases the socket did not fit.

The amputee put on weight and the socket became too tight.

The inner surface of the socket became granular.

The stump swelled.

There were pains in the stump.

Walking was difficult because of a heart condition.

In two cases the socket split.

There was a jarring sound from the knee joint of the prosthesis.

In one case the amputee was so used to his old prosthesis that he preferred it.

The SACH foot became loose, the socket was tight, and the knee mechanism functioned differently from what it did in the old prosthesis.

In three cases the skin became irritated.

In one case the stump was operated upon after the prosthesis had been finished.

The socket became too wide.

The stiffness of the knee mechanism was a hindrance while fishing.

The socket became too tight.

In many cases modification and repair of the prosthesis put an end to the trouble.

3. *Have you worn your prosthesis (a) when working indoors, (b) when working outdoors, (c) when working outdoors in very cold weather?* Of those replying to the questionnaire, 128 (85.3

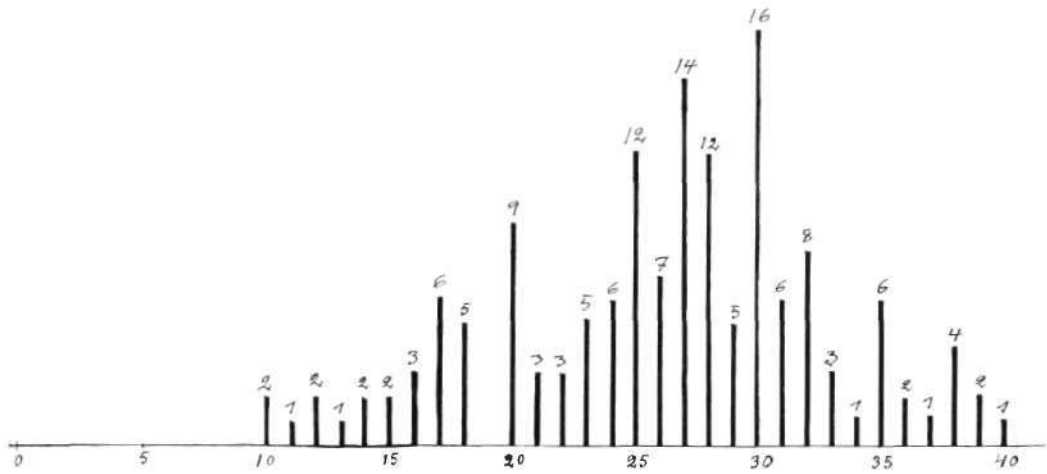


Fig. 2. Lengths of the amputation stumps.

per cent) had worn their prostheses while working indoors, 100 (66.7 per cent) had worn their prostheses while working outdoors, and 72 (48.0 per cent) had worn them outdoors in very cold weather. Some amputees had been in a position to wear the prosthesis only during the warm season at the time of the questionnaire.

4. *Have you worn your prosthesis in some additional—part-time—occupation?* (The intention was to elicit data regarding incidental jobs, recreation, and hobbies.) Only eight amputees indicated that they had such activities: fishing in one case, gardening in one case, agricultural work and lumbering in two, work as a doorkeeper in one case, two cases in which the patients had built their own cottages, and one case in which the amputee participated in ball games.

5. *Have you previously used a prosthesis of some other material (wood, leather, or light metal)?* Conventional prostheses of wood had been worn by 147 amputees (98 per cent), one (0.7 per cent) had worn a leather prosthesis, and one (0.7 per cent) had worn a prosthesis of light metal. One patient (0.7 per cent) was a recent amputee and had been fitted with his first prosthesis.

6. *Have you been satisfied with your prosthesis?* There were 112 (74.5 per cent) satisfied wearers and 38 (25.5 per cent) who were dissatisfied.

7. *Do you think this prosthesis is (a) better than, (b) just as good as, (c) not as good as your previous limb?* The replies were as follows:

Better	81 (54.0 per cent)
Just as good	36 (24.0 per cent)
Not as good	33 (22.0 per cent)

8. *What defects or drawbacks have you observed in your total-contact prosthesis?* Listed below are the complaints of 39 patients (26 per cent). In 32 cases the stump had caused trouble and in seven cases there was something wrong with the prosthesis. But no sharp distinction can be drawn between these two groups. Quite frequently, the prosthesis is the ultimate source of the discomfort.

Amputation stump	
The skin did not tolerate the prosthesis	12
Perspiration from the stump and an unpleasant odor	15
Cold in winter	2
Stump end became discolored	1
Warm in summer, cold in winter	2
	32

Prosthesis	
Plastic socket split	2
Socket was too closed	2
Socket did not fit	1
Knee mechanism too stiff	1
Socket too tight	1
	7

9. *Has perspiration of the stump constituted a problem?* In 33 cases (22 per cent) perspiration had been profuse, in 99 cases (66 per cent) moderate, and in 17 (11.3 per cent) it had caused no trouble. Only one patient (0.7 per cent) stated that perspiration gradually became less of a problem. As a rule, summer was the worst season from this standpoint.

10. *Has perspiration caused any repulsive odor?* The replies of 113 amputees (74.7 per cent) were in the affirmative, while 37 patients (25.3 per cent) replied in the negative. When the odor of the sweat in the closed socket mingled with the odor of the plastic, which is particularly strong in new sockets still containing traces of the solvents used in the fabrication, the effect is extremely disagreeable to both the amputee and his environment. The plastic socket can be washed with soap and water, but personal hygiene varies widely. Many patients have stated that perspiration is not a major problem, if the stump and the prosthesis are washed regularly.

11. *Has the skin on the stump tolerated the total-contact prosthesis?* In 118 cases (79.0 per cent) the skin on the stump had shown no symptoms, while in 32 cases (21.0 per cent) it had not tolerated the strain of the intimate fit of the socket.

12. *Have reddening of the skin and eczema occurred?* In 51 cases (34 per cent) there had been reddening, which may be a transient phenomenon of no significance, but 23 amputees (15.3 per cent) had had eczema, and ulceration had occurred in 18 cases (12 per cent).

13. *Has the end of the stump become discolored after adoption of the new prosthesis?* Discoloration of the end of the stump had occurred in 34 cases (22.7 per cent). This phenomenon is the result of circulatory disturbances in the end of the stump. The most frequent cause is that pressure on the blood vessels is too strong.

14. *Did reddening, eczema, or ulceration of the stump occur before you started wearing a total-contact prosthesis?* Reddening had occurred in 60 cases (40 per cent), eczema in 45 (20 per cent), and ulceration in 5 (3.3 per cent). These replies do not differ greatly from those to question No. 12. But it must be remembered that the previous, conventional prosthesis of wood, leather, or light metal had been worn for a long time, while the total-contact prosthesis had been worn only one-half year to one year. Therefore, the two groups cannot be directly compared.

15. *What are your experiences with the new prosthesis outdoors in cold weather?* Thirty-two patients (35.1 per cent) had not experienced discomfort during the winter, while 61 (64.9 per cent) had found their prostheses very cold.

16. *Have you skied with the new prosthesis?* Only 23 (15.3 per cent) patients answered in the affirmative. As a rule, above-knee amputees are not likely to participate in this sport. The below-knee amputees found on skis are much more numerous.

17. *If you experienced phantom pains previously, have they been aggravated or alleviated after adoption of the new prosthesis?* The replies were as follows:

No previous phantom pains	32 (22 per cent)
Phantom pains aggravated	15 (10 per cent)
Phantom pains unchanged	94 (62.3 per cent)
Phantom pains alleviated	8 (5.3 per cent)
	149 (99.6 per cent)

18. *Have you had pains in the amputation stump (a) after adoption of the new prosthesis, (b) with the old prosthesis?* Sixty-six patients (44 per cent) had experienced pain after adoption of the new prosthesis, and 66 (44 per cent) had had pains while wearing their old limb. In this respect the type of prosthesis seemed to make no difference. But it should be noted that no direct comparison is possible because the total-contact prosthesis had been worn for a shorter period than the old one. In nine cases the total-contact prosthesis was abandoned in favor of the open-end prosthesis previously worn. These cases were subjected to a more detailed study, presented in Table 2.

The table discloses that the occupations of the patients had little to do with the failure. The ages of the patients did not differ from the mean age of the series as a whole. In two cases the stump was short, 12 cm and 15 cm, respectively. In the entire series there were 10

TABLE 2. AMPUTEES WHO COULD NOT WEAR THE TOTAL-CONTACT PROSTHESIS

Case No.	Occupation	Stump Length cm	Previous Prosthesis	Cause of Failure
1	Welder	33	Open-end	Excessive perspiration, odor, discoloration of the stump end, eczema
2	Welder	25	Open-end	Perspiration, odor, coldness
3	Farmer	31	Open-end	Perspiration, odor, coldness
4	Student	15	Open-end	Perspiration, odor, ulceration
5	Fitter	27	Open-end	Perspiration, odor, eczema
6	Retired	20	Open-end	Perspiration, swelling, ulceration
7	Carpenter	28	Open-end	Perspiration, odor
8	Farmer	12	Open-end	Perspiration, odor, ulceration, eczema, discoloration of the stump end
9	Farmer	30	Open-end	Perspiration, odor, allergy, eczema, discoloration of the stump end

stumps measuring 10 cm to 15 cm, three measuring 16 cm, six measuring 17 cm, and five measuring 18 cm. In all cases except the two mentioned at first, fitting with a total-contact prosthesis proved successful. In general, short stumps constitute a problem to the prosthetist. No. 8 in Table 2 was one of a number of amputees who had not been able to wear any prosthesis without complications. No. 9 was the only patient who was tested for allergy.

As appears from the replies to the questionnaire, perspiration and skin changes constituted problems in the wearing of total-contact prostheses. These troubles arose from the properties of the socket: its intimate fit around the stump, and the airtightness of the plastic material. Partly because of the solvents used in the fabrication, the plastic socket sometimes has an irritating effect on the skin, especially when it is new. This irritation is increased by the decomposition of the sweat caused by the heat of the closed socket. In a considerable number of cases, however, the difficulties may have been caused by inadequate curing of the plastic laminate. Also, prostheses made of wood or leather are not free from perspiration.

The possible occurrence of allergic reactions is another problem. In Finland, amputees suspected of allergy are remitted to the Dermatological Department of the Helsinki University Central Hospital. The present series includes only one such case. Perhaps the question of allergy has not been sufficiently taken into account.

The majority of the remaining troubles were readily dealt with in the prosthetist's shop.

It should be emphasized, however, that the view of the total-contact prosthesis derived from the replies that have been reported may be too unfavorable. To the amputee, it is a great advantage to be able to walk with greater ease than with a conventional prosthesis, because of the firm adherence of the total-contact socket to the stump. No pelvic joint and belt are needed. As mentioned earlier in this article, a principal advantage of the total-contact socket is the mild, gentle counterpressure on the distal end of the stump during the stance phase. This positive pressure, alternating with the negative during the swing phase, assists circulation. Some of the cases with dermatologic problems had poor fits, usually as the result of stump changes. In a number of cases, the difficulties may well have been caused by inadequate curing of the plastic laminate. Also, a number of the problems did not relate to the principle of the total-contact socket as such but would have occurred with other designs.

SUMMARY

This study was performed on 150 amputees fitted with total-contact prostheses. It is based on personal follow-up examinations, replies to questionnaires, and data obtained from record cards kept on the amputees.

The age group 40 through 54 years is the largest. War veterans constitute the majority (96.3 per cent of the series).

Seventy-two per cent had worn their pros-

theses regularly from the outset, and 74.5 per cent were satisfied with them. The airtightness of the socket elicited unfavorable reactions from the skin of a number of the patients (21 per cent). Twenty-two per cent of the amputees complained of profuse, and 66 per cent of moderate, perspiration of the stump. Some of the cases with dermatological problems had poorly fitting sockets, usually as the result of stump changes. In a considerable number of the cases, the difficulties may well have resulted from inadequate curing of the plastic laminate. The majority of the problems were readily dealt with in the prosthetist's shop.

The skin requires meticulous hygiene. In contrast to leather and wood, the plastic socket is readily washed. Conventional prostheses are not free from dermatological problems.

The total-contact prosthesis has been used in the performance of heavy labor and while outdoors in cold weather.

Some of the problems of the patients did not relate to the principle of the total-contact socket and would have occurred with other designs.

The gentle, alternating, positive and negative pressure afforded by the total-contact socket to the patient as he walks improves the circulation of the stump and constitutes one of the socket's main advantages.

LITERATURE CITED

1. Foort, J., *Adjustable-brim fitting of the total-contact above-knee socket*, University of California, Biomechanics Laboratory (Berkeley and San Francisco), 1963.
2. Foort, J., and N. C. Johnson, *Edema in lower-extremity ampulees*, University of California, Biomechanics Laboratory (Berkeley and San Francisco), 1962.

News and Notes

Prosthetics–Orthotics Education

Prosthetics–Orthotics Education at UCLA

The UCLA Certificate Program in Prosthetics and Orthotics is an intensive educational program designed to provide initial training for persons entering the profession. For the academic year 1967–1968, the program commences on August 23 with a three-week orientation in such basic prosthetics skills as drilling, tapping, plaster work, laminating, and PVA bag fabrication. This is followed by a five-week course in upper-extremity prosthetics and two weeks of clinical practice in upper-extremity prosthetics. A five-week course in below-knee prosthetics, three weeks of clinical practice in below-knee prosthetics, a five-week course in above-knee prosthetics, and three weeks of above-knee clinical experience take the student through February 23, 1968. He then receives three weeks of instruction in hip-disarticulation and Syme's prostheses, one week of clinical practice with these devices, and one week of child-amputee prosthetics. One week of orientation in fundamental skills in orthotics, such as silver soldering, upright shaping, and buffing and polishing, follows. He is now prepared for the five-week course in lower-extremity orthotics, two weeks of clinical experience in special problems, two weeks of upper-extremity orthotics, and final examinations. The entire certificate program requires slightly less than 2,000 hours.

Arrangements have been completed for certificate students to rotate—two or three at a time—through other prosthetics–orthotics facilities during their clinical practice and courses in special problems. The most important of these facilities is the Veterans Administration Center in West Los Angeles, where the students have the opportunity to work in the laboratories under the supervision of Roddy Chupurdia, C.P.O., Chief of Prosthetic–Orthotic Service at the Center, and his staff.

It is planned to enroll 12 certificate students, if possible, for the 1967–1968 academic year. As of June 1, eight enrollments were confirmed. This will prevent the enrollment of experienced prosthetists who may wish to take one or two courses. However, other arrangements are being made to meet their needs.

Six UCLA Certificate Program in Prosthetics and Orthotics students graduating in June 1967. Left to right: Jerry D. Fullerton, Kenneth G. Schwarz, Rodney M. K. Pang, Richard E. Pickle, William D. Hamilton, and Hans Schaub.

Negotiations continue with California State College, Long Beach, to develop a two-year program in prosthetics–orthotics leading to the degree of Bachelor of Science. A favorable outcome is anticipated, but it will not be possible to put the program into effect during the 1967–1968 academic year. For this reason, except for two graduates of the Cerritos College program who have the degree of Associate in Arts, all certificate program students accepted have the degree of Bachelor of Science. It was hoped that the two Cerritos College graduates would be able to work toward Bachelor of Science degrees immediately, but this will not be possible.

Because of an unanticipated demand by experienced prosthetists for a course in total-contact, above-knee plastic socket techniques, hydraulics, and other new developments, a special two-week course was offered at UCLA during March 1967 for 12 students who had had from seven to 27 years' experience in the profession. Each student paid $300 tuition to defray the costs of the course, which was conducted by Mr. Chupurdia and Donald F. Colwell, C.P.O., formerly an instructor at UCLA and now a partner in C and S Prosthetics, Van Nuys, Calif.

The course was planned on the basis that the students did not require instruction in fundamentals, thus enabling the instructors to concentrate on the new skills and procedures. The course was well received, and the students

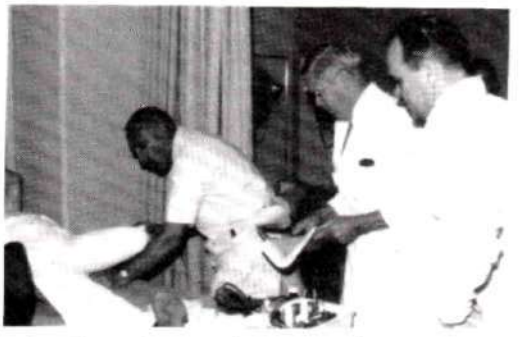
Class members and UCLA faculty and staff, First Course in Immediate Postsurgical Prosthetics Fitting.

suggested that other courses for experienced prosthetists would attract their interest. As a result, three classes have been scheduled for 1967–1968, as follows: *Below-Knee Prosthetics*, March 18–29; *Above-Knee Prosthetics*, July 8–12; either *Hip-Disarticulation Prosthetics* or *Upper-Extremity Harnessing and Fitting*, for whichever there is the greater demand, July 22–August 2.

Applications for the courses will be accepted when accompanied by the tuition fee. If 12 applications are received, the course will be given. Otherwise, the course will be canceled and fees refunded. If there is more demand for some other subject than those listed, a switch will be made to the more popular subject.

Five two-week courses in upper- and lower-extremity prosthetics and orthotics will be offered for physicians and therapists during 1967–1968, as follows: October 16–27, December 4–15, February 19–March 1, March 25–April 5, and May 13–24. The courses will include a unit of instruction on immediate postsurgical prosthetics fitting. An optional half-day of laboratory practice in applying rigid dressings and prosthetic units will be available to surgeons who are interested. Miss Marylouise Knott, who is in charge of amputee training at the Veterans Administration Center in West Los Angeles, will make a presentation on the role of the physical therapist in working with the patient to whom immediate fitting procedures have been applied.

The first course to be offered in immediate postsurgical prosthetics fitting was given by the UCLA Prosthetics-Orthotics Education Program, May 4–6, 1967. The class was attended by 35 students, of whom 16 were surgeons and 19 were prosthetists.



First Course in Immediate Postsurgical Prosthetics Fitting at UCLA. Edward W. Snygg, C.P.O., Edwin R. Schottstaedt, M.D., and Leigh A. Wilson, C.P., apply a rigid dressing to an above-knee amputee.

Head instructor for the course was Ernest M. Burgess, M.D., orthopaedic surgeon, who is Principal Investigator at the Prosthetics Research Study in Seattle, where he has had extensive experience in developing and applying immediate postsurgical prosthetics fitting procedures. Dr. Burgess was assisted during the course by two of his associates from the Prosthetics Research Study, Joseph E. Traub, who is Director of the Study, and Joseph H. Zettl, C. P. The work of the Prosthetics Research Study is supported by the Veterans Administration.

The students were formed into 16 teams for laboratory practice, and each student had the experience of applying the rigid dressing and prosthetic unit to a below-knee and above-knee amputee. Physicians and prosthetists worked together during the practice sessions,

First Course in Immediate Postsurgical Prosthetics Fitting at UCLA. Charles A. Hennessy, C.P.O., former UCLA staff member, describes how it feels to be an amputee on whom immediate postsurgical prosthetics procedures have been applied. Mr. Hennessy was re-amputated three weeks before this picture was taken.

Ernest M. Burgess, M.D., head instructor in the First Course in Immediate Postsurgical Prosthetics Fitting at UCLA, points out a slight error in cable placement to Charles R. Newton, C.P.O.

each going through the complete procedure of applying the rigid dressing to the amputee's stump, installing the prosthetic unit, and practicing the removal of the cast.

Another try-out class in immediate postsurgical prosthetics fitting was scheduled for June 8–10, 1967. The arrangements for this class were modified on the basis of experience gained with the first trial class, and the outcome represents the style and format that will be followed during the five three-day courses scheduled for 1967–1968. The dates for these courses are: September 16–18, September 27–29, November 15–17, April 24–26, and June 19–21.

Information concerning UCLA instructional offerings in prosthetics and orthotics, together with application forms, can be obtained from Dr. Miles H. Anderson, Director, Prosthetics-Orthotics Program, University of California Rehabilitation Center, 1000 Veteran Ave., Los Angeles, Calif. 90024.

Prosthetics-Orthotics Education at NYU

With the anticipated award of the degree of Bachelor of Science in Prosthetics and Orthotics to eight students in June 1967, New York University passes another milestone in its pioneering four-year undergraduate program. Begun in 1964, the program was undertaken to help meet the growing need for professionally trained persons to provide leadership in the clinical, research, and teaching aspects of prosthetics and orthotics. The urgency of this need is emphasized by the large number of offers of employment received by the senior students in the program, as well as by the successful placement of the four previous graduates.

Eight students receiving the degree of Bachelor of Science in Prosthetics and Orthotics at New York University in June 1967. Front row, left to right: Charles Conroy, Narendra Parekh, Benjamin Pulizzi, and William Webb. Rear row, left to right: Charles H. Dankmeyer, Henry K. Saur, Ivan Sabel, and Eugene Silver.

Senior students busy in the shop during the above-knee prosthetics course at New York University.

Twenty-nine students (five freshmen, six sophomores, nine juniors, and nine seniors) were registered in the curriculum during the academic year 1966–1967. Included were three students from abroad, representing India, Hong Kong, and Portugal. Six junior-year and eight senior-year students received traineeship assistance from the Vocational Rehabilitation Administration.

Of special interest was the enrollment as a junior of the first woman student in the Bachelor of Science program. A graduate occupational therapist, Miss Martha Stibitz matriculated because of her interest in hand function and her belief that present upper-extremity braces and prostheses are inadequate. She also believes that the psychological needs of the wearers are too often neglected. She hopes to concentrate her postgraduate studies on the design of upper-extremity devices and the psychological support of the patient during and following fitting. Miss Stibitz recently married a resident in physical medicine from India, and the two of them plan to pursue their careers as a team.

As a result of the experience gained over the past three years, several changes have been made in the Bachelor of Science curriculum. The following are curriculum requirements, effective September 1967:

Freshman Year

Fall

English Composition	3
History of Western Civilization	3
Introduction to Mathematics	4
Elements and Literature of Music	3
Man and Society	3
	16 hours

Spring

English Composition	3
History of Western Civilization	3
Nature of Matter	4
Fundamentals of Speech	2
General Metalworking	4
	16 hours

Sophomore Year

Fall

Man in the Biological World	4
Introduction to Modern Chemistry	4
Literary Heritage	3
Government and Politics	3
Fundamentals of Speech	2
	16 hours

Spring

Literary Heritage	3
Development of Physics	4
Sociology of Education	2
Prosthetic and Orthotic Techniques	5
Mechanical Drawing	2
	16 hours

Junior Year

Fall

Survey of Physical Defects	2
Introduction to Psychology	3
Anatomy and Physiology I	5
Mechanics	2
Spinal Orthotics	5
	17 hours

Spring

Anatomy and Physiology II	5
Developmental Psychology	2
Biomechanics	2
Properties of Materials	2
Below-Knee Prosthetics	6
	17 hours

Senior Year

Fall

Painting in the Western World	3
Philosophical Analysis	3
Lower-Extremity Orthotics	6
Upper-Extremity Prosthetics	5
	17 hours

Spring

Above-Knee Prosthetics	8
Upper-Extremity Orthotics	3

Professional Problems in Prosthetics and Orthotics	2
Clinical Affiliation	4
	17 hours

To fulfill the requirement for 1,440 hours of supervised clinical practice, students worked at the following institutional and commercial facilities in the New York metropolitan area: Institute for the Crippled and Disabled, Institute for Rehabilitation Medicine, NYU Prosthetics and Orthotics, Veterans Administration Prosthetics Center, Arthur A. Beitman Co., J. E. Hanger Co., John N. Eschen Co., Kessler Associates, Schwarz Orthopedic Appliances Co., and Winterkorn Orthopedic Appliance Co. They also obtained experience at the following out-of-town facilities: Abbey Orthopedics, and Frees and Tyo, Syracuse, N. Y.; Louis Yellin Co., Philadelphia, Pa.; and the United Limb and Brace Co., Boston, Mass.

As a result of discussions with the American Board for Certification in Orthotics and Prosthetics, Inc., and with the University Council on Orthotic-Prosthetic Education, the ABC bylaws have been revised so that a graduate of the Bachelor of Science curriculum is now eligible for the certification examination in either prosthetics or orthotics after one year of postgraduate experience. Following an additional year's experience, he is eligible for the other certification examination. The graduates also meet the contractual requirements set by the Veterans Administration and several state vocational rehabilitation agencies for providing services to their beneficiaries.

It is estimated that 35 to 40 students will be enrolled in the four-year program during the 1967–1968 academic year. This increasing enrollment, combined with the inadequacy of general library facilities for this specialized field, has led to the establishment of a small prosthetics and orthotics library for student and faculty use, under the supervision of a professional staff member.

During May 1967 the undergraduate program was invited to prepare an exhibit for a career fair jointly sponsored by the New York City Board of Education and Station WCBS-TV and held in the Kingsbridge Armory in the Bronx. This was the largest career fair ever presented, with approximately 100,000 students from New York City high schools being given one-half day released time to attend. The prosthetics and orthotics booth was monitored for the two-week period by faculty members, and more than 5,000 copies each of the brochures *Professional Preparation in Prosthetics and Orthotics* and *Traineeship Assistance for Undergraduate Study in Prosthetics and Orthotics* were distributed. The display, which included two amputee demonstrators, generated considerable interest and enthusiasm.

The New York University Prosthetics and Orthotics postgraduate education program, now in its eleventh year, provides short-term intensive courses for physicians and surgeons, therapists, prosthetists, orthotists, and rehabilitation counselors. During the 1966 1967 academic year, 780 students attended 33 sections of 14 different courses. The student enrollment during the period from March 1956 to June 1967 was:

Physicians and Surgeons	2,309
Therapists	1,694
Prosthetists and Orthotists	1,068
Rehabilitation Counselors	629
Total	5,700

The continuing growth in student enrollment led to a pressing need for expanded quarters. Classes were severely limited by the size of the available classrooms, and many students had to be turned away. Therefore, beginning with the 1967–1968 academic year, courses for physicians, surgeons, therapists, and rehabilitation counselors will be offered in new quarters on the 11th floor at 317 East 34th St. Shop instruction for prosthetists and orthotists will remain at the present location at 342 East 26th St.

The new 4,000-sq.-ft. area will comprise two large, modern classrooms accommodating up to 50 students each (present classroom capacity is 30 to 40), a reception area, a patient dressing and waiting room, a student lounge, an audiovisual and projection room, office space, and storage areas. Faculty offices will be consolidated with those of the research personnel on the tenth floor of the same building.

During the 1967–1968 academic year, new areas of instruction will be added to existing

courses and several new courses will be given for the first time:

Immediate and Early Postsurgical Prosthetics. Four sections of a new three-day course for physicians and surgeons and of a new six-day course for prosthetists in the field of immediate and early postsurgical prosthetics will be offered. The course for physicians and surgeons will coincide with the first three days of the prosthetists' course so that each group will have the opportunity to work with the other and increase its understanding of the other's functions and points of view. Developed in conjunction with the University Council on Orthotic-Prosthetic Education, these courses are designed for students who already have substantial experience in prosthetic management.

Spinal Orthotics. As a result of extensive preparatory work with a group of consulting orthotists, a new course in spinal orthotics for orthotists will be offered for the first time in January 1968. The course will be devoted to instruction and laboratory practice in the fabrication of four basic spinal braces (with specified variations) which provide all the significant functions of the numerous brace designs currently in existence.

Upper-Extremity Prosthetics and Orthotics. Courses in upper-extremity prosthetics for physicians and surgeons and therapists will now include considerable material on upper-extremity orthotics and be retitled *Upper-Extremity Prosthetics and Orthotics.* By tightening the instruction in prosthetics, thus leaving greater time for orthotics, it will be possible to keep the courses the same length. Orthotics instruction will include functional anatomy and biomechanics of the hand, orthotic components, fitting and management procedures, and clinical presentations of various upper-extremity disabilities requiring bracing.

The schedule of courses to be offered during the 1967-1968 academic year follows. Additional information and application forms can be obtained by writing to Dr. Sidney Fishman, Coordinator, Prosthetics and Orthotics, NYU Post-Graduate Medical School, 317 East 34th St., New York, N. Y. 10016.

Prosthetists

Below-Knee Prosthetics—Sept. 5–22.
Immediate and Early Postsurgical Prosthetics—Oct. 2–7; Jan. 15–20; Mar. 25–30.
Upper-Extremity Prosthetics—Jan. 22–Feb. 2.
Above-Knee Prosthetics—May 27–June 14.

Orthotists

Spinal Orthotics—Jan. 22–Feb. 2.
Lower-Extremity Orthotics—June 17–28.

Physicians and Surgeons

Lower-Extremity Prosthetics—Sept. 25–30; Nov. 13–18; Feb. 26–Mar. 2; May 13–18.
Immediate and Early Postsurgical Prosthetics—Oct. 2–4; Nov. 27–29; Jan. 15–17; Mar. 25–27.
Lower-Extremity Orthotics—Oct. 16–20; Mar. 4–8; Apr. 8–12.
Upper-Extremity Prosthetics and Orthotics—Dec. 11–15; Apr. 1–5.

Therapists

Lower-Extremity Prosthetics—Sept. 11–22; Oct. 30–Nov. 10; Feb. 5–16; Apr. 29–May 10.
Lower-Extremity Orthotics—Oct. 16–20; Mar. 4–8; Apr. 8–12.
Upper-Extremity Prosthetics and Orthotics—Dec. 4–15; Mar. 25–Apr. 5.

Rehabilitation Counselors

Prosthetics and Orthotics—Nov. 6–10; Feb. 12–16; May 6–10.

NYU Prosthetics and Orthotics is pleased to announce that Basil Peters, C.P.O., will become a full-time member of the faculty. Mr. Peters is presently affiliated with Basil Peters and Associates, Inc., Philadelphia, Pa., and is President-Elect of the American Orthotics and Prosthetics Association. His extensive experi-

Basil Peters, C.P.O., new faculty member, Prosthetics and Orthotics, New York University.

ence in all phases of prosthetics and orthotics will make him a valuable addition to the teaching and research staff.

During the past year, staff members of NYU Prosthetics and Orthotics participated in a variety of committee, lecture, and consultation activities.

During August 1966, Dr. Sidney Fishman made presentations to the staffs of the Central Prosthetic Research Institutes of the USSR in Leningrad and Moscow regarding current procedures taught at New York University.

At the invitation of the Georgia Division of Vocational Rehabilitation, Warren Springer organized a five-day course, *Orientation to Prosthetics and Orthotics*, which was attended by 43 rehabilitation counselors from Georgia and South Carolina. Dr. Fishman and Mrs. Joan Edelstein also lectured in this program, which was held in Atlanta, Ga., during January 1967.

Mrs. Edelstein conducted courses in functional anatomy and kinesiology for prosthetist–orthotist technicians at the Institute for the Crippled and Disabled and presented a two-day program on lower-extremity prosthetics for undergraduate physical therapists at the NYU School of Education.

Messrs. Ivan Dillee and Hans R. Lehneis presented papers at a total of five AOPA regional meetings.

A unique project was inaugurated this year when Dr. Fishman agreed to help establish and staff a prosthetics and orthotics shop aboard the Hospital Ship *Hope*, at the request of Dr. William Walsh, Director of Project Hope. The NYU staff has planned the shop layout, advised on the purchase of equipment and supplies, and recruited one full-time staff member and several others who will provide six-week periods of service. Thus for the first time this international medical project will be able to provide prosthetic and orthotic services to patients.

Prosthetics-Orthotics Education at NU

The academic year 1966–1967 marked the eighth year of classes offered by Prosthetic-Orthotic Education, Northwestern University. A brief summary of the offerings, together with future plans, follows.

Lower-Extremity Prosthetics for Physicians and Therapists. Again, the 1966–1967 academic year showed a marked increase in attendance. The physicians-in-charge of residency programs continue to regard this course as the basic prosthetics course in residency training. NU Prosthetic–Orthotic Education plans nine sections during 1967–1968 with four lower-extremity and four upper-extremity courses scheduled in consecutive weeks. Four cases are presented during the Friday morning clinic team practice sessions, with local certified prosthetists assisting. Originally, it was planned that students in the Associate-in-Arts degree program would serve as clinic team prosthetists during the spring sessions, but their inexperience and the teaching schedules did not permit this. As a result, the costs for all courses in which prosthetists serve as consultants have risen considerably over previous years.

Upper-Extremity Prosthetics for Physicians and Therapists. For more than a year serious consideration was given to shortening this course. During April 1967 it was reduced to a four-day session. Areas shortened or revised are: amputation surgery, management of the juvenile amputee, and components. Additional time is given to harnessing. Because fewer students were enrolled during the fall of 1966, only four sections of this course will be offered during the 1967–1968 academic year.

Management of the Juvenile Amputee for Physicians, Therapists, and Prosthetists. Two sections of this course will be offered during the 1967–1968 academic year. Critiques of the course have been favorable, and few changes have been made in recent years. The additions of workshop seminars and teaching sessions on fabrication and fitting of prostheses for children with congenital anomalies are two improvements which have been made in recent courses and will be continued during 1967–1968.

Orthotics for Physicians and Therapists. Two sections of this course were offered during 1966–1967. Interest in the course has increased, and the faculty has elected to offer three sections during the 1967–1968 academic year. The 1966–1967 academic year was the first in which physical therapists were accepted for

enrollment. Because of their response and interest, their applications will continue to be accepted. Acceptance of therapists for enrollment is based upon their prosthetics orthotics educational background and current professional assignment.

Residency Training in Prosthetics and Orthotics. Seventy-eight physicians-in-charge of residency programs in orthopaedic surgery and physical medicine are coordinating the training of their residents in prosthetics and orthotics with Northwestern. During 1963 1964, 160 residents were trained. Over the years the numbers have increased; physicians-in-charge have requested 480 spaces for residents during 1967-1968.

Joseph E. Traub, Director of the Prosthetics Research Study in Seattle, addressing a conference on immediate postsurgical prosthetics fitting procedures at Northwestern University in January 1967. As a result of the conference, UCLA, NYU, and NU have elected to offer three-day courses in immediate postsurgical prosthetics fitting procedures to physicians and prosthetists.

Clinton L. Compere, M.D., NU Prosthetic-Orthotic Education, addresses the conference on immediate postsurgical prosthetics fitting procedures at Northwestern University.

Immediate Postsurgical Prosthetics Fitting. The NU Prosthetic–Orthotic Education faculty has elected to teach five sections in immediate postsurgical prosthetics fittings during the 1967-1968 academic year. Each section will be limited to 10 prosthetists and 10 orthopaedic surgeons. The training will cover: rationale, including indications and contraindications for using the procedure; amputation surgery; components and materials; applications of rigid dressings, above-knee, below-knee, Syme's, and hip-disarticulation; postoperative considerations. The first section is scheduled for June 21-23, 1967, on an invitation basis. Dr. Ernest M. Burgess and Messrs. Joseph E. Traub and Joseph H. Zettl will have the major teaching responsibilities.

Associate-in-Arts Degree Program. The first candidates for the degree of Associate in Arts will complete their studies and be awarded their degrees in June 1967. The program has

Captain Frank L. Golbranson, Medical Officer-in-Charge of the Navy Prosthetics Research Laboratory, addresses the conference on immediate postsurgical fitting procedures at Northwestern University.

been a rewarding experience for the staffs of Northwestern and the Chicago City College. During 1966–1967, twelve students were in the program at NU Prosthetic–Orthotic Education. Nine will graduate in June 1967. An extensive recruitment program is under way, with a view toward obtaining a good freshman class in the fall of 1967.

Orientation in Prosthetics and Orthotics for Rehabilitation Counselors. Five sections of this course were offered during 1966–1967, and more personnel were trained than during the previous year. During 1963–1964, 90 were trained; during 1964–1965, 101; during 1965–1966, 153; and during 1966–1967, 200. The state of Ohio has again requested NU Prosthetic–Orthotic Education to present a course in Columbus during the 1967–1968 academic year, as in 1966–1967. The curriculum will be the same as for the orientation course presented at Northwestern, and the manual will be identical. Local physicians, therapists, prosthetists, and orthotists who have attended courses at NU, UCLA, or NYU will supplement the teaching of NU Prosthetic–Orthotic Education faculty members.

Spinal Orthotics for Orthotists. Two sections of this course were offered during 1966–1967, and three are planned for 1967–1968. The course includes instruction in anatomy, kinesiology, clinical problems, and bracing of the spine. Twenty-five orthotists were trained during 1966–1967.

Total enrollment figures indicated an increase in the number of students trained during 1966–1967. Twenty-nine courses were offered, and a total of 1,005 students were trained. It is anticipated that approximately 1,020 students will register for courses in 1967–1968.

Inquiries concerning instructional offerings

by Northwestern University in prosthetics and orthotics should be directed to Dr. Jack D. Armold, Director, Prosthetic–Orthotic Education, Northwestern University Medical School, 401 East Ohio St., Chicago, Ill. 60611.

There has been continued interest in the Northwestern University film and film strips entitled *Gait Analysis*. The film strip sets have been very successful; 40 have been sold, with the funds reverting to the Committee on Prosthetic–Orthotic Education.

At the request of the Committee on Prosthetic–Orthotic Education, NU Prosthetic–Orthotic Education produced the film *Upper-Extremity Harnessing and Control Systems*. The film, which is approximately 30 minutes in length, covers biomechanical principles, control systems, and typical harnessing patterns for below-elbow, above-elbow, and shoulder-disarticulation prostheses. Distribution of the film is coordinated by the American Academy of Orthopaedic Surgeons. There have been more than 100 showings of the film to date during 1967.

The film *Management of the Juvenile Amputee* was completed in 1967 and will be available through the American Academy of Orthopaedic Surgeons during the fall of 1967. It covers the management of standard, acquired amputations in children. The Michigan Department of Health, Division of Services to Crippled Children, financed the project.

In cooperation with the Committee on Prosthetic–Orthotic Education, NU Prosthetic–Orthotic Education is planning a film on the basic techniques in the management of amputees, paralytics, and other patients requiring prosthetic or orthotic devices. The film is intended for use in long-term rehabilitation nursing programs.

The following series of tape-recorded lectures correlated with slides on subjects related to prosthetics and orthotics is being developed: proximal femoral focal deficiencies, upper-extremity prosthetic training, biomechanics, amputation surgery, lower-extremity prosthetics, upper-extremity prosthetics, special prostheses, classification of congenital deficiencies, and immediate postsurgical prosthetics fittings.

During the past year, faculty and staff members of NU Prosthetic–Orthotic Education participated in a variety of extracurricular activities.

Drs. Jack D. Armold and Clinton L. Compere and Messrs. Edwin H. Bonk, Charles M. Fryer, Fred Hampton, Herbert Blair Hanger, and Don E. Irish participated in the annual assembly of the American Orthotics and Prosthetics Association at Palm Springs, Calif., during October 1966. In addition, Dr. Armold and Messrs. Ian J. Currell, Fryer, Hampton, Hanger, and Gunter Gehl have participated in a number of regional meetings of AOPA.

Drs. Armold and Compere and Messrs. Bonk and Fryer have participated in meetings of the Committee on Prosthetic–Orthotic Education.

Mr. Fryer has presented papers on *Lower-Extremity Biomechanics* at the Cook County Graduate School of Medicine and at the University of Michigan.

Dr. Armold has met with various groups concerned with planning for technical education, including the Annual Institute of Administrators and Supervisors of Technical Education at Oklahoma State University and a National Invitational Research Planning Conference at Ohio State University.

Annual Meeting of the Committee on Prosthetic-Orthotic Education

The annual meeting of the Committee on Prosthetic–Orthotic Education was held at the New York University Medical Center on April 27, 1967, with Dr. Roy M. Hoover, Chairman of CPOE, presiding. Dr. Hoover welcomed guests representing governmental and other organizations interested in rehabilitation of the orthopaedically disabled. He also welcomed Dr. J. Warren Perry, Dean of the School of Health Related Professions, State University of New York at Buffalo, as a new member of the Committee. Dr. Perry is well known to the other members of CPOE, having represented the Training Division, Vocational Rehabilitation Administration, at many meetings in the past.

Reports were received from the standing subcommittees.

Colonel Ruth A. Robinson, U.S. Army

(Ret.), chairman of the Subcommittee on Paramedical Education, reviewed the work of the Subcommittee's *ad hoc* groups. Colonel Robinson reported that the *Ad Hoc* Committee to Review Prosthetic-Orthotic Educational Materials met during February 1967 primarily for the purpose of reviewing films. Present for that meeting were Miss Mary Poole, chairman of the *ad hoc* group, and Miss Nancy Ellis, Miss Lena Plaisted, and Miss Muriel Zimmerman. Colonel Robinson said that the annotated bibliography prepared by this *ad hoc* committee was near completion and would appear in a forthcoming issue of *Artificial Limbs*. Because the mission of this *ad hoc* committee is of a continuing nature, CPOE decided to upgrade its status to that of a standing Subcommittee on Prosthetic-Orthotic Educational Materials and to expand its mission to include the stimulation of the development of needed teaching and educational materials. A physician, a prosthetist, and an orthotist will be added to the membership.

Colonel Robinson reported that the *Ad Hoc* Committee on Prosthetics in Nursing Education met at the Rehabilitation Institute of Chicago during October 1966. Miss Teresa Fallon of the National League for Nursing presided as chairman. Members present were Miss Nancy Martin, Miss Lena Plaisted, and Miss Mary Tomasiewicz. Also present were Dr. Jack D. Armold and Mr. Charles Fryer, both of Northwestern University. It was brought out at that meeting that, from the viewpoint of nurse educators, the nurse's role in the rehabilitation of the amputee is not fully recognized. Recommendations to rectify the situation included the publication of articles in nursing journals and the sponsorship of presentations at national and regional nurses' meetings. Northwestern University is producing a film which will emphasize the role of the nurse in the care of the amputee. As a result of this report, CPOE voted to add a nurse educator to its membership.

Colonel Robinson also reported that a working group of the Subcommittee on Paramedical Education had met to consider the desirability of sponsoring orthotics workshops for physical and occupational therapists. Colonel Robinson said that there is some demand for therapists to provide simple splints for the orthopaedically disabled, as a result of the availability of new plastic materials. Members of the working group were studying the operations of orthotics facilities before formulating definite plans to support the implementation of new workshops.

Dr. Herbert E. Pedersen, chairman of the Subcommittee on Prosthetics Clinical Studies, said that a major objective of the Subcommittee is to develop an educational program for surgeons in the conservative management of patients with lower-extremity amputations resulting from peripheral vascular disease. A prerequisite to such a program, he said, is the documentation of the results being achieved in various centers that have widely varying philosophies for the surgical management of such cases. The Subcommittee intends to make a review of reported studies on the results of conservative management.

Dr. Richard Warren, Clinical Professor of Surgery at Harvard Medical School, reported that a retrospective study of ischemic amputations performed during 1964 at 14 Veterans Administration hospitals was completed and that a detailed one-year prospective study now being conducted in 23 hospitals will provide more than 400 cases.

Dr. Jacquelin Perry, chairman of the Subcommittee on Orthotics, reported that the second meeting of the Subcommittee was held in Chicago during December 1966. In addition to herself, the meeting was attended by Norman Berger, Dr. E. Burke Evans, Charles W. Rosenquist, and Roy Snelson.

Dr. Jacquelin Perry said that the Subcommittee had conducted a pilot survey of current practice in the use of external support in the treatment of low back pain. Results of the survey, in which 90 orthopaedic surgeons participated, indicated that data collection of this kind could yield valuable information for educational purposes. Although a considerable number of appliances were identified in the study, there was marked preference for just a few types. On the basis of these results, a checklist-type of questionnaire has been designed for use in surveying the entire membership of the American Academy of Ortho-

paedic Surgeons. Information solicited will include:

1. The frequency of each device used for each disability.
2. The frequency of each device for all disabilities.
3. The frequency of each class of devices for all disabilities.
4. The frequency of each disability being treated by each class of support.
5. The frequency of each disability being treated with any type of external support.

It was decided by CPOE to establish a standing Subcommittee on Educational Projects in Prosthetics and Orthotics to serve in an advisory capacity regarding the long-term training of persons in prosthetics and orthotics. Chairman of the Subcommittee is Dr. J. Warren Perry, and the membership will include representation from the University Council on Orthotic-Prosthetic Education, the American Orthotics and Prosthetics Association, and the Vocational Rehabilitation Administration.

Mrs. Florence S. Linduff of the Training Division of VRA said that this agency will continue to support education and training in the fields of prosthetics and orthotics. She said that the University of California, Los Angeles, will soon initiate a program leading to a baccalaureate degree. In closing, Mrs. Linduff expressed appreciation to CPOE for its assistance to the VRA program.

Mr. William M. Bernstock of the Veterans Administration's Prosthetic and Sensory Aids Service also expressed appreciation to CPOE for its assistance to VA. He announced that the book *Human Limbs and Their Substitutes*, out of print for many years, is being updated and republished. Also being published under VA auspices is a brochure entitled *Immediate Postsurgical Prosthetics in the Management of Lower-Extremity Amputees*, by Dr. Ernest M. Burgess, Joseph E. Traub, and A. Bennett Wilson, Jr.

It was announced that new sets of prosthetics instructional slides were being produced and would soon be ready for distribution, together with a pamphlet describing each slide. Also being developed was a selection pattern for various types of lectures.

Mr. Edwin H. Bonk showed a film on the management of children with acquired amputations. The film was produced at Northwestern University under his direction. Associated with Northwestern in the production of the film were the Area Child Amputee Clinic at Grand Rapids and the Children's Clinic at the University of Illinois. Persons who viewed the film at the meeting considered it excellent. Mr. Bonk said that a film on congenital amputees was in the planning stage.

There was discussion of the question of compensation for prosthetists for their professional services as well as for the devices which they furnish. It was noted that sometimes a prosthetist is called upon for consultation concerning a patient who may not obtain devices from the prosthetist's facility.

Dr. Charles D. Shields, chairman of the Committee on Rehabilitation of the American Medical Association, reported on a conference of AMA-sponsored rehabilitation societies which had been attended by representatives from interested governmental agencies.

Dr. William J. Erdman, II, reported that the American Congress on Physical Medicine and Rehabilitation had changed its name to the Congress on Rehabilitation Medicine and opened its membership to individuals in the allied health professions.

Dr. Clinton L. Compere announced that the Committee on Braces and Prostheses of the American Academy of Orthopaedic Surgeons is obtaining financial support from VA for the revision of the *Orthopaedic Appliances Atlas*, Volume 1, *Braces, Splints, Shoe Alterations.*

Mr. A. Bennett Wilson, Jr., Executive Director of the Committee on Prosthetics Research and Development, mentioned the participation of CPRD in the development of a standard nomenclature for orthotic devices and components. Mr. Wilson also announced that a conference on the biomechanics of the human foot and ankle will be held under CPRD auspices during the coming year.

Mr. George H. Lambert, Sr., President of the American Orthotics and Prosthetics Association, summarized some of the Association's activities, such as the evaluation of a shop manual by the Conference of Prosthetists, and planning for a training program for prosthetics-orthotics support personnel at Del-

gado College in New Orleans. Mr. Herbert B. Warburton, Executive Director of AOPA, said that Medicare appears to be increasing the workload of prosthetists by approximately 5 per cent to 7 per cent and that payment of reimbursements was unduly delayed because of administrative procedures.

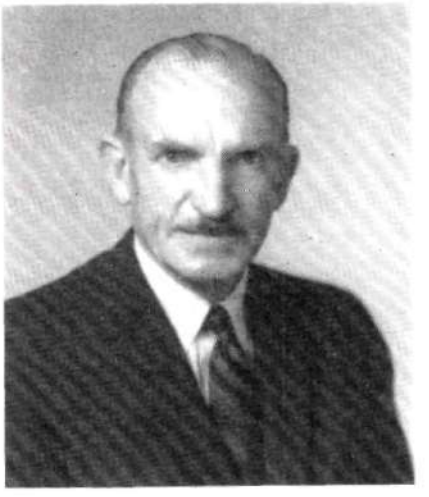
The educational activities of the University of California, Los Angeles, New York University, and Northwestern University in the field of prosthetics and orthotics were described by Mr. Charles M. Scott, Dr. Sidney Fishman, and Dr. Jack D. Armold, respectively.

Dr. Harold W. Glattly Honored by American Academy of Orthopaedic Surgeons

Harold W. Glattly, Brigadier General, Medical Corps, U.S. Army (Ret.), was recently elected to honorary membership in the American Academy of Orthopaedic Surgeons, a most unusual distinction for persons who are not orthopaedists. Dr. Glattly serves as Executive Secretary of the Committee on Prosthetic–Orthotic Education, the Committee on the Skeletal System, and the Committee on the Genito–Urinary System of the National Research Council's Division of Medical Sciences. The Certificate of Honorary Membership was presented to Dr. Glattly by Dr. Charles H. Herndon, President-Elect of the American Academy of Orthopaedic Surgeons, who is the retiring Chairman of the Committee on the Skeletal System, at a workshop on *Orthopaedic Literature Information Services*, sponsored by the Committee at the National Library of Medicine on May 19, 1967.

In connection with the presentation, Dr. Herndon read a testimonial letter which the Committee on the Skeletal System had authorized him to send to the Secretary of the Army. In part, the letter reads:

> Dr. Glattly has participated in generating the acquisitive and inquisitive curiosities of the Committee in the scientific area in many rewarding manners and thus significantly advancing the academic and research depth of American orthopaedics. In the opinion of the Committee, such expertise merits comment and recognition. This letter simply serves to document these superior administrative and scientific accomplishments of Dr. Glattly. It is forwarded to you as a recognition and appreciation of the contribution of military medicine to civilian medicine at the highest level of national interest.



Dr. Harold W. Glattly, Executive Secretary, Committee on Prosthetic-Orthotic Education.

In his presentation, Dr. Herndon noted that a number of accomplishments were directly attributable to Dr. Glattly's efforts, including the establishment of seminars for chiefs of training programs in orthopaedic surgery and the founding of the Joint Committee on Orthopaedic Research and Education Seminars. He also noted that the National Institutes of Health had instituted a program providing support for orthopaedists who wish to enter academic and research careers. He stated that

> information regarding the mechanics of funding research in orthopaedics and musculoskeletal problems has been disseminated as never before. Seminars and workshops on specific orthopaedic problems that have required development have been conducted with great success. Dr. Glattly has a way of going neatly to the heart of the matter and bypassing the trivia, which has been a tremendous help to us in orthopaedics.

Conference on Prosthetics and Orthotics

At the request of the Vocational Rehabilitation Administration, the Committee on Prosthetics Research and Development held a conference on prosthetics and orthotics at the National Academy of Sciences, December 12 and 13, 1966. The purpose of the conference was to develop information for use in planning research and development activities in prosthetics and orthotics for the next five years and longer. Some 35 participants, chosen for

their experience in these fields, were supplied with reference material well in advance of the conference.

Dr. Herbert Elftman, Chairman of CPRD, welcomed the participants on behalf of the Committee and introduced Dr. James F. Garrett, Associate Commissioner for VRA Research and Training.

In his remarks to the conferees, Dr. Garrett said that VRA is faced with the problem of defining major areas of research and indicating the appropriate programming emphasis. For prosthetics and orthotics research, the requirement is for a program that is sequential and significant. Moreover, the program should be justifiable in terms of costs and benefits. For each dollar spent, there should be some definite benefit for the handicapped. Dr. Garrett believed that this relationship could be shown specifically in prosthetics and orthotics, because the prosthetics and orthotics program has a tradition of translating its developments into services for individuals. Dr. Garrett expressed the hope that the conference would develop goals and approaches that would be particularly appropriate for VRA in the employment of its resources, keeping in mind the complementary relationship between VRA and the Veterans Administration. He emphasized that the relationship between the two agencies is complementary, and not competitive.

The work of the conference was undertaken by seven panels, each with its own chairman, as follows:

Lower-Extremity Prosthetics and Orthotics—Anthony Staros, chairman.
Upper-Extremity Prosthetics and Orthotics—Miles H. Anderson, Ph.D., chairman.
Surgical and Medical Considerations—George T. Aitken, M.D., chairman.
Engineering Problems—James B. Reswick, Sc.D., chairman.
Fundamental Studies—J. Raymond Pearson, chairman.
Design and Development—Colin A. McLaurin, chairman.
Evaluation— Howard R. Thranhardt, chairman.

In its conclusions, the conference found that great progress has been made in prosthetics during the past two decades and continues today. This has been the result of the utilization of fundamental studies of function to provide criteria for design and fitting and the continual adaptation to prosthetics of technological advances, including the availability of new materials.

The following recommendations were made in the field of lower-extremity prosthetics:

1. Accelerate stump-socket pressure studies so that criteria can be established for improved socket design.
2. Encourage development of improved stance-phase controls.
3. Encourage development of improved foot-ankle units.
4. Develop a device that permits appropriate rotation about the long axis of the prosthesis.
5. Initiate development of improved tools and instruments for clinical check-out of fit, alignment, and function.
6. Continue the development of prostheses and fabrication methods especially suitable for temporary use, but also filling the requirement for definitive use.
7. Publish a comprehensive text on the management of lower-extremity amputees.

The following recommendations were made in the field of upper-extremity prosthetics:

1. The entire upper-extremity program should be reviewed thoroughly.
2. A survey of previously fitted upper-extremity amputees should be conducted.
3. Fundamental studies of the functions of the upper extremity should be reactivated. It is still not known which functions should be carried out with external power and which should be carried out with body power.
4. Support should be continued for the preparation and publication of a new manual on *Upper-Extremity Prosthetics for Prosthetists.*
5. The preparation of a manual on *Upper-Extremity Prosthetics for Physicians and Therapists* should be initiated.

With respect to orthotics, the conference concluded that although persons in need of braces are much more numerous than those requiring prosthetic replacement, only minimal progress has been made in providing orthotic devices capable of giving functional rehabilitation. There is a real technical difficulty in developing a device which cannot be self-sufficient but must work in harmony with remnants of the original mechanism. At present, the entire field of orthotics is cluttered with a multitude of devices, varying in use

from region to region, and from practitioner to practitioner. It was considered that there is an imperative need for a survey of the braces now in use to select those which have some merit and to allow their redesign in accordance with modern engineering practice. The survey would also disclose the need for new devices and lead to their design and development.

The conferees noted that lower-extremity orthotics has received little attention, even before poliomyelitis was vanquished. The increasing number of lower-extremity disabilities resulting from numerous other causes calls for immediate resumption of research and development in this area. Specific recommendations in the field of lower-extremity orthotics were made as follows:

1. A survey of present practice.
2. Encouragement of new work in the design and development of lower-extremity orthoses.
3. Reactivation of work on the UCB biaxial ankle brace.
4. Further investigation of braces which redistribute load on different parts of the lower extremity. Particular attention was invited to the importance of such braces in the healing of fractures.

The conferees noted that upper-extremity orthotics has received more attention during the past ten years than lower-extremity orthotics. Much has been learned about the treatment of patients with impaired upper extremities, but very little of this knowledge is available in centers other than those engaged in research. Specific recommendations in the field of upper-extremity orthotics were made as follows:

1. A survey of present practice.
2. Formation of a Panel on Upper-Extremity Orthotics by CPRD to survey current research efforts.
3. Evaluation of promising devices and techniques to validate those which have merit and make them available for country-wide use. The cost of such an evaluation program and its importance should not be underestimated.
4. Initiation of new projects and recruitment of new talent.

Concerning spinal orthotics, the conference noted the acute need for improvement in the field and the technical difficulty of designing an external brace for an internal structure. However, it was considered that research and development must necessarily wait for positive recommendations from orthopaedic committees now studying the problem.

With respect to fundamental studies, the conferees noted that the results of studies of locomotion and upper-extremity function have been very useful to designers in the past, but much remains to be done. The following specific recommendations were made:

1. Locomotion studies be continued.
2. Studies of the functions of the upper extremity be reactivated.
3. Studies of the effects of pressures on tissues be initiated. Results of such studies would affect the design of sockets, braces, and surgical techniques.
4. A thorough review be made of the effectiveness of electromyography as a measuring instrument.
5. Further studies in soft tissue physiology and body mechanics be carried out.

With respect to surgical and medical problems, the following specific recommendations were made:

1. Indications and contraindications for amputation surgery.
2. Determination of best level of amputation.
3. Determination of relative values of various sites of amputation, such as knee disarticulation *versus* short below knee.
4. Surgical techniques—treatment of muscle, bone, nerves, etc.
5. The contributions of the various factors involved in immediate postsurgical fitting.
6. Persistent painful phantoms.

In a foreword to the report of the conference proceedings, Miss Mary E. Switzer, Commissioner of the Vocational Rehabilitation Administration, comments: "In a field that is not always in peaceful, harmonious agreement on all things, we deeply appreciate the breadth of experience applied, the earnest effort made to sharpen understanding of the problems, and the many decisions on priorities that went into the final recommendations here contained. This report is an outstanding step toward the wise use of the resources that can be applied to the problems in prosthetics and orthotics, and a tool that should be put to use immediately by public and private agencies, researchers, clinicians, and all others

who contribute to the vocational rehabilitation program for the disabled."

Copies of the report may be obtained from the Committee on Prosthetics Research and Development.

Meeting of CPRD Subcommittee on Child Prosthetics Problems

The Subcommittee on Child Prosthetics Problems of the Committee on Prosthetics Research and Development met in the American Chemical Society Building in Washington, D. C., March 20 and 21, 1967. Chairman of the Subcommittee, Dr. George T. Aitken, presided. Subcommittee members present at the meeting were Colin A. McLaurin and Drs. Sidney Fishman, Richard E. King, Claude N. Lambert, and Newton C. McCollough. Dr. Arthur J. Lesser, Deputy Chief of the Children's Bureau, Department of Health, Education, and Welfare, was present as liaison representative of the Children's Bureau, the agency largely responsible for funding the child prosthetics program. The Army Medical Biomechanical Research Laboratory was represented by Dr. Fred Leonard, Scientific Director of AMBRL, and Albert B. Colman, Roy I. Katsuren, Leonard F. Marcus, Lloyd L. Salisbury, and Alfonzo Spencer. New York University was represented by C. B. Taft. Also present were Dr. Herbert Elftman, Chairman of CPRD; A. Bennett Wilson, Jr., Executive Director of CPRD; and Hector W. Kay, Assistant Executive Director of CPRD.

In his opening remarks, Dr. Aitken spoke of the vigorous growth of the child amputee research program under the leadership of Dr. Charles H. Frantz, former Chairman of the Subcommittee.

Four more child amputee clinics were approved as participating members in the Subcommittee's cooperative clinic program, making a total of 26 clinics now participating in the program. The clinics joining the program are Children's Hospital, Denver, Colo.; Children's Hospital, Akron, Ohio; Shriners Hospitals for Crippled Children, Springfield, Mass.; and Shriners Hospitals for Crippled Children, St. Louis, Mo. Fifteen additional clinics were noted as being in various stages of development, indicating the potential future growth of the program.

The goal of the Subcommittee on Child Prosthetics Problems—to have an approved child amputee clinic conveniently available to every major population center throughout North America—appears to be approaching realization. While most of the clinics are solely concerned with patient service, several clinics combine research and service. An annual meeting of the participating clinic chiefs and a monthly publication—the *Inter-Clinic Information Bulletin*—both under the sponsorship of the Subcommittee, aid in the coordination of the program.

Evaluation projects considered by the Subcommittee included the MCCC electric feeder arm, the AIPR pneumatic prosthesis, the Winnipeg adjustable pylon, AMBRL porous prostheses, the AMBRL electric elbow, the AMBRL friction shoulder joint, the AMBRL flex-action hook, the OCCC electric hook, the OCCC voluntary-opening opposition post, New Brunswick myoelectric units, the NPRC variable-friction knee, the NU disk-friction knee, the NU electric linear actuator, the CAPP nylon wrist unit, and the Münster-type below-elbow prosthesis.

Several developmental projects were considered, including the OCCC electric wrist unit, the OCCC electric elbow, the OCCC swivel walker, the AMBRL piezoelectric hand, the AMBRL electric elbow unlock, and the AMBRL resilient hand.

Among possible new field studies considered by the Subcommittee were the immediate postsurgical fitting of prostheses to children and a survey of sports participation by amputee children.

It was decided that the next meeting of the Subcommittee would be held during the fall of 1967.

Workshop Panel on Lower-Extremity Orthotics Convened by CPRD Subcommittee on Design and Development

The Fourth Workshop Panel on Lower-Extremity Orthotics of the Subcommittee on Design and Development, Committee on Prosthetics Research and Development, met in Santa Monica, Calif., March 6-8, 1967.

Anthony Staros, panel chairman, presided. Panel members attending the meeting were Roddy Chupurdia, Thorkild J. Engen, Fred Hampton, Verne T. Inman, M.D., H. R. Lehneis, Fred Leonard, Hans A. Mauch, William J. McIlmurray, Vert Mooney, M.D., Gilbert M. Motis, Edward Peizer, Charles W. Rosenquist, Charles M. Scott, Roy Snelson, Joseph E. Traub, and Randolph N. Witt. Manufacturers were represented by Robert H. Klebba, Siegfried W. Jesswein, and Ralph A. Storrs. Guests attending the session were Miles H. Anderson, Ph.D., Ernest Bontrager, S. Chang W. M. Motloch, Eugene F. Murphy, Ph.D., and Gordon Robin. Also present were Herbert Elftman, Ph.D., Chairman of CPRD; Howard R. Thranhardt, Chairman of the CPRD Subcommittee on Evaluation; and A. Bennett Wilson, Jr., Executive Director of CPRD.

Major topics considered by the panel included the effectiveness of unweighting systems, foot pressure distribution, mechanical linkages of the foot, brace structures, the UCLA functional long leg brace, the UC–BL brace, and crutches and canes.

In his summary of the meeting, Mr. Staros said that a lot of ground was covered and added:

> The excellent work going on at Rancho Los Amigos on fracture bracing and the parallel experiences of Sarmiento in Miami are recognized. We can judge that for the time being the panel need not focus on these programs except to give proper support to the primary research groups when requested.
>
> The relatively complex problems of the foot and shoe, the foot-ankle system, and the relationship of foot-ankle and other brace component function to knee stability demand more and more attention. Hopefully, some of the fogginess will be dissipated with results from the plan submitted to have the Subcommittee on Fundamental Studies treat the foot, shoe, and shoe modifications in a meeting of interested and expert parties to take place soon. Thus the clarification process begins.
>
> The UC–BL brace with its subtalar analogue is being submitted to the Subcommittee on Evaluation for wider-scale clinical testing. From this program we expect to learn more about proper bracing of the foot-ankle complex.
>
> Bioengineering studies of the UCLA brace will give us additional insight into the relationship of the functions of the foot-ankle and other brace components to knee stability. As these studies proceed, perhaps we can obtain a better foundation for offering new designs for Program consideration. Moreover, we shall encourage the appropriate agency to conduct a survey of disabilities requiring bracing, at least to determine where our emphases might be. In partnership with the program of the American Academy of Orthopaedic Surgeons and the American Orthotics and Prosthetics Association to develop a brace nomenclature, we expect to establish a functional catalog of present brace components and combinations of components. This will in part define the present state of the art.
>
> Meanwhile, the clever designs for brace structures offered by the Army Medical Biomechanical Research Laboratory, the University of California at Los Angeles, the Texas Institute for Rehabilitation and Research, and the Veterans Administration Prosthetics Center can be treated by the panel in some detail with what we now know. Plastic brace uprights, inflatable ones, the simplification in design offered by Engen, and the single-bar system of McIlmurray—to some extent related to the French single-tube design—can be further developed for experimental patient application in the near future. The unique design offered by Lehneis employing rubber joints and his interesting approach to coordination of knee and foot-ankle function can be monitored not only to obtain some guidance on still other designs but possibly to be developed for early clinical utility. . . .
>
> Gradually some of the confusion will dissipate. Subsequently, we shall be able to offer the Program significant contributions—some sooner, based on what we now know, and later, more revolutionary ones, based on what we learn from the studies we proposed.

Workshop Panel on Lower-Extremity Prosthetics Fitting Convened by CPRD Subcommittee on Design and Development

The Sixth Workshop Panel on Lower-Extremity Prosthetics Fitting of the Subcommittee on Design and Development, Committee on Prosthetics Research and Development, met at Blair House, Durham, N. C., May 1, 1967. James Foort, panel chairman, presided. Panel participants were J. Hamilton Allan, M.D., Francis A. Appoldt, Charles C. Asbelle, Harry L. Beazell, Jr., John Bray, Frank W. Clippinger, Jr., M.D., Carlton E. Fillauer, Robert O. Gooch, Edward C. Grahn, John Harder, M.D., Grace C. Horton, Herbert E. Kramer, David W. Lewis, Ph.D., Ronald Lipskin, Alvin L. Muilenburg, Thomas Pirrello, Laurence Porten, Charles M. Scott, Anthony Staros, W. A. Stewart, Howard R. Thranhardt, Bert R. Titus, Joseph E. Traub, Keith Vinnecour, and Leigh A. Wilson. Also present were Dr. Herbert Elftman, Chairman of CPRD; A. Bennett Wilson, Jr., Executive Director of CPRD; and Hector W. Kay, Assistant Executive Director of CPRD.

In his opening remarks, Mr. Foort reminded the conferees that more than a year had elapsed since the panel had met, and that much had happened in the research laboratories during that period. He outlined the hoped-for accomplishments of the meeting as follows:

1. Reports from each of the laboratories would bring all of the participants up to date.
2. Consideration would be given to the manner in which the various research projects were related, so that developments might complement each other and duplication be avoided.
3. Consideration would be given to the relationship between current developments in lower-extremity prosthetics fitting techniques and other aspects of prosthesis design and amputee management.
4. The interchange of ideas would stimulate fresh activity when the conferees returned to their respective laboratories.

With these objectives in mind, Mr. Foort divided the meeting into two parts: the first part to be concerned with status reports on various projects, and the second part to be devoted to a freewheeling discussion in the hope of opening new horizons in concepts of lower-extremity prosthetics fitting.

Messrs. A. Bennett Wilson, Jr., and Joseph E. Traub reported that an active program of immediate postsurgical fitting of prostheses was in progress throughout the United States. The three prosthetics schools planned to conduct courses for physicians and prosthetists during the 1967–1968 academic year. Veterans Administration centers were participating in a follow-up study of immediate postsurgical fittings.

Mr. Leigh Wilson reported on the patellar-tendon-bearing air-cushion socket developed at the Biomechanics Laboratory of the University of California, San Francisco. A pilot school had been conducted for the local industry, and some 60 patients had been fitted in the San Francisco area. Mr. Wilson believed that leakage, adjustment, and shrinkage problems related to the air-cushion socket had been essentially resolved, and that the technique provided a foolproof method of achieving total contact.

Mr. Pirrello reported on experimental use by the Veterans Administration Prosthetics Center of Polysar, a plastic material made by the Polymer Corp., Sarnia, Ont. Obtained in conical forms, the material becomes malleable at low temperature and can be formed directly on the patient's stump. Several below-elbow sockets were in use. In applications to below-knee amputees, the material had been formed by means of the Gardner pneumatic casting technique, with foam injected into the end of the socket for total contact. A manual on the use of Polysar for below-elbow and below-knee fittings was being prepared, and plans were under consideration for a training course for panel members.

Mr. Fillauer reported on a prefabricated socket being developed at his facility. It is an adjustable temporary prosthesis for above-knee amputees, of quadrilateral shape, with a rigid medial wall and a flexible lateral wall. A

James Foort, panel chairman, explaining features of an adjustable socket.

latch is used to stabilize the adjustment, and a Silesian bandage suspension is used.

Mr. Foort reported on prefabricated sockets developed at the Manitoba Rehabilitation Hospital: an above-knee item, of which 100 have been fitted; and a device for below-knee amputees, which has been fitted to 22 patients.

Mr. A. Bennett Wilson, Jr., mentioned a patellar-tendon supra-condylar (PTS) socket which had been developed by M. Guy Fajal in France. Mr. Wilson pointed out that the device had not been actively investigated in the United States, although some fittings had been made. He thought that further study might be warranted.

With respect to below-knee casting, Mr. Leigh Wilson reported that the University of California, Berkeley and San Francisco, was still using the hand-shaping procedures developed at that institution. Mr. Grahn stated that suspension casting was being used routinely at Northwestern University and being taught there. The value of suspension casting was endorsed by Mr. Foort, who indicated that he had been using the technique since being introduced to it by Mr. Fred Hampton of Northwestern University. Mr. Staros reported that the Veterans Administration Prosthetics Center was routinely using the Gardner pneumatic technique. Mr. Kramer said that New York University had been experimenting with a balloon technique similar to that used for the UCB shoe insert.

With respect to above-knee casting, Mr. Leigh Wilson and Mr. Foort reported that the UCB adjustable brim technique was still in use at the University of California, Berkeley and San Francisco, and at the Manitoba Rehabilitation Hospital, respectively. Mr. Grahn indicated that a suspension casting method was in use at Northwestern University.

Mr. Appoldt distributed a preliminary report on socket pressure studies being conducted at the New York University School of Engineering and Science. Essentially, the procedure used in the studies involved the provision of 25 to 30 recording positions in an above-knee socket utilizing transducers with which readings could be obtained from six positions at a time. Mr. Appoldt said that expansion of the studies is planned. Additional subjects will be included and further data gathered.

Dr. Harder reported on plans for a study at North Carolina State College to investigate the swelling and shrinking of stumps from amputation to maturity. An unusual feature of the proposed study is the use of ultrasonic waves bounced off the flesh and bone of the stump as an aid in determining stump volumes.

Mr. Beazell reported on a study being conducted at the University of Virginia, involving the measurement of pressures between the stump and the socket. Variables to be studied

Sixth Workshop Panel on Lower-Extremity Prosthetics Fitting.

or monitored included pressure and pressure distribution, bone position, contour relationship of stump and socket, transient skin temperature, electromyographic signals from certain muscles, and an instrumented pylon.

Mr. Grahn reported on four above-knee socket fittings made at Northwestern University, involving the use of sphygmomanometer cuffs inserted between a flexible inner wall and a rigid outer wall of the socket.

Mr. Stewart described sockets being tested at Toronto which incorporated linings fabricated from silicone fluid (Dow Corning 200) and Silastic elastomer 385. He demonstrated a sample socket and swatches showing various combinations of the fluid and elastomer.

Mr. Porten showed pictures and presented materials illustrative of his invention of pneumatic stump sockets, cuffs, and pads. The inserts, liners, and cuffs demonstrated by Mr. Porten involved the use of Naugahyde and Koroseal materials and inflation by means of a sphygmomanometer bulb. A special feature of the Porten procedures was the use of heat to seal the materials.

In opening the second part of the meeting—the freewheeling discussion—Mr. Foort suggested that the participants consider what might constitute the ideal prostheses of the future, that is, within the next 10 to 15 years, and how current efforts might relate to these goals.

It was suggested that the Mauch hydraulic ankle control unit now under development might constitute an outstanding advancement with respect to prosthetic feet. The need for feet which could be readily adjusted for heels of different heights was mentioned.

With regard to medical and surgical research, mention was made of the insertion of Silastic plugs into amputated long bones to improve their weight-bearing capability and attempts to develop endoskeletal prostheses, that is, prostheses which could be attached directly to the bones. There was agreement that if these items of research come to fruition, whole new concepts of fitting and alignment, components, and the attachment of components would probably be necessary.

With respect to sockets, the desirability of eliminating the use of plaster of Paris in casting stumps and of the lamination process in fabrication was urged.

The need to be able to check socket fit continuously was urged by Mr. Kramer, also the development of transparent sockets or other methods of monitoring fit.

Mr. Bray suggested that there should be less concern with pressure over bony prominences and more concern with shears, or motion between the stump and the socket. He believed that attention should be given to means of controlling or stopping this shear. More information was needed concerning the biomechanics of the stump-socket interface. It was suggested that a study of these factors might be combined with investigations of fluid-lined sockets now being conducted. Two somewhat conflicting considerations appeared to be involved: socket rigidity to hold the stump and reduce the shears between the stump and the socket, and fluid liners or pads for adjustment to volume changes and to increase comfort.

The desirability of having sockets which could be easily adjusted, or be fabricated so simply and inexpensively that they could be replaced, was stressed. Mention was made of the possible advantages of sockets possessing phasic self-adjustability, that is, changing during different conditions such as stance, swing, and sitting.

The need was expressed for an authoritative article on the fitting of the knee-disarticulation amputee. It was suggested that a number of prosthetists experienced and interested in this area might submit their views in the form of articles to Mr. Kay, who would coordinate the material submitted. If necessary, a work session in knee-disarticulation socket design could be scheduled. Panelists indicating an interest in this venture were Messrs. Bray, Fillauer, Foort, Muilenburg, Pirrello, Thranhardt, Titus, Traub, and Leigh Wilson.

The lack of a satisfactory knee-disarticulation knee unit was also cited. It was reported that a Dupaco pneumatic system for the knee-disarticulation prosthesis was under development and that the University of California, Berkeley and San Francisco, was also working on a polycentric knee mechanism. These developments would be followed.

NAS Conference on Sensory Aids Recommends Sustained Program for the Blind

A conference on sensory aids, organized by the Subcommittee on Sensory Aids of the Committee on Prosthetics Research and Development, met at the National Academy of Sciences, March 30 and 31, 1967.

Chairman of the conference was Professor Robert W. Mann, Department of Mechanical Engineering, Massachusetts Institute of Technology. There were some 35 participants, including representatives from the Vocational Rehabilitation Administration, the National Institutes of Health, the Veterans Administration, the Children's Bureau, the Office of Education, and the Library of Congress.

Greeting the conferees on behalf of the Veterans Administration, the agency supplying the funds for conference expenses, Dr. Eugene F. Murphy, Chief of the Research and Development Division of the VA Prosthetic and Sensory Aids Service, expressed appreciation for the independent advice of the National Research Council on a wide variety of topics. He mentioned particularly a recent survey by the Subcommittee on Sensory Aids of VA development activities in the field of sensory aids for the blind. Dr. Murphy said that several of the devices had arrived at a point where it seemed that they should be made available in fairly large numbers to users within the next few years. To carry out such long-range plans would require substantial funds. Dr. Murphy congratulated the Subcommittee on Sensory Aids for appreciating this problem and calling attention to it.

In orienting the conference participants, Professor Mann said that a need exists for a comprehensive inspection and inventory of what should be done for the blind. He said that the concern of the conference, in its development of a start toward long-range plans, should be confined to helping persons who are already blind rather than the prevention of blindness.

Position papers were presented as follows: on research and development, by Dr. James C. Bliss of Stanford Research Institute and Dr. Patrick W. Nye of the California Institute of Technology; on evaluation, by John K. Dupress of the Sensory Aids Evaluation and Development Center at MIT; and on deployment, by Professor Mann. Following general discussion, the participants met separately as panels to consider research and development, evaluation, and deployment, respectively.

For the concluding session, the conferees reassembled for informal discussion of the recommendations to be made in the report of the conference proceedings. Among the general recommendations were:

1. Organization of the scientific, technological, and financial resources of the nation into an effective and sustained program for the blind.
2. Emphasis on the reading problem because of the present promise that devices and techniques now under development would be beneficial.
3. Continued attention to the mobility problem.
4. Development of technical aids to widen the vocational horizons of the blind.

It was considered that basic research is essential to include:

1. Assessment of human sensory aid capability.
2. Assessment of the informational requirement of the blind.
3. Related study of acquisition processing and display of information for the blind.

To carry out these recommendations of the conference, it was the consensus that steps should be taken toward the establishment of a Committee on Blindness, to be staffed and funded within the NAS–NAE–NRC structure. In concluding the conference, Professor Mann expressed the hope that the final report would be a document which would provide an effective basis for setting up such a committee and obtaining support for a long-term program for the blind.

Sixty-Five Receive Travel Grants to Participate in Stockholm Conference on Biomedical Engineering

The United States National Committee on Engineering in Medicine and Biology has awarded travel grants to 65 persons to attend the 7th International Conference on Medical and Biological Engineering to be held in Stockholm, Sweden, during August 1967. The grants were made from funds provided by the National Institute of General Medical Studies of the National Institutes of Health for the

purpose of supporting United States participation in the Stockholm conference.

The availability of the grants was publicized, and some 500 completed applications were received. In making its selections, USNCEMB was impressed by the large number of highly qualified applicants, which far exceeded the total amount of funds available for travel grant awards, even though the grants were made on an austere basis; that is, no grant exceeded the price of a round-trip economy fare on a jet aircraft.

Administered by the Division of Engineering of the National Research Council, USNCEMB was established by the National Academy of Engineering in November 1966 to enable American engineers in the fields of medicine and biology to participate in the activities of international organizations such as the International Federation for Medical and Biological Engineering, the sponsoring organization for the Stockholm conference. Chairman of USNCEMB is Murray Eden, Ph.D., Professor of Electrical Engineering at the Massachusetts Institute of Technology. Vice Chairman is Edward F. Leonard, Ph.D., Department of Chemical Engineering, Columbia University. Other members are Ralph E. DeForest, M.D., Director, Department of Postgraduate Programs, American Medical Association; Leo Fox, Ph.D., Human Research Division, National Aeronautics and Space Administration; Albert S. Gates, Jr., Chief, Engineering Section, Environmental Services Branch, National Institutes of Health; John Lyman, Ph.D., Head, Biotechnology Laboratory, University of California, Los Angeles; John W. Moore, Ph.D., Department of Physiology, Duke University; Harold W. Shipton, State University of Iowa College of Medicine; Lawrence Slote, Ph.D., Grumman Aircraft Engineering Corp.; and Sigmund Wesolowski, M.D., Mercy Hospital, Rockville Centre, N.Y.

Staff Executive of USNCEMB is James R. Kingham, who also continues to serve as Staff Editor of the Committee on Prosthetics Research and Development.

NATIONAL ACADEMY OF SCIENCES—NATIONAL RESEARCH COUNCIL

THE NATIONAL ACADEMY OF SCIENCES is a private, honorary organization of more than 700 scientists and engineers elected on the basis of outstanding contributions to knowledge. Established by a Congressional Act of Incorporation signed by Abraham Lincoln on March 3, 1863, and supported by private and public funds, the Academy works to further science and its use for the general welfare by bringing together the most qualified individuals to deal with scientific and technological problems of broad significance.

Under the terms of its Congressional charter, the Academy is also called upon to act as an official—yet independent—adviser to the Federal Government in any matter of science and technology. This provision accounts for the close ties that have always existed between the Academy and the Government, although the Academy is not a governmental agency and its activities are not limited to those on behalf of the Government.

THE NATIONAL ACADEMY OF ENGINEERING was established on December 5, 1964. On that date the Council of the National Academy of Sciences, under the authority of its Act of Incorporation, adopted Articles of Organization bringing the National Academy of Engineering into being, independent and autonomous in its organization and the election of its members, and closely coordinated with the National Academy of Sciences in its advisory activities. The two Academies join in the furtherance of science and engineering and share the responsibility of advising the Federal Government, upon request, on any subject of science or technology.

THE NATIONAL RESEARCH COUNCIL was organized as an agency of the National Academy of Sciences in 1916, at the request of President Wilson, to enable the broad community of U. S. scientists and engineers to associate their efforts with the limited membership of the Academy in service to science and the nation. Its members, who receive their appointments from the President of the National Academy of Sciences, are drawn from academic, industrial and government organizations throughout the country. The National Research Council serves both Academies in the discharge of their responsibilities.

Supported by private and public contributions, grants, and contracts, and voluntary contributions of time and effort by several thousand of the nation's leading scientists and engineers, the Academies and their Research Council thus work to serve the national interest, to foster the sound development of science and engineering, and to promote their effective application for the benefit of society.

COMMITTEE ON PROSTHETICS RESEARCH AND DEVELOPMENT
COMMITTEE ON PROSTHETIC-ORTHOTIC EDUCATION

The *Committee on Prosthetics Research and Development* and the *Committee on Prosthetic-Orthotic Education*, units of the Division of Engineering and the Division of Medical Sciences, respectively, undertake activities serving research and education in the fields of prosthetics and orthotics, when such activities are accepted by the Academy as a part of its functions. Activities of the Committees are presently supported by the Department of Health, Education, and Welfare and the Veterans Administration. Information or reports developed by activities of the Committees are officially transmitted and published through the National Academy of Sciences.