Autumn 1967

Artificial Limbs

A Review of Current Developments

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Still a Long Way to Go[1]

D. s. MCKENZIE, M.D.[2]

IT IS probably a common experience to those of us who work in the field of artificial limbs to receive odious comparison between the relatively primitive prostheses and the sophisticated hardware deriving from space technology, nuclear physics, and the like. The implication usually is that, if similar expenditure on research were made in our field, similar dramatic advances would be made. I do not think that the problem is as simple as this reasoning would imply, and there is some evidence to support my view. I am told that, once upon a time, a great American aviation company undertook to develop an artificial arm and that, some years and a million or two dollars later, they reverted with relief to the relatively simple matter of designing aircraft.

And yet we must acknowledge that the externally powered upper-extremity prostheses of today are poor things. It is very doubtful indeed whether the unilateral arm amputee can obtain from them any functional or emotional gain over that deriving from the conventional body-powered prosthesis; indeed, in some respects there may be a loss. It is even doubtful whether any bilateral amputee with measurable humeral stumps would be improved, except perhaps by making it possible to superimpose an additional degree of freedom such as pronation-supination on the existing body-powered prostheses. Indeed, I would go so far as to say that the amelics and bilateral shoulder-disarticulation patients would be better off functionally if they only had sufficient sites available for harnessing with sufficient power and excursion for body-powered control. Currently available externally powered limbs are acceptable to these patients only because a little function is better than none at all. How little that is, is exemplified by the readiness with which the children with upper-extremity amelia and normal lower limbs revert to using their feet for prehension and manipulation.

It is of more than passing interest to attempt to analyze why these things should be so, and I think there are a number of reasons.

[1] Published with permission of the Controller of Her Majesty's Stationery Office.

[2] Director, Ministry of Health, Biomechanical Research and Development Unit, Roehampton, London, S.W. 15, England.

First, the power-weight ratio of available actuators and power storage components is still not advantageous enough for us to provide truly acceptable responses.

Second, we have not yet discovered enough control sites capable of providing a sufficient number of degrees of freedom to position the hand or terminal device in space, to put it in the optimum attitude in relation to each task to be performed, and still leave an adequate reserve for prehension.

The problem of simulating normal prehension has not been solved, nor, in my opinion, has a truly acceptable compromise been attained. Most writers agree that a well-designed hook is more functional than any of the many so-called functional hands, and yet few would claim that the hook contributes anything to cosmetic restoration or that it is likely to be emotionally satisfying to more than a small proportion of patients. Various ingenious hands purport to provide a selection of different types of grasp, such as the power grasp, precision grasp, "three-jaw chuck," and so forth, and some even achieve this. But none of them, nor of the hooks for that matter, is capable of manipulation within the grasp. This results in the exasperating experience for the user that any object he picks up is seldom immediately in a position of function; he is unable to manipulate it into such a position and has to resort to inelegant procedures such as transferring the object to the mouth and back to the hand again. Furthermore, many tasks that we do are achieved by manipulation—screwing, modeling, squeezing, and a host of others-—which, for the amputee, have to be done by energy-consuming gross arm movements or even gross body movements, and he cannot feel what he is doing. It is not surprising that the unilateral amputee elects to use his remaining hand, and the amelic his toes.

The foregoing difficulties apply in the main both to externally powered and body-powered prostheses, and I have said little about sensory feedback, a degree of which is available to the users of the latter systems. The control cable offers a built-in position servo, while a great deal of information about the forces applied at the output can be derived from the reactions of the harness against the body and those of the socket on the stump. When external power is used, these afferent channels either cease to exist or are severely attenuated, and it becomes necessary to consider the provision of artificial sensory loops which in their turn introduce difficulties in interpretation.

We are thus confronted with what I believe to be the main barrier to progress in externally powered prostheses—the man-machine interface. This should be taken to mean not only the physical attachment of the prosthesis to the wearer, but also the boundary through which all command signals from the biological system of the wearer must pass to the mechanical system of the prosthesis and through which all information relating to the output of the prosthesis must return to the biological system if the wearer is to make the best use of such information to modulate performance.

It is on these channels of communication that the effective control of externally powered devices depends. I am quite certain that we do not know enough about their mechanism to exploit them to best advantage. No one has yet attempted to measure the "goodness" of the channels—for example, in terms of communication theory—and yet I believe that effective systems design would follow on such data as surely as night after day.

One of the greatest virtues of biological systems is that they are highly adaptive. The human control system—and in particular the computer as represented by the central nervous system—is no exception to this. The pattern of manual activity which we require in order to enjoy a full life is so infinitely variable that I have very serious doubts whether any form of programmed operation within the prosthetic system will satisfy a user for any length of time. The concept of programming the trajectory of the terminal device so as to limit the decision-making demand upon the user to commanding the system to move it from *A* to *B* is open to this criticism. Even if provision were made for the user to override the program and revert to voluntary control, I suspect that the switch would soon be left permanently in the override position. In any event, the case for this sort of programming seems to me to be accepting that the interface is inevitably poor in a communications sense. It may be that a better understanding of the interface will make this an unduly pessimistic view.

Reverting to the adaptive properties of the biological system in general, and of the central nervous system in particular, it seems to me that significant progress in externally powered limbs will be made only when it becomes possible to link the central nervous system "on line" with the prosthetic control system. Servo loops crossing the interface would make an integrated and adaptive system. It might be said that a start had already been made on this by exploiting the myoelectric discharges for control. In such an integrated system, however, the command signal is being derived by tapping the middle of the efferent loop. Such sensory information as returns by afferent channels is derived from the muscles and their tendons. Essentially, this is a backwater of the main stream of the afferent channel of the man-machine complex. It follows that information about the output of the man-machine system can only be inferred rather than known. In my view, Simpson's position-controlled servos and Bottomley's pressure-demand pneumatic valve have more prospects of achieving a truly adaptive output and might be regarded as among the first breaches in the man-machine interface.

Taking all these matters into consideration, besides many other difficulties which I will not discuss for reasons of space, we are in no position to be complacent about externally powered arms. Indeed, the state of the art is so relatively primitive that the only overriding indication for prescribing them at this time is bilateral high-level amputation or the equivalent—only a handful of patients out of the total upper-extremity case load of any prosthetic service and an even smaller proportion of the total case load. The difficulties are so great, and the amount of fundamental information lacking is so formidable, that one is continually surprised at the surge of interest in the field and the amount of effort that is going into it. Indeed the budget for prosthetics research and development in Great Britain for next year envisages that over 30 per cent of the total expenditure will go to work on external power. From what I saw when I visited the United States in May 1967, I would think that a similar proportional expenditure is being made there. Taking into account the tiny number of immediate beneficiaries—although admittedly they are among the most severely disabled—it is proper to take stock and consider whether this level of expenditure of money and effort is justified. Have we got our priorities right? Of course, there is much common ground in the orthotics field, and many developments arising from purely prosthetics requirements would have direct application here. This would increase the number of potential beneficiaries, but they would still be a small proportion of the total disabled population. I think the justification as well as the reason for the interest in the subject is the fact that we believe the possibility of introducing a new order of function to *all* upper-extremity amputees lies in external power and possibly to lower-limb amputees as well.

May I use these pages to make a plea, if not that hardware development should cease, at least that some of the effort should be put into fundamental research into problems such as those I have indicated? Indeed, all of us already engaged in such work should devote sufficient time to discovering what the patient really needs, rather than to providing him with what we think he ought to need.

External Power in Prosthetics and Orthotics, an Overview

JAMES B. RESWICK, Sc.D.,[2]
AND LOJZE VODOVNIK, D.Sc.[3]

THE large number of persons who could be materially helped if highly developed orthotics and prosthetics systems were available is not generally appreciated. The conquest of infectious diseases has increased life expectancy to the point where disability caused by the failure of physiological systems is common in old age. The ever-increasing rate of injuries resulting from vehicle accidents adds to the numbers of paralyzed and maimed, and at the present time the Vietnam conflict is adding its toll.

Detailed statistics are difficult to obtain, but it has been estimated that there are 25,000 to 30,000 amputations per year in the United States from all causes. The Veterans Administration reported 25,000 lower-extremity and 6,000 upper-extremity service-connected cases treated during 1967 (incomplete figures), resulting from several wars. There are no immediately available statistics related to the Vietnam conflict.

Dr. Virginia Badger[4] has estimated the numbers of patients in the United States with various types of rheumatic, arthritic, and neurological disorders, including quadriplegia, as follows:

NATURE OF DISORDER	TOTAL NUMBER
Arthritic and Rheumatic	12,000,000
Neurological Disorders:	
Epilepsy	1,800,000
Cerebral Palsy	550,000
Multiple Sclerosis	500,000
Muscular Dystrophy	200,000
Parkinsonism	500,000
Stroke	2,000,000
Quadriplegia	500,000 (20,000 to 30,000 high level)

Of these patients, Dr. Badger estimates that 2\ million could benefit markedly from orthotic devices, provided that the difficult problems of patient acceptance could be overcome.

Unfortunately, much remains to be done in defining the need more precisely. Many persons suffering from neurological disorders are not recorded in hospital statistics; and, if they are, the nature of their disability is not. The specific types and numbers of disabilities need to be codified in a way which could lead to the development of engineering specifications and decisions on priorities of effort and specific engineering designs.

THE MAN-MACHINE SYSTEM

The human being and his assistive device comprise a man-machine system. When the orthotics or prosthetics system uses external power and is operated by means of feedback

[1] Based upon a paper entitled *Orthotic/Prosthetic Systems*, delivered by Dr. James B. Reswick at an international Conference on Future Goals of Engineering in Biology and Medicine held, under the sponsorship of the National Institute of General Medical Sciences, at the Sheraton-Park Hotel, Washington, D. C, September 8-9, 1967.

[2] Leonard Case Professor of Engineering and Director of the Engineering Design Center, Case Western Reserve University, University Circle, Cleveland, Ohio 44106.

[3] Assistant Professor of Engineering, Engineering Design Center, Case Western Reserve University, University Circle, Cleveland, Ohio 44106, and Associate Professor of Electrical Engineering, University of Ljubljana, Yugoslavia.

[4] Instructor in Orthopaedic Surgery, Washington University School of Medicine, St. Louis, Mo. Data presented at combined meeting of the Panel on Control of External Power and the Panel on Upper-Extremity Orthotics of the Subcommittee on Design and Development, Committee on Prosthetics Research and Development, in New York, N.Y., May 15-17, 1967.

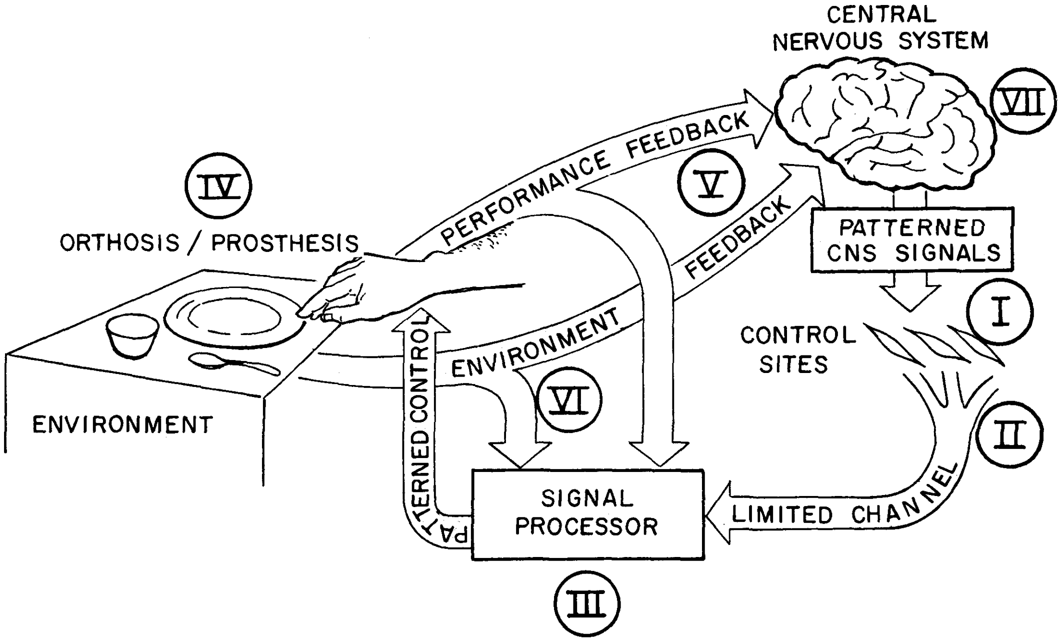

Fig. 1. Elements of a prosthetics or an orthotics system. *I.* Signal Sources: muscle motion, electromyographic, electroneurographic, electroencephalographic, eyeball motion, sound. *II.* Transducers: direct connections, switches, valves, proportional analog, proportional digital, electrodes, radio transmitters. *III.* Signal Processors: on-off, electromyographic, coupled function devices, proportional or velocity control systems, adaptive computer. *IV.* Output Systems: communication devices, environment and tools designed to work with the orthotics or prosthetics system, vehicles controlled by the orthotics or prosthetics system. *IV. A.* Prosthetic: terminal devices, upper-extremity components, lower-extremity components. *IV. B.* Orthotic: splints and casts, implant bone supports, body-powered splints, externally controlled splints, externally powered splints, functional electrical stimulation. *V.* Feedback Receptors: vision, hearing, proprioception, touch, "stereo" vibration, "stereo" electrical stimulation. *VI.* Local Feedback: Pressure sensors, slippage sensors, position, velocity, force. *VII.* Adaptive Learning.

control, the result is a cybernetic system in the true sense of the term. Figure 1 illustrates the possible information paths of an orthotics or a prosthetics system. The following important elements are depicted: I. Signal Sources; II. Transducers; III. Signal Processors; IV. Output Systems; V. Feedback Receptors; and VI. Local Feedback. In addition to these physically identifiable elements, an important element in the performance of the system is the capability of man to learn to use a complex assistive device (VII. Adaptive Learning). Here, age and motivation are important; for example, "thalidomide children" show tremendous learning capacity with complex prostheses, while many geriatric lower-extremity amputees are not able, or are not motivated, to use an artificial leg.

This article will discuss each of the elements of the prosthetics or orthotics system depicted in Figure 1, briefly indicating the present levels of research activity and future possibilities.

I. SIGNAL SOURCES

The human desire to initiate movement of an orthotics or a prosthetics system originates at some conscious level in the central nervous system, but it must take the form of some voluntary physical action if a result is to be achieved. This action may be, for example, a simple muscle movement resulting in the closing of a switch, the pressing of a key, or the very sophisticated use of the tongue (Fig. 2) to activate a keyboard of miniature switches.

Recently, electrical signals associated with muscle and neuron activity have been explored for use as control signals. Although electroneurographic (ENG) signals seem attractive because of their proximity to the central nervous system (3), the practical difficulty of

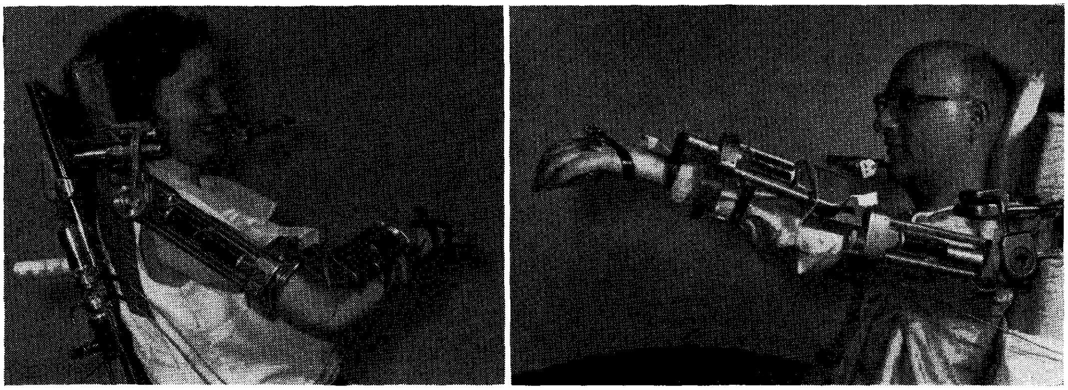

Fig. 2. The Rancho Los Amigos Hospital electric arm orthosis. The various degrees of freedom are actuated by a series of bidirectional microswitches placed in front of the patient's mouth and operated by his tongue. A number of these devices are in use.

maintaining electrodes proximal to nerves in human subjects over extended periods of time has not been overcome. Instead, the more accessible electromyographic (EMG) signals have been used as sources of control signals. Most practical to date has been the use of so-called surface EMG signals obtained by means of electrodes resting on the surface of the skin near a muscle whose electrical activity is to be detected.

A number of prosthetic hands and some hand orthoses have been developed to operate from EMG signals picked up through surface skin electrodes *(5,6,8,9,10,11,12,18,26,38,40,41, 66,76).* More recently, interest has grown in obtaining EMG signals from within a muscle. Such intramuscular EMG signals exhibit a wider range (from single motor unit pulses to signals of many asynchronous pulse combinations) and are more free from "cross talk" resulting from the activity of neighboring muscles *(4,12,13,24,61,62,63,64).* Practical use of intramuscular EMG signals requires either wire electrodes which penetrate the skin and which can exist for long periods of time without breaking or promoting infection (Fig. 3), or the development of implantable radio transmitters capable of long-term operation (Figs. 4 and 5) *(35,37.)* Future research will undoubtedly press in both of these directions.

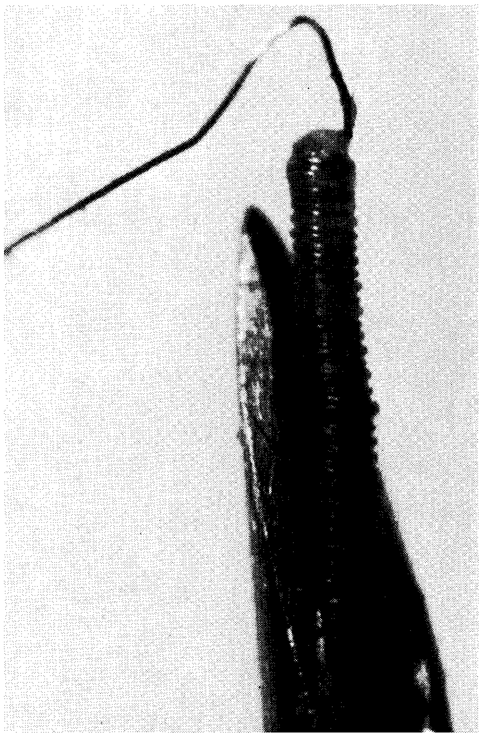

Fig. 3. A monopolar, helically wound, percutaneous electrode. It is used to detect electrical activity within a muscle. The electrode is inserted into the proper muscle by a hypodermic needle which, when withdrawn, leaves the electrode comfortably implanted. A surface connector protects the electrode-skin interface.

Many other sources for voluntary signals from the human being have been suggested from time to time. The electroencephalogram (EEG) signal is often mentioned, but, to date,

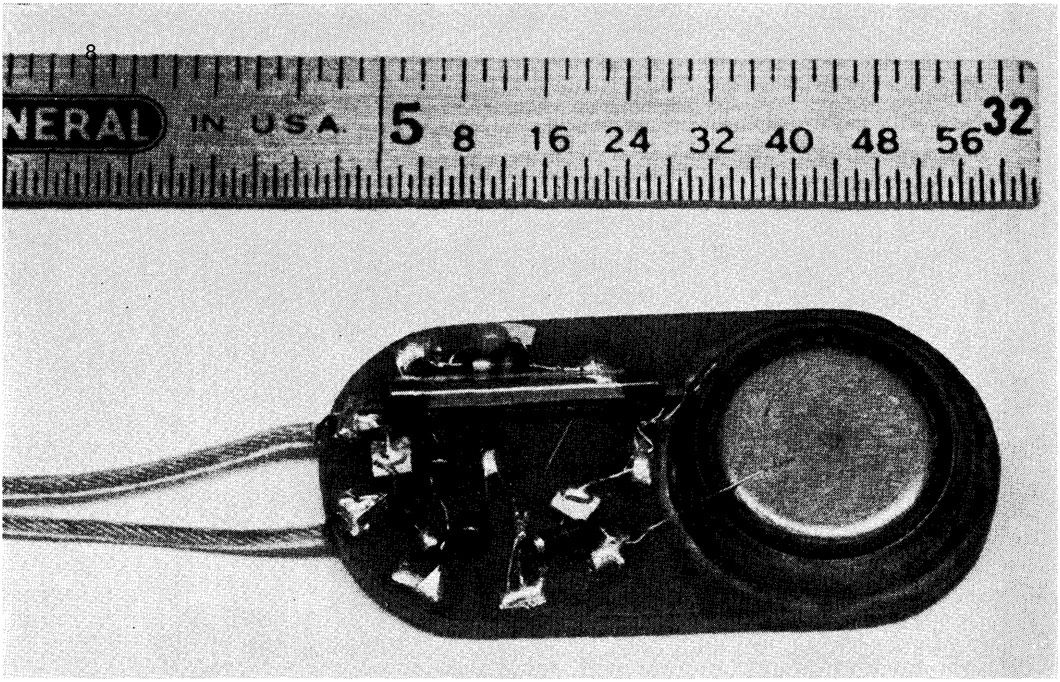

Fig. 4. Miniature FM radio transmitter used to obtain electromyographic signals by complete implantation. The signals are received externally and, after processing, can be used as control inputs in a control system. The transmitter shown will be encapsulated in epoxy and coated with medical grade silicone rubber.

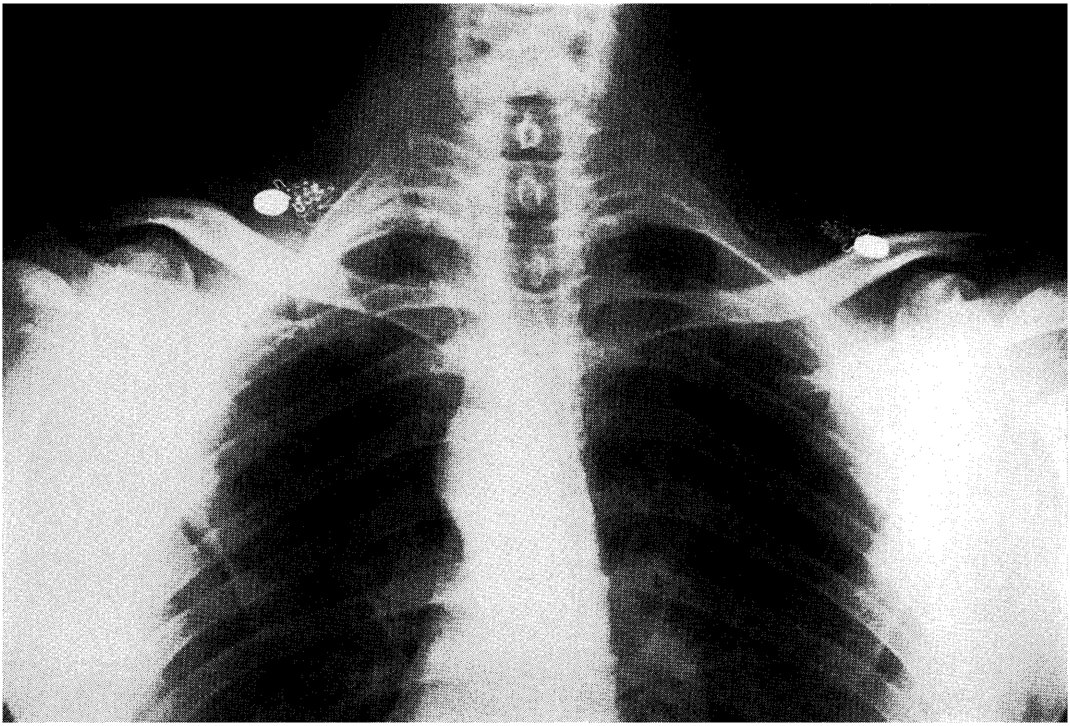

Fig. 5. Transmitters implanted in a human and attached to the trapezius muscles. The electromyographic signal obtained by lifting the shoulder (a motion possessed by many quadriplegics) was used to drive a variable-speed motor, a bidirectional prehensile hand splint, and a multilevel selector. The transmitter was turned on by changing the state of a magnetic switch influenced by an external magnetic field.

it has been used only as an on-off switch responding to the presence or absence of the alpha rhythm *(16).* Enticing as the idea may be, many years must pass before thoughts will will be transformed directly into meaningful electrical signals.

The human voice, including whistles and the like, has been proposed and used as a signal source. Much research at present is devoted to machine recognition of human speech for voice-operated typewriters and for speaking directly to a computer *(56).* These efforts show promise, but they are probably far too complicated at present to be considered for use in a prosthetics or an orthotics system. The human eye has also been used to switch devices by means of ultrasonic and infrared reflections *(67).* Unfortunately, many such promising sources of control signals are involved in the normal activities of living, such as eating, looking around, speaking, and the like. This could be a disadvantage when the patient desired to control his orthotics or prosthetics system with a signal such as sound while he was talking or eating *(14).*

II. TRANSDUCERS

Transducers are the devices used to change physiological phenomena into engineering signals that provide inputs to signal processors and output systems. A transducer may be as simple as an on-off switch or as complicated as an implantable FM radio transmitter. Some elements of orthotics and prosthetics systems are difficult to classify. Bowden cables used to transmit shoulder movements to an amputee's terminal device are an example. More recently, hydraulic systems which function as a wire cable have been demonstrated *(54).* Such systems combine the roles of transducer and actuator in a single unit.

Electric switches and pneumatic-hydraulic control valves which convert body movements into changes in electric current or fluid flow are highly developed. Many types of reliable, very small electric switches have been easily adapted to prosthetics and orthotics systems, but, in the case of hydraulic and pneumatic control valves, it has been necessary to develop a number of appropriate special valves.

Not so widely used in prosthetics and orthotics systems, but highly developed for general instrumentation purposes, is a wide range of proportional analog and digital transducers capable of converting pressure or movement into voltage or current changes. These devices range from analog potentiometers and capacitive and inductive devices which convert motion to smooth voltage changes, to linear transducers which produce pulse-coded signals proportional to incremental changes or absolute position. Also available are the very ingenious accelerometers and other motion transducers developed for space research and guidance control systems. Accelerometers have been used in at least one head-motion-activated control system *(65).*

Generally speaking, the mechanical-to-electric transducers have been highly developed, but only limited use has been made of their capabilities in prosthetics and orthotics systems. This does not imply, however, that a number of mechanical - to - electric transducers are immediately available for use in prosthetics and orthotics systems. An actual application often requires either a major redesign or a new design to take into account the unique problems inherent in physiological-data transduction. It is appropriate to mention here the National Aeronautics and Space Administration's Space Technology Utilization Program, in which NASA is actively searching for ways to apply transducers developed for space applications in orthotics and prosthetics systems.

The recent interest in electrophysiological signals for control of orthotics and prosthetics systems has focused attention on the development of electrodes. A large variety of surface electrodes used in electrocardiographic diagnosis and long-term monitoring systems is already available. From space technology come the "spray-on" electrodes and other surface electrodes used in telemetry and in obtaining physiological data from astronauts.

Two main approaches exist for obtaining EMG signals from within a muscle, namely: percutaneous wires inserted by means of hypodermic needles; and surgically implanted radio-transmitting devices. In the first method, wires leading through the surface of the skin from inside the muscle must be capable of flexing as the muscle moves and maintaining contact with motor units for many months. Present indications are that tissue-reaction and infection at the point of exit from the skin are minimal. Some newly developed silastic-impregnated spiral electrodes show promise of solving the problem of mechanical reliability *(75).* Similar problems exist for the electrodes of surgically implanted devices. In fact, the electrodes may well prove to be the weakest link in a biotransmitting system. It is well known that electrode failures in heart pacers continue to be a vexing problem. Research will continue to find ways to prevent metal fatigue and to discover contact materials which produce no body-tissue reaction, and which do not corrode and weaken.

In the foregoing paragraph, electrodes were discussed in the context of signal-sensing devices. Their importance is much more critical in transducers used for the electrical stimulation of muscle, as in the case of functional electrical stimulation to be described later on in this article, and in heart pacemakers and bladder stimulators, which have been excluded from this discussion of orthotics and prosthetics systems. The relatively higher currents associated with electrical stimulation, as compared with detection of electrophysiological signals, create problems. It is believed that the material, corrosion, and tissue-reaction problems associated with electrodes for picking up signals are not severe and can be easily overcome through present technology.

Electrical powering, long-term body acceptance, and sealing of the package are the issues around the active transmitters used for detecting electrophysiological signals from within the body and the passive and active implantable transducers for electrical stimulation of muscles. At present, all such experimental devices are powered by mercury cell batteries. Much effort is being devoted to minimize total electrical power requirements and to obtain electrical energy from within the body through mechanical and chemical transformers *(31,36, 51,52,59).* Battery-powered biotransmitters of a total size of 0.1 cu. in. have operated continuously for 200 hr. and, intermittently, over a three-month period in dogs. An EMG transmitter was first implanted in a human being in Sweden in 1966 *(25).* More recently, one was implanted in a subject in Cleveland, Ohio *(75).* Many problems remain to be overcome before such transmitters can be used routinely in the clinical situation, but progress with packaging techniques which produce no tissue-reaction in animals over long periods of time, and with electrode designs which can survive mechanical and electrolytic effects, indicates that prototype systems will be evaluated in human subjects within the year.

III. SIGNAL PROCESSORS

This discussion of signal processors is concerned primarily with the special electronic and computer-type systems used for converting low-level control signals containing noise and artifacts to useful, high-level input for orthotic or prosthetic devices.

Although not specifically designed for signal processing, the mechanical and hydraulic characteristics of many systems may be viewed as signal processors. For example, the speed of response of a gas-powered orthotics or prosthetics system is often limited by the size of the valve openings and tubing used in the system. In this way, the on-off characteristic of the valve is converted inherently into a velocity output and is so observed by the patient. In fact, subjects are often very much aware of the noises and speeds of response associated with their control devices, and improve their skills with practice and knowledge of how the system will perform for given input operations.

Signal processors designed specifically to alter electrical wave forms include a wide range of circuits used for processing EMG information. Most such circuits involve rectification, integration, and various nonlinear components used to reject noise and provide the smoothest possible electrical systems for operating the orthotic or prosthetic device. Since the EMG signal, especially when detected from within the muscle, consists of an asynchronous train of pulses, signal conditioners based upon digital - signal - handling theory are being developed. Some of these systems would "clean up" the pulse signals from within a muscle to the point where they might be used as direct signals into a digital computer.

Under another kind of theory for signal processing, combined or patterned functions are produced from one or more inputs. Among body-powered orthotic devices, the linkage feeders widely used by quadriplegics are an example *(6,29,30)*. These mechanical linkage systems support the forearm and allow the patient to convert shoulder and trunk movement into controlled movement of his hand. When given a controlled prehensile function, patients often learn to feed themselves and perform many other useful tasks. Externally powered arm prostheses have been designed for children, with coupled movements such that the programmed movement of an eating implement is obtained by the child through a single input action *(48,49)*. The conversion of a single input action to interrelated movements of each part of the prosthesis may be regarded as a type of signal processing, especially when one considers the possibility of using an electrical computer to do the same sort of thing. The sophisticated prosthetic hands built in France and, more recently, in Yugoslavia and Japan *(44,46,58,69,70)*, in which a simple set of input signals is mechanically converted to a smoothly closing movement of all fingers, constitute a type of signal processing.

Another type of signal processing is found in the automatic control systems used in some orthotic and prosthetic devices (Fig. 6). Recently, interest has developed in systems possessing automatic proportional and velocity control. Such systems differ from so-called "open-loop" systems in that feedback position or force signals are fed back to the control system itself rather than the patient. The patient provides command signals, such as a new position, to which the control system automatically responds. Such techniques have not been widely used in orthotics and prosthetics systems to date, but they have been

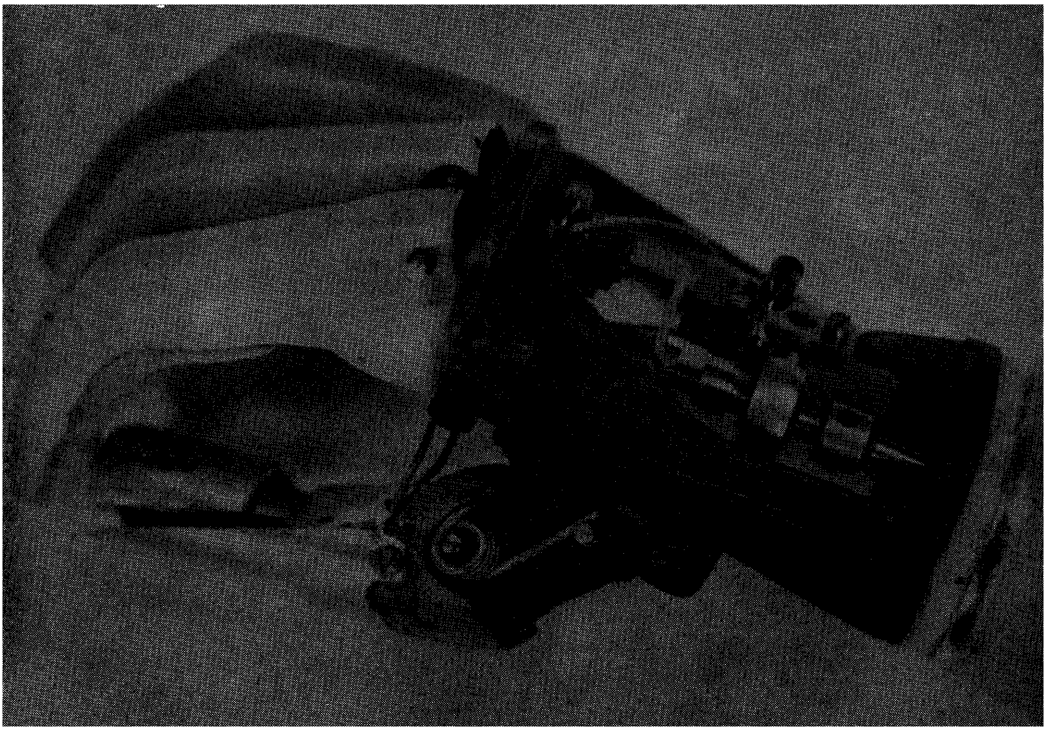

Fig. 6. A prototype automatic prehension system developed at the Army Medical Biomechanical Research Laboratory. It includes miniaturized electronics, a motor-driven No. 4 hand, and a thumb sensor. A cosmetic glove is worn over the assembly.

demonstrated in research prototypes and will probably find increasing application *(60).*

Most human motor activity is a combination of direct conscious control and patterned movements which are coordinated at levels below the conscious nervous system. Many research projects are now concerned with using computers or high-speed data processors to perform for an advanced prosthetics or orthotics system what the lower motor neuron system does for the human being. The problem is essentially one of information-channel capacity, wherein much information may be required to control a complex device but only limited channels are available for converting the desires of the patient into electrical command signals *(20,43).*

One approach to this problem was the Case Research Arm Aid, Mark I (Fig. 7) *(14),* which used a computer with pre-programmed tapes for a number of activities of daily living. The quadriplegic patient was required to select the portion of tape appropriate for the action he wished to accomplish, but he did not need to be actively involved once the action had started. More recently, proposals have been made for using computers adaptively to learn to provide patterned functions. The idea would be to store within the computer patterns or subroutines for elementary body movements which combine to produce walking or upper-extremity movement. The subject would then provide only "coarse" information about where he wanted his limb to go, and the computer would calculate according to some pre-programmed strategy how best to move his limb most efficiently from one place to another. The tremendous progress in machine computation has opened unlimited possibilities for research in such systems which can be reduced

Fig. 7. The Case Research Arm Aid, Mark I. The pneumatic system shown allowed five degrees of freedom through the shoulder, arm, and wrist. Modifications being made include conversion from a pre-programmed tape control to computer-calculated trajectories by means of myoelectric input control signals.

practically to patient needs. One can visualize, for example, a paralyzed leg being electrically stimulated according to a patterned program stored in a solid-state, micrologic computer worn on the belt. Although such a system can be imagined, it will be many years before it is technically and economically feasible *(47,71)*.

IV. OUTPUT SYSTEMS

In the past, most of the research, development, and clinical application of orthotics and prosthetics systems has been concerned with the output systems, for these are the hardware devices which perform the functions required by the handicapped person. Through intuition, designers have shown awareness of control and feedback, but their attention has been primarily directed toward the powering and fitting of devices to improve the function of the handicapped.

Almost all the elements in the man-machine systems are applicable to both orthotics and prosthetics; but, when output systems are considered, it is necessary to discuss orthoses and prostheses independently, except for certain communication devices which apply to both. For example, much effort has been devoted to modifying telephone, recorder, typewriter, radio and television equipment for easier use by handicapped persons. Touch dialing, alone, is an important asset. Tape-recording and typewriters operated through coded signals from the tongue or voice make it possible for the paralyzed person to carry on a business and communicate with friends.

In addition to communication devices, attention has also been given to the development of special tools and machines so that the handicapped can perform useful work. Interestingly, much of the philosophy in the development of such tools is common with the development of special tools for astronauts to use in space. This occurs because the normal man in an alien environment is similar in many respects to the handicapped man in a normal environment. Vehicles for the transportation of handicapped persons, including powered wheelchairs (Fig. 8) and modified automobiles, must also be included in output systems for the handicapped.

Prosthetics

The term "prosthesis" brings to mind artificial hands, arms, and legs. The historical development of these artificial limbs is an extensive and fascinating study in itself. Although seemingly simple and perhaps crude, the cable-controlled, rubber-band hooks commonly used by below-elbow amputees are, in fact, quite sophisticated, and many amputees have developed remarkable dexterity with them. Probably many years will elapse before the users of EMG-controlled, electrically powered hands achieve the same level of reliability and dexterity now found in thousands of skilled hook-users around the world.

The problem is much more severe for the above - elbow and shoulder - disarticulation amputee, especially the bilateral case. It is a fact that when a patient has one good arm the margin of increase in function provided by a prosthetic second arm is often too small to make it worth his while to learn to use it. Much effort is now under way to provide improved functions for high-level amputees, especially bilateral cases. The most successful systems to date are powered by gas or electricity *(2,19,28,32,33,34,50)*. Each clinical application represents a major engineering achievement, and each one is usually somewhat different from all others. This is the real limitation in the development of sophisticated upper-extremity systems, for the problem of fitting and the nature of disability are so different among the relatively limited numbers of amputee patients and congenitally deformed children that the sophisticated engineering required is often economically unjustified. However, the obvious challenge presented by the creation of an artificial human limb continues to fire the imagination of engineers throughout the world, and one may expect continued progress.

The case for the lower-extremity prostheses is somewhat different, because a man cannot walk with just one leg. Much effort has been devoted to developing lower-extremity prostheses for both above-knee and below-knee amputees. A successful prosthetic application requires close collaboration between the orthopaedic surgeon and the prosthetist. Thoughtful

Fig. 8. Ampersand Research, Highland View Hospital, three-level electromyographic control of wheelchair and flexorhinge splint.

planning concerning the nature of the stump to be produced can make a great difference in the effectiveness of the final prosthesis. Walking is one of the most sophisticated patterned functions in man. Many muscles are interrelated in producing a gait of minimum energy expenditure. One area of intensive research has been the study of human gait in order to improve the design of lower-extremity prosthetic and orthotic devices. Although considerable data have been gained through cinematography and EMG studies, there is still much to be learned, and one can expect continuing research in this area *(27,53).*

Lower-extremity prostheses are more complicated than one might imagine. The acceleration sequences required for normal human gait are not produced by a simple pendulum swing. Instead, one must build nonlinear damping devices into a lower-extremity prosthesis to control the swing phase so that it will approximate that of a normal human being. In the simplest versions, disks of leather are used to provide this friction. Recently, nonlinear and hydraulic devices have been built into artificial limbs. These hydraulic devices still suffer occasionally from seal and other failures, but they have been successfully used by amputees under a Veterans Administration evaluation program.

The problem of socket design and fitting is still under investigation, for one must transfer considerable forces to the limb, both in direct compression and in torsion. Sockets providing total-surface contact, air cushions, "breathing effect" and special types of support have been developed. For a number of years, researchers have attempted to measure the pressure distributions occurring under dynamic conditions within lower-extremity sockets. In general, these attempts have not been successful, and this remains a challenging area for future research. Such pressure-distribution data are urgently needed for the intelligent design of lower-extremity prostheses and, in some cases, for upper-extremity devices.

Orthotics

The first orthoses were the splints used to support a fractured limb and the canes and crutches used by early man. Bracing of weakened limbs due to neurological disorders and the therapeutic appliances used to overcome deformities have been widely applied by the orthopaedic surgeon and his collaborating orthotist. Through surgical reconstruction and tendon transplants, the orthopaedic surgeon can provide concepts for rehabilitation which complement improved engineering systems *(1,23).* The future possibilities of such combined surgical intervention and engineering systems development have been only hinted at and much research undoubtedly will be carried on between the engineer and the surgeon in this area.

A number of new, externally powered, and controlled splint systems are being made available to paralyzed patients. A kind of race is now occurring between the proponents of gas-powered orthotics systems and electrically powered systems. Actually, these systems are highly competitive when one considers the energy-storage capacity and weight of motors and batteries as compared to gas actuators and storage containers. The gas-powered systems still provide the best force-to-weight capability, but electric motors are being improved continuously and the overall simplicity of an all-electric system has many advantages *(22,57).*

A number of prehensile splints to provide grasp to paralyzed patients have been applied routinely, and many new multiaxis powered splints are being applied *(2,19,28).* As in the case of the complex prosthesis, the need for many different approaches to meet the many different types of disability in paralysis or neurological disorders has slowed down the broad development of externally powered orthotic systems. We believe, however, that engineering developments will soon reach the point where such systems will be widely applied to the very large number of patients who can benefit from increased functions, especially in old age. Expanded research and development in externally powered orthoses for both upper and lower extremities is certainly going to occur.

A promising new approach is being investigated throughout the world. This approach suggests the use of electrical stimulation of muscles for functional activity *(15,17,21,39,42,* *73,74).* While electrical stimulation of muscles has been used extensively for a number of years in diagnosis and in therapy, its use for functional action has only recently been studied. The increased sophistication of electronic systems and the possibility of passive and active implants suggest the realization of controlled muscle activity. Such systems would certainly operate in parallel with some sort of external functional bracing, for in the foreseeable future one can imagine only a limited number of agonist and antagonist muscles being functionally stimulated.

There is much to be learned about whether denervated muscles can be kept in an active stimulatable condition for long periods of time and whether intact lower motor systems will respond to controlled stimulation without inducing spasticity and other aberrations. The progress to date, however, is exciting and it is urged that serious consideration be given to programs of electrical stimulation of the muscles of recent victims of neuron lesions so that the atrophy of involved muscles can be retarded awaiting the day that functional stimulation can be made available.

Expanded research around the understanding of the process of functional stimulation and physiologic factors in muscle stimulation, both from a physiological and an engineering point of view, is to be expected.

V. AND VI. FEEDBACK RECEPTORS AND LOCAL FEEDBACK

A human being controlling either the most simple or the most complex assistive device must have feedback information. In normal human motor activity, feedback comes via sight, sound, touch (pressure), and proprioceptive senses. These normal feedback channels are always impaired to some degree in handicapped persons and may be altogether missing. The visual path is still the most important for control in most orthotics and prosthetics systems, but much research has been undertaken recently to relieve the patient of the need to keep his eyes consciously fastened on each part of an output task. The sounds of electric motors and gas-operated systems provide many cues for feedback control, some of which may not be consciously appreciated by the subject. Many amputees learn to interpret reflected forces and motions through Bowden cables and other body-powered components.

Much interest in sensory feedback research has been shown throughout the world, but only minimal progress has been made to date. Stereo effects are also being investigated, including transducers which produce vibration of varying phase and intensity at two points on the surface of the skin from which a sensation of spatial position proportional to an actual position can be produced *(68).* The possibility of producing a similar spatial position sense through "stereo" electrical stimulation at two different points on the surface of the skin is also being investigated.

Recently proposed orthotics and prosthetics systems, using data processes, may require local feedback which is not processed by the human. Figure 1 indicates some paths which are analogous to some afferent paths in lower motor neuron systems in the human. Systems to select the grasping pressure in terminal devices have been developed. A recent approach to the problem at the Army Medical Biomechanical Research Laboratory uses a sound pickup to detect incipient slip in lieu of pressure to modulate the force applied in an artificial hand *(60).*

To date, feedback control of orthotics and prosthetics systems has been severely limited by the inability to provide effective artificial sensory feedback, and will constitute a major barrier to overall system effectiveness for some years to come. It seems clear that a maximum research effort should be made to develop effective pseudosensory feedback signals, not only for orthotics and prosthetics systems, but also for sensory aids to the blind and deaf—areas which are, of course, closely related.

VII. ADAPTIVE LEARNING

The success of any orthotics or prosthetics system or device must depend on acceptance by a patient and his abilty to learn to use it effectively. If the device proves to be more trouble than it is worth, it will be rejected. Thousands of rejected devices now rest in closets and dark corners.

An important element of an orthotics or prosthetics system is the capability of a

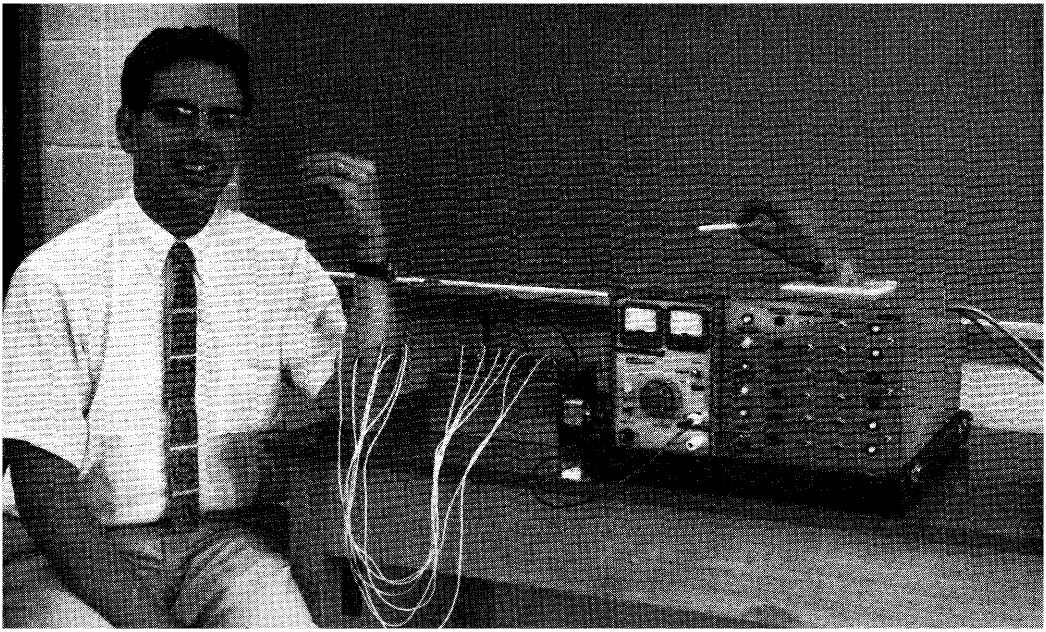

Fig. 9. A test of the feasibility of exercising three degrees of freedom by means of myoelectric control. Six muscle sites received percutaneous electrodes, all in the forearm. The six sites were then connected to a model hand trainer possessing three degrees of freedom. The motions of the trainer could be controlled to correspond with those of the control muscles.

patient, whether young or old, to learn to employ his device skillfully *(72).*

As new systems become ever more complex with many degrees of freedom (moving elements), the problem of control becomes more difficult *(45,46,78).* One may visualize a multiaxis orthosis controlled by EMG signals from six or more voluntarily excited muscles (Fig. 9). An unanswered question remains as to how well the patient can train the six or more muscles to perform the functions required, especially when the functions may be very different from those for which the muscle was naturally used. The authors have discussed this difference between so-called naturally conditioned communication channels (NCCC) and operant-conditioned communication channels (OCCC) (Fig. 10) *(75).* It appears intuitively correct to use the naturally conditioned channels wherever possible as signal sources for natural functions. The EMG-controlled artificial hands previously referred to use signals obtained from the prehensile extensors and flexors so that the amputee may open and close his artificial hand with the same muscles he would have used prior to the amputation. However, as degrees of freedom increase and the nature of the disability precludes naturally conditioned sources, one is forced to employ other muscles, such as the auriculares muscles behind the ears *(7)* or the trapezius muscles in the shoulders, as signal sources.

It is clear that much research on these issues remains to be done. Age is certainly an important factor, for it is known that young children adapt very much more easily to orthotic and prosthetic devices than do older persons. Learning capability is closely related to the amount of information being received by the patient through his feedback channels and to the amount of patterning and programming that can be done at the signal-processing level. No doubt the future will bring clarification of these matters.

EVALUATION

Before closing, a major problem which continues to face the American orthotics and pros-

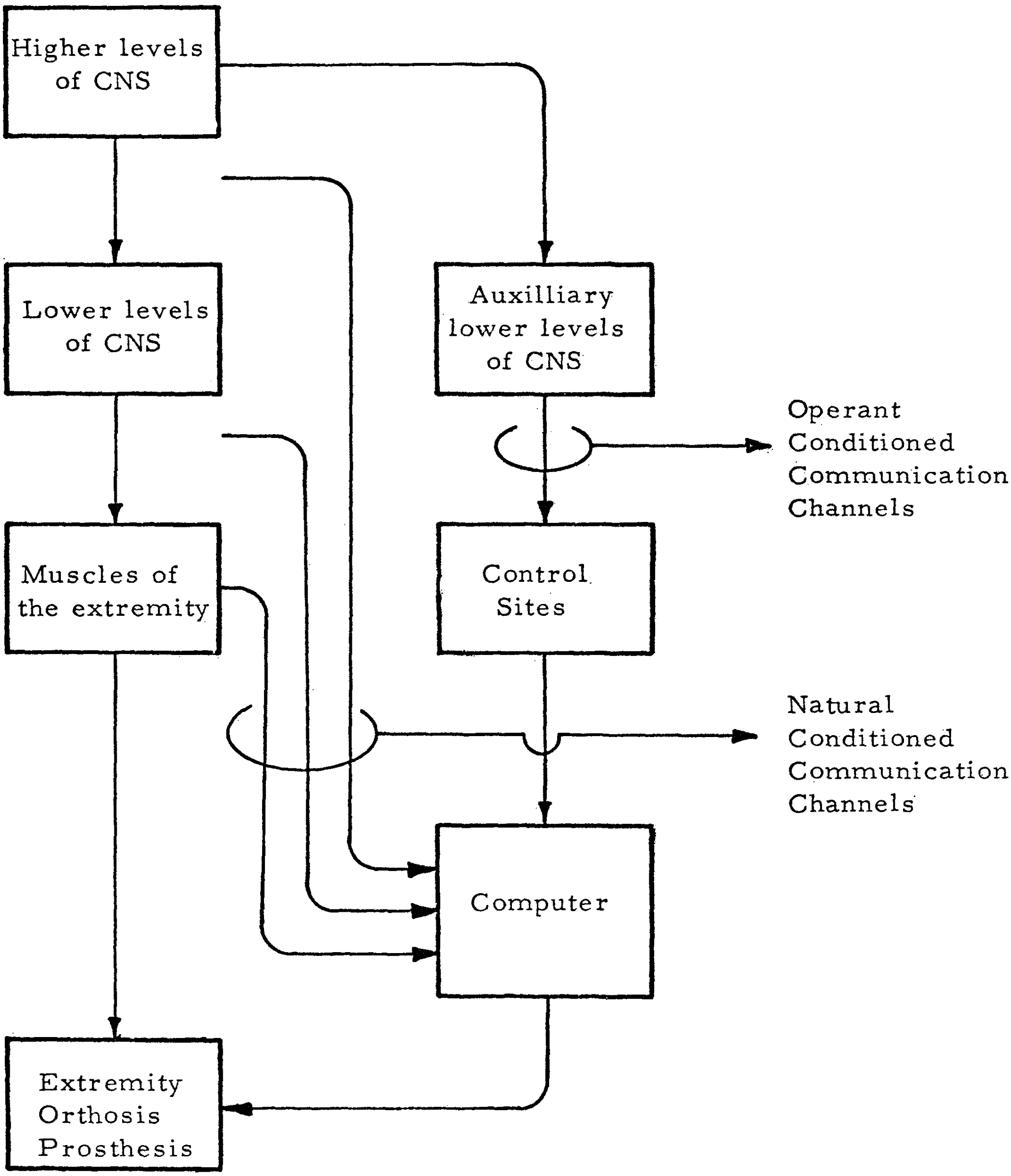

Fig. 10. Schematic representation of naturally conditioned communication channels (NCCC) and operant-conditioned communication channels (OCCC).

thetics research, development, and clinical application program should be mentioned. This is the important issue of effective *evaluation.* Evaluation does not stand alone as a specific activity. The theory that a prototype developed by one group can be taken over by a separate evaluation agency to determine if it "works," and if it works can then be taken over by a manufacturer for production, just does not often succeed in practice. Problems in the medical engineering field of prosthetics and orthotics development are immensely complicated, and often the true nature of the problem to be solved is not understood until one or two attempts have been made at solution. A constant interplay between the needs of the patient, the requirements of the physician, and the technical development by the engineer must be maintained. It is the rule, rather than the exception, that most new developments brought to the prototype stage require continued research and redesign. It seldom happens that a first-prototype development can be picked up and replicated in quantity for the field.

The implication of the foregoing remarks is that the evaluation process is a continuing and integral part of the overall design-development process and is perhaps the hardest and most expensive part. To date, inadequate funds have been allocated for its accomplishment in grant programs. The result has been that not nearly so many fruits have accrued from the research and development programs as might otherwise have been the case.

The specific need could be met by providing an overall systems-management function for the broad spectrum of activities throughout the nation. This systems-management function would be a cooperative effort authorized by federal government agencies and their advising groups. The lessons learned by the National Aeronautics and Space Administration in the management of the space effort seem applicable here, and it is the strong recommendation of these authors that the need for systems management in the broad field of orthotics and prosthetics research and development be recognized.

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Need for Research in Surgical and Medical Considerations Dealing with Prosthetics and Orthotics

GEORGE T. AITKEN, M.D.[2]

The discussion of the Panel on Surgical and Medical Considerations at a Conference on Prosthetics and Orthotics sponsored by the Committee on Prosthetics Research and Development was divided into two parts—those considerations dealing with prosthetics and those dealing with orthotics.

PROSTHETICS

Much fundamental work in the area of amputation surgery remains to be done, as briefly outlined in this article.

INDICATIONS FOR AMPUTATION

It is believed that the modern methods of amputee management may have made amputation a more desirable procedure now than some reconstructive procedures currently in use, and the entire field needs a comprehensive review.

[1] Based upon the report of the Panel on Surgical and Medical Considerations of a Conference on Prosthetics and Orthotics held, under the auspices of the Committee on Prosthetics Research and Development, at the National Academy of Sciences, Washington, D.C., December 12-13, 1966. Funds to support the conference were supplied by the Vocational Rehabilitation Administration, Department of Health, Education, and Welfare.

[2] Orthopaedic surgeon, College Avenue Medical Building, 50 College Ave., S.E., Grand Rapids, Mich. 49503; Chairman, Subcommittee on Child Prosthetics Problems, Committee on Prosthetics Research and Development. Dr. Aitken served as Chairman of the Panel on Surgical and Medical Considerations of the Conference on Prosthetics and Orthotics.

SELECTION OF LEVEL OF AMPUTATION, ESPECIALLY IN CASES WITH VASCULAR INSUFFICIENCY

No reliable test for measurement of circulation in the extremities exists. As a result, it is the practice in many centers to amputate above the knee in virtually all cases with peripheral vascular disease. However, it has been shown that many times the knee joint can be saved even when standard tests indicate that the blood supply is apt to be insufficient. Objective tests of circulation coupled with surgical studies should result in more below-knee amputations and fewer above-knee amputations.

SITES OF ELECTION OF AMPUTATION

Although it is generally agreed that all length possible should be saved, a study should be made in which length of stump is correlated with function and comfort when current fitting practices are used.

SURGICAL TECHNIQUES

A comprehensive review of surgical techniques should be made. This should include special attention to the care of transected muscles.

The advantages of end-bearing and how much should be carefully reviewed in order to determine whether different techniques, such as myoplasty, osteoplasty and nonviable implants, should be vigorously tested in order to obtain varying degrees of end-bearing. Muscles that must be transected may eventually be control points for externally powered devices and careful attention must be focused on the preservation of their optimal ability to provide control sources such as myoelectric signals or pure biomechanical motion.

POSTSURGICAL PROCEDURES

Rigid Postsurgical Dressing

There was agreement that the application of a rigid dressing postsurgically is desirable. To achieve the best results consistently it is necessary to determine the range and distribution of pressures that bring about the best results. Techniques for achieving and maintaining proper pressure will then need to be developed. Included in this study, of course, will be the problems of suspension of the cast.

Ambulation

Studies of the effect of ambulation should be made. Included in such studies would be such factors as time to begin ambulation, the amount of weight-bearing that should be taken, and alignment.

Effect of Immediate Postsurgical Fitting on Cases with Vascular Problems

In the opinion of some, immediate postsurgical fitting permits amputation at a lower level than is the case with conventional procedures, but no data have been accumulated to substantiate this opinion. This should be investigated, because the presence of the "normal" knee joint permits meaningful function that cannot be approached with an artificial limb and provides a much better chance for rehabilitation measures to succeed.

Immobilization of the Next Proximal Joint

Although it is recognized that a study of the effect of immobilization of the next joint in the early stage of immediate postsurgical fitting is a part of the overall suspension problem, it was recommended that attention be given this matter.

THE PHANTOM SENSATION

Although a good deal of work has been carried out in the study of the phantom sensation, especially in reference to phantom pain, very little is understood about these phenomena. It is felt that attention should be continued in this area.

ORTHOTICS

Out of a general discussion of the surgical and medical considerations in orthotics, three broad recommendations developed.

1. There is an urgent need for the development of criteria for the design of bracing based on the biomechanical needs of patients. Perhaps a system of classification of disability based on biomechanics is not only the proper approach to criteria development but, when brace components are related to it, a sounder basis for prescription can be developed.
2. Little is known about the response of human tissues to the application of pressure, yet every function of an orthopaedic brace involves the application of pressure. Studies on the effect of pressure are needed before it is possible to determine the efficacy of certain treatment procedures, especially some of those for children.
3. Studies involving buried and partially buried implants for facilitating control of externally powered devices should be continued.

Need for Research in Fundamental Biomechanical Studies[1]

J. RAYMOND PEARSON, M.S.M.E.[2]

The Subcommittee on Fundamental Studies of the Committee on Prosthetics Research and Development is interested in the promotion of scientific and technological investigations that are fundamental to applied research studies of prosthetic and orthotic devices. Hopefully, the results of the subcommittee's efforts will lead to the establishment and dissemination of knowledge that is of common interest to researchers and clinicians concerned with the design and development of assistive devices.

Past experience with such research and its current state of development suggest that future studies should be made in the areas outlined in this article.

CONCEPTS of METHODOLOGY

SYSTEMS ANALYSIS

It is believed that the application of modern techniques of systems analysis to discern and clearly define the needs of the disabled could lead to the establishment of appropriate specifications for use in the design of devices.

[1] Based upon the report of the Panel on Fundamental Studies of a Conference on Prosthetics and Orthotics held, under the auspices of the Committee on Prosthetics Research and Development, at the National Academy of Sciences, Washington, D.C., December 12-13, 1966. Funds to support the conference were supplied by the Vocational Rehabilitation Administration, Department of Health, Education, and Welfare.

[2] Professor of Mechanical Engineering, University of Michigan, Ann Arbor, Mich. 48104; Chairman, Subcommittee on Fundamental Studies, Committee on Prosthetics Research and Development. Professor Pearson served as Chairman of the Panel on Fundamental Studies of the Conference on Prosthetics and Orthotics.

THE DISABLED CONDITION AS IT AFFECTS EXPERIMENTATION AND EVALUATION

Studies of the disabled condition should include investigation of psychological reactions to the use of prosthetic and orthotic devices. Thought should be given to the interplay of psychological and physiological reactions to the application of constraints and restraints. A study of the interactions of physiological systems might prove to be beneficial since it is apparent that there is an interplay of effects from one anatomical system to another.

DISABILITY EVALUATIONS

Corrective assistive devices alter the joint of the musculoskeletal system. Since positions, forces, kinematics, or stresses of the original condition may be changed by the therapeutic device, it is essential that the biomechanics of the normal, abnormal, and treated condition be well understood. This information is necessary for the proper use of such devices and the design of improved devices.

The biomechanical analysis of any system must necessarily be preceded by an adequate, accurate description of the system. If forces are involved, it is essential to know the points of application of the forces and the direction of forces applied either by muscles or by constraining passive tissues such as ligaments.

The addition of an assistive device to any part of the anatomy results in a hybrid mechanical-anatomical system. Complete understanding of the effect of such assistive devices rests upon the proper analysis of the hybrid system as a whole.

Analysis rests upon quantitative data which can be secured only by measurement. Taking such measurements often involves the design and development of the experiment and instruments. This subject in itself is a worthwhile area of investigation.

SPECIFIC RESEARCH AREAS

FUNDAMENTAL PHYSIOLOGY OF MUSCLE

Inconvenience, negative psychological reactions, and the complexity of design of exoskeletal devices all lead to the hope that one day it may be possible in appropriate cases to stimulate muscles which have been denervated by trauma or disease. Some research in this area has been conducted, but very little is known about the optimum type of stimulation, the response characteristic of stimulated muscle in the disabled condition, and the ultimate possibility of using electromyographic signals of one muscle to control stimulation of another.

Since muscles represent the actuators of the musculoskeletal system, it would be helpful to know more about the mechanical characteristics of muscle in terms of its strength, endurance, and efficiency. Hopefully, modern methods of measurements would permit the accumulation of quantitative data *in vivo* if research were pursued in this direction.

While upper and lower motor neuron lesions usually lead to atrophy of associated muscles, it has been shown that exogenous stimulation of muscle counteracts atrophy to some degree. If research should lead to solutions of this type, it will be necessary to know more about stimulative hypertrophy of muscle.

BODY AND DEVICE MECHANICS

Data for proper design of orthotic and prosthetic devices require a knowledge of existing force capacity and range of motion for both normal and various selected abnormal conditions of frequent occurrence. It would be of much benefit to the designers to have such data assembled in a convenient reference volume.

More knowledge of the kinematics and kinetics of the upper extremity, comparable to that of the ambulation cycle in the lower extremity, would also represent essential and valuable data for the design of devices. The existence of accelerometers and potentiometers for measurement of inertia forces and position facilitates the gathering of such information by experimental means.

Recent advances in the art of simulation of linkages in engineering suggest that the musculoskeletal system of the upper extremity can be treated in a manner that will permit study of the effects of constraints or supplemental power to upper-extremity orthoses. It may prove to be possible to optimize designs with regard to various possible constraints to meet the needs of common motion patterns.

COMPARISON OF MECHANICAL WORK AND PHYSIOLOGICAL ENERGY CONSUMPTION OF NATURAL AS WELL AS PATHOLOGICAL MOVEMENTS

Since one of the important criteria of evaluation of assistive and prosthetic devices is the conservation of the energy of the patient, it would be most helpful to devise ways and means of measurement of physiological energy consumption of discrete muscles or muscle systems for a determinable quantity of mechanical work output in the performance of needed tasks. While total oxygen-consumption measurements have been made for subjects with and without assistive devices in ambulation, very little has been done with regard to the upper extremity, particularly for discrete activities.

CONTROL MODES AND LOCATIONS IN PATIENTS

Underlying the problem of control of external power by electromyographic signals is the problem of proper association of biological signal and motion to be executed. In the case of amputation, the existence of the electromyographic signal of a remote muscle might be used as a control signal. However, this involves a retraining procedure for the subject. The improper or irrational selection of a control site may lead to an excessively complex learning procedure that would defeat the purpose of the design. The effects of paralysis may bring about a similar situation where the cause is a pathologic condition other than amputation. In any event, the success of any external power system controlled by electromyographic signals is highly dependent upon the rational selection of the site from which the biological signal is taken. The pursuit of such knowledge is highly important to the success of electromyographic control.

Recent investigations of the feasibility of single motor units of muscles as a source of biological signal for controlled purposes indicate the value of pursuing this idea as an eventual method of associating thought processes with limb action. Such solutions should lead to utilizing a portion of the muscle signal without impairing the usefulness of the muscle for its original intended purpose. As this study is in its infancy, considerably more information is needed in order to evaluate its potential.

RHEOLOGY OF HUMAN TISSUE

In the study of the biomechanics of joints, it becomes evident that the forces applied through bones find their reactions in the soft, passive tissues of constraint. Relative displacements of the bones of the joint are then a function of the mechanical characteristics of these tissues. The stress-strain ratio of the collagen tissue of tendon has been shown to be rate dependent for low and moderate rates of loading. Also, strain is a function of time; the tissue shows a recovery capacity when unloaded, demonstrating that viscosity plays a role in the mechanism of response. Investigations of some of the factors of some discrete tissues are examples of what can and should be done in the future by way of establishing factual knowledge of the response of component tissues and joints as a whole to the types of loading brought to bear by corrective devices.

Past achievements have demonstrated that this kind of information is also useful in detecting the reasons for certain types of deformities. Such understanding leads to better therapy and to devices designed to counteract the system of forces causing the deformity.

It is hoped that future research in this area will bring more knowledge of the factors involved. Investigation of more of the tissues involved is also essential.

Further studies of the mechanical characteristics of bone, especially under loadings of the type encountered in orthoses and prostheses, are, of course, part of this picture.

PHYSIOLOGICAL AND RHEOLOGICAL CHARACTERISTICS OF THE STUMP

In addition to knowledge of the rheological characteristics of the tissues of the stump, which is needed for the determination of pressure and tension on skin and subcutaneous tissue, knowledge of tissue compartitions and the interplay of effects of forces thereon is also necessary. Interference with the flow of blood brings deleterious effects to the health of the tissue, and faulty distribution of pressure or skin tension can affect nerves and bring pain, Knowledge of the type proposed here would assist in avoiding these dangers.

One of the problems encountered in the fitting of prostheses is that of edema. Measurement of the pressure encountered and the deformations involved should permit compensatory procedures providing better design.

Since rheological experimentation has shown that the stress-strain ratios are rate dependent and load dependent, it seems that special studies of the properties of compressed and deformed tissues should prove to be beneficial.

RESPONSE OF BONE AND CONNECTIVE TISSUE TO EXTERNAL LOADS

Knowledge of the nature of the distribution of stress and strain in bone as a response to the implantation of pins in the marrow, such as those encountered in endoprosthetic joints and transcutaneous pylons, will be essential if these experimental methods are to develop into practical, clinical therapies.

The tolerance of the tissues to implantation and to the magnitudes and types of loading will also be an important factor in this research.

IMPLANTATION OF ARTIFICIAL ORGANS OF THE MUSCULOSKELETAL SYSTEM

Another aspect of the possibility of utilizing as much as possible of the natural anatomical system instead of exoskeletal devices is the use of implanted artificial muscles. It is envisioned that plastics capable of contraction excited by external signal will become available. Study of the materials and the tolerance of biological tissues for them will be required to realize this possibility.

The effects of implantation on endoprostheses and endoorthoses need more comprehension if materials are to be developed to make approaches practicable. This will include the chemical and physiological reactions as well as the biomechanics of the arrangements.

Of vital importance is knowledge of the tissue reactions to implants if methods of this type are to succeed.

Application of Prosthetics-Orthotics Principles to Treatment of Fractures

AUGUSTO SARMIENTO, M.D.,[1] AND
WILLIAM F. SINCLAIR, C.P.[1]

Greater knowledge and understanding of bioengineering by the prosthetics and orthotics industries during the past twenty years have resulted in the development of highly functional and sophisticated appliances. For example, modern prostheses for lower- and upper-extremity amputees are now designed with proper attention given to energy expenditures and other physiological factors based on scientific information obtained from laboratory and clinical studies. Close liaison between medical and engineering disciplines has contributed enormously to the revolutionary changes that prosthetics and orthotics have undergone during the past two decades.

Experience in the management of amputees has given the authors the opportunity to study the possibilities of utilizing prosthetics principles in the management of orthopaedic conditions. The first of these came as a result of clinical work with below-knee amputees. Prior to the development of the patellar-tendon-bearing (PTB) prosthesis in 1957, the below-knee amputee ambulated with an appliance which required a thigh corset to provide stability and to assist in the distribution of weight-bearing forces. The PTB prosthesis proved that the below-knee stump could take the pressures necessary for weight-bearing during ordinary activities without assistance from a thigh corset. The snug, total-contact fit and the firm contouring of the tibial flare and patellar tendon make possible weight-bearing ambulation without undue pressure being exerted over small areas or appreciable telescoping of the stump in the prosthesis.

[1] School of Medicine, University of Miami, Jackson Memorial Hospital, Miami, Fla. 33152.

The traditional belief in orthopaedic circles has been that fractures of the tibia require the joints above and below the fracture site to be immobilized, the knee joint to be held in flexion to increase rotational stability, and weight-bearing to be avoided until fracture healing is complete. Some reports have appeared in the literature where ambulation on the fractured extremity is encouraged while the injured limb is stabilized in a groin-to-toe cast. This method, however, makes motion of the knee and ankle joints impossible *(1).*

Convinced that the patellar-tendon-bearing prosthesis can adequately stabilize the stump without excessive piston action or rotation, the senior author applied the principles of this appliance to the treatment of tibial fractures. Three and a half years ago, he constructed a total-contact, below-knee cast firmly molded over the entire leg and contoured over the proximal tibia in a.manner identical to that of the patellar-tendon-bearing prosthesis (Fig. 1). The results were encouraging, since the fracture united without loss of the reduction originally obtained and without additional shortening, angulation, or rotation of the fragments. Since then we have treated 200 patients with various fractures of the tibia, malleoli, or os calcis (2).

The impossibility of providing flexion in the proximal segment of the cast, as in the case of the PTB prosthesis, soon convinced the authors that the patellar tendon was not a major contributor to the distribution of weight-bearing pressures. In most cases, we do provide the patellar-tendon indentation and high condylar wings because they appear to be valuable in enhancing rotational stability, particularly in cases of high tibial fractures.

With this short-leg, total-contact PTB-like cast, weight-bearing forces are transmitted

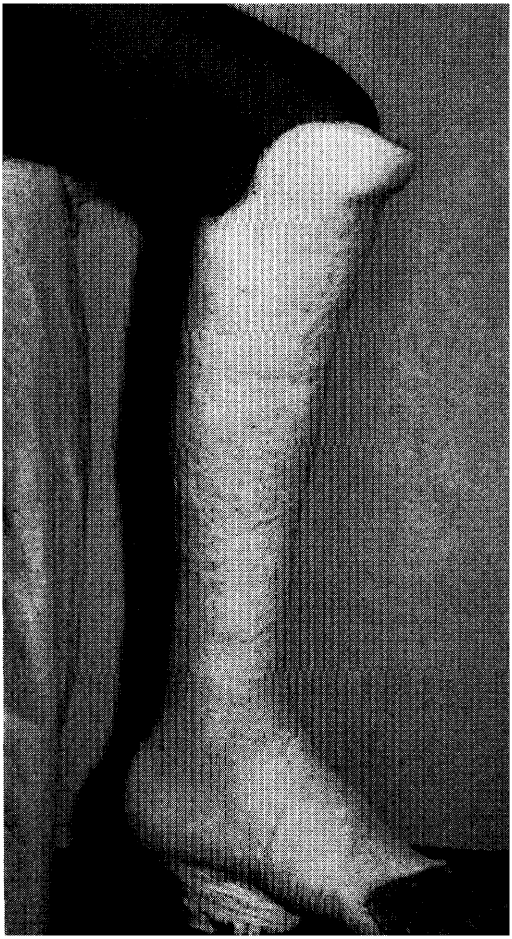

Fig. 1. Short-leg total-contact PTB-like cast for tibial fractures.

from the ground to the proximal tibia, virtually bypassing the fracture site. At first glance, such a method of treatment appears to conflict with orthopaedic principles. It is the authors' belief, however, that it utilizes to a fuller degree the knowledge of basic principles governing osteogenesis and fracture repair. The active use of the extremity in a near-normal manner seems to place the fractured limb in a physiological environment more conducive to uneventful healing.

Experience with the first 200 cases and the addition to the staff of the University of Miami School of Medicine of the junior author of this paper made it possible to attempt elimination of the foot and ankle portion of the cast, the object being the transmission of weight-bearing forces from the ground to the proximal tibia by means of metallic uprights attached distally to the patient's shoe and proximally to the cast (Figs. 2 and 3). We have treated 40 tibial fractures with this cast-brace with encouraging results.

In order to utilize the benefits of a near-normal physiological environment in fractured limbs, we have used short-leg, total-contact casts with or without the orthotic components in many instances of delayed unions with or without associated chronic osteomyelitis. A complete report on these cases will be published in the near future.

In the same manner that the patellar-tendon-bearing prosthesis led to the development of the short-leg, total-contact cast, we have introduced the principles of the quadrilateral, ischial weight-bearing prosthesis to the treatment of fractured femurs. We have con-

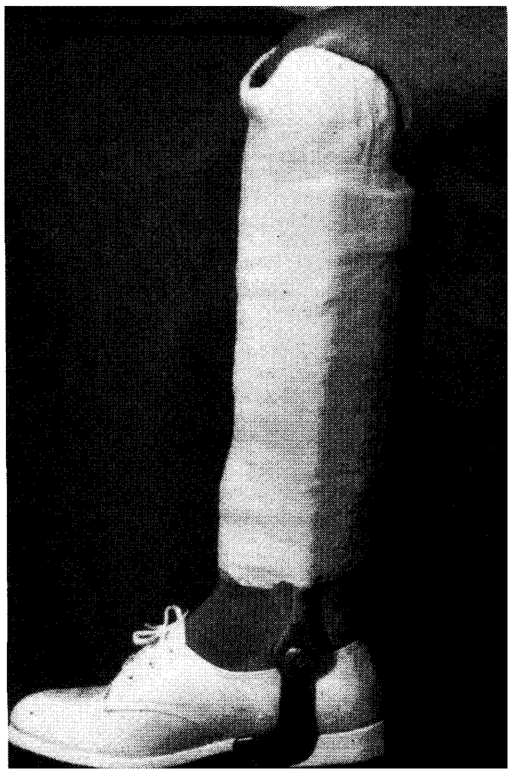

Fig. 2. Short-leg total-contact cast-brace used in the treatment of tibial fractures.

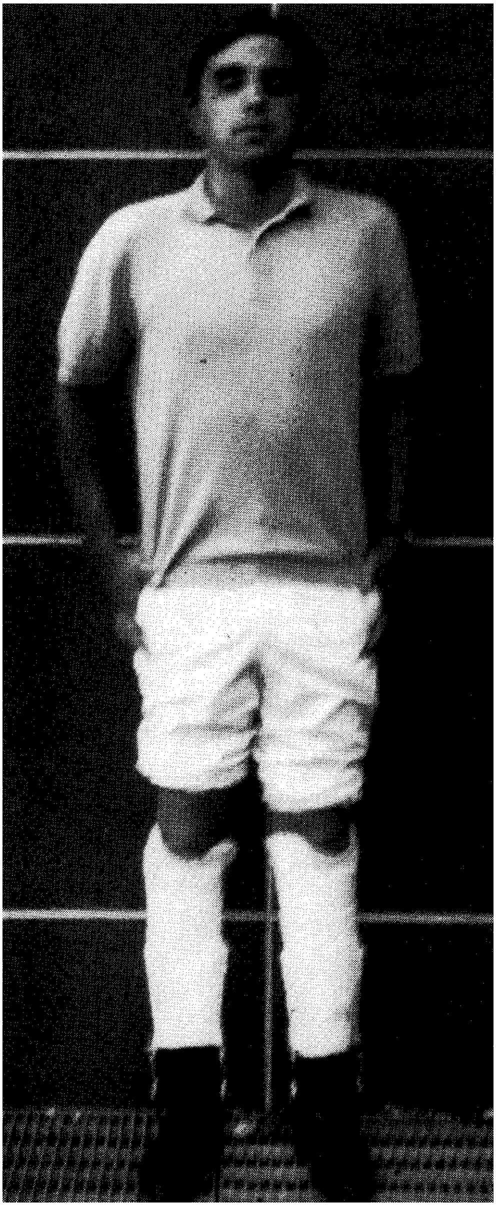

Fig. 3. Bilateral short-leg total-contact cast-braces used in delayed union of tibial fractures.

structed a cast-brace that stabilizes the fractured femur but permits freedom of motion of the hip, knee, and ankle joints (Fig. 4).

This cast-brace is applied with the patient standing on his normal limb while the ischium on the affected side rests on the platform of an above-knee casting stand. Ambulation results in transmission of weight-bearing pressures from the ground to the ischium, thus preventing shortening of the fractured fragments, angulation, and rotation. Our experience has been limited, and so we are in no position at this time to state whether or not this cast-brace will earn a place in the armamentarium of the orthopaedic surgeon.

We have utilized the basic construction design of the Munster prosthesis as applied to the very short below-elbow amputee, and have constructed a cast in a manner similar to that of this prosthesis. To prevent rotation of the forearm, the cast is molded in such a manner that its anteroposterior diameter is as narrow

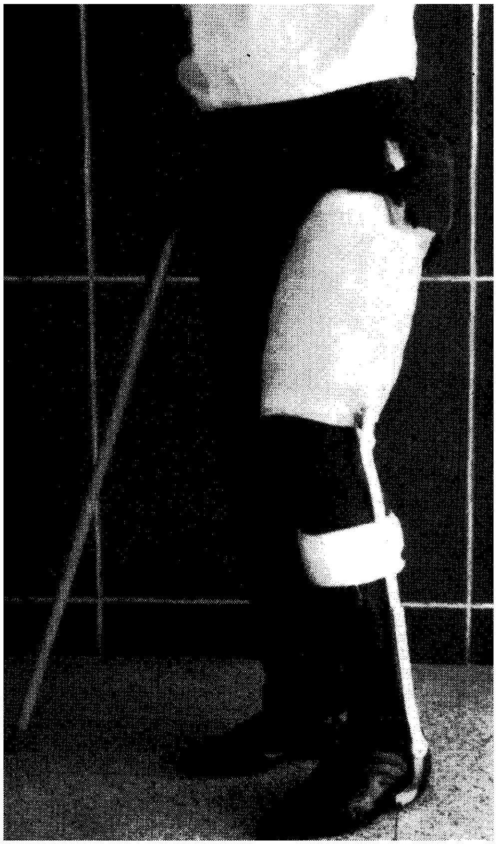

Fig. 4. Ischial weight-bearing cast-brace for femoral fractures.

Fig. 5. Cast-brace with articulated wrist joint for forearm fractures.

as possible. The high condylar wings firmly contoured over and around the bony prominences of the forearm and humerus enhance rotational stability. A metal joint makes possible freedom of motion of the wrist joint (Fig. 5).

The possible applications of these cast-braces may be numerous in the everyday practice of orthopaedics. Additional investigations should be conducted before arriving at any final conclusions regarding the value of these approaches.

CONCLUSION

Familiarity with prosthetic appliances has resulted in the application of their basic principles to the management of orthopaedic conditions of the upper and lower extremities.

A functional short-leg, total-contact cast based on the patellar-tendon-bearing (PTB) prosthesis was developed and used in 200 cases of tibial, malleolar, and os calcis fractures. In addition, a short-leg, total-contact cast-brace which permits motion of the knee and ankle joint has been utilized in 40 cases of fresh and old tibial fractures.

Attempts have also been made to stabilize femoral and forearm fractures with cast-brace appliances. These cast-braces are constructed with features resembling those of the ischial weight-bearing quadrilateral socket and the

Miinster prostheses used by above-knee and below-elbow amputees, respectively.

There are many clinical situations in orthopaedics which provide opportunities for further study of the utilization of prosthetics-orthotics principles.

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The Geriatric Amputee

ROBERT MAZET, JR., M.D.[1]

The geriatric amputee not infrequently suffers from debilitating diseases other than the one which caused his amputation. These affect his prognosis for life, for retention of his other leg, his ability to use a prosthesis, the performance of activities of daily living, his participation in social affairs, his ability to work, and often his finances.

Does the elderly amputee live as long as a nonamputee of similar age? Do diabetic amputees die sooner, do they lose the opposite extremity more often, than nondiabetics? Which amputees will use a prosthesis? To answer these and other related questions the Amputee Clinic Teams of the Los Angeles County General Hospital and the Veterans Administration Hospital reviewed 1,770 geriatric patients who, during a ten-year period, became lower-extremity amputees at or above the ankle. We have more recently studied 110 patients who were initially ambulated on preparatory prostheses at the Veterans Administration Hospital. From these studies criteria for probable successful performance on an artificial leg have been derived. Also evolving from these criteria are the procedure employed in the selection of amputees for prosthetic prescription, the training program followed by the Los Angeles Veterans Administration Hospital Amputee Clinic Team, and the development of a special type of prosthesis for a small but worrisome group of patient?.

The combined County and Veterans Hospital study disclosed that the geriatric amputee is more likely to die during the year immediately following his amputation than his nonamputee counterpart (Fig. 1). At the end of a year 94 per cent of the otherwise-comparable general population were living, while only 67 per cent of the VA patients and 55 per cent of the County patients had survived. However, if the amputee does not succumb during the initial critical year, he has essentially the same probability of survival as the nonamputee.

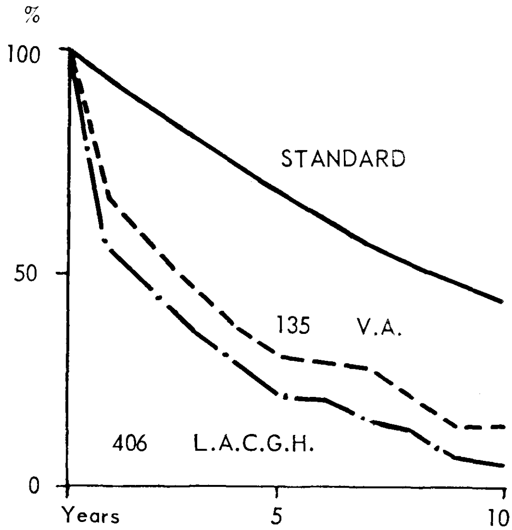

Fig. 1. Survival of geriatric amputees as compared with that of the general geriatric population. The survival rate of the general population over 55 years of age is shown by the solid curve, that of the VA amputees by the broken curve, and that of the Los Angeles County General Hospital amputees by the dot-dash curve. The curve marked "standard" represents a population comparable on the basis of race, sex, and age to the County patients. It is based upon mortality tables for the United States for the years 1949-1951 as given in *Vital Statistics of the United States,* U.S. Department of Health, Education, and Welfare.

The same study shows that the gloomy outlook propounded for the diabetic amputee is not justified. It will be noted that the survival rates for diabetic and nondiabetic amputees are equally good (Fig. 2).

The one area in which the diabetic is at a disadvantage is in the probability of loss of the

[1] Chief, Orthopaedic Service, Veterans Administration Center, Wilshire and Sawtelle Blvds., Los Angeles, Calif. 90073.

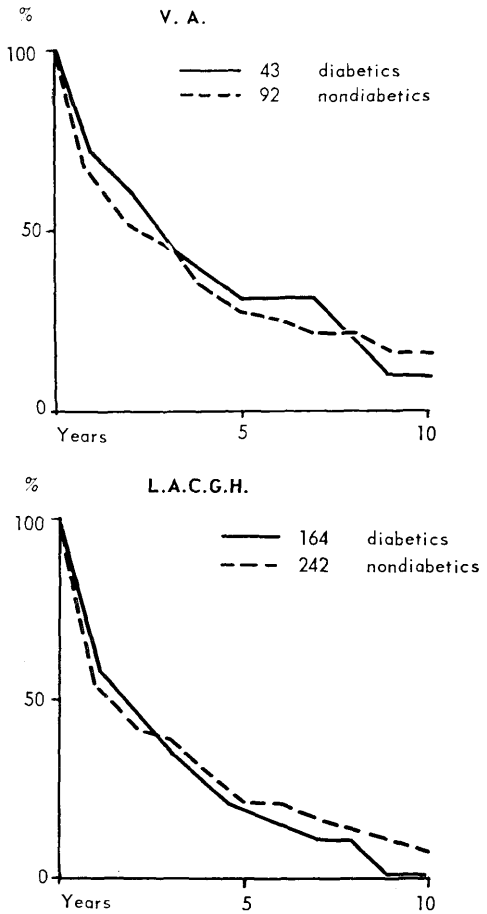

Fig. 2. Survival curves for diabetics and nondiabetics. *Top,* the VA patients. *Bottom,* the Los Angeles County General Hospital group.

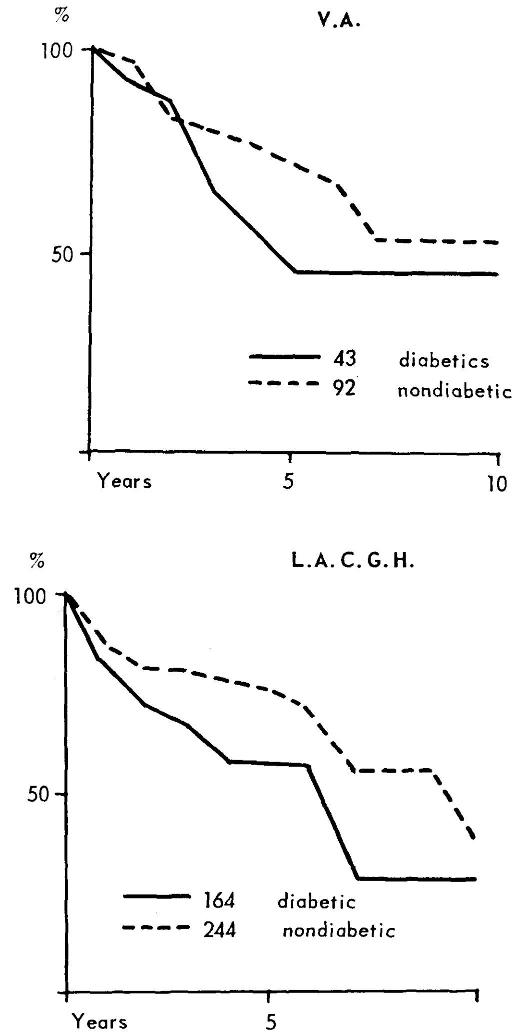

Fig. 3. Survival of opposite extremity in diabetics as compared with nondiabetics. *Top,* the VA patients. *Bottom,* the Los Angeles County General Hospital group.

opposite leg. The diabetic *is* more likely to lose the second leg. Among the VA patients two years after amputation 18 per cent of both groups had become bilateral amputees, but five years later 28 per cent of the nondiabetics and 66 per cent of the diabetics had lost the opposite leg. Among the County patients 20 per cent of the nondiabetics and 28 per cent of the diabetics had lost both legs at the end of two years, and at the end of five years 28 per cent of the nondiabetics and 46 per cent of the diabetics were bilateral amputees (Fig. 3).

Many patients in the combined study who received prostheses did not use them for long. Sixty per cent discarded their artificial legs within six months. McKenzie (5) reported that 50 per cent of the geriatric amputees fitted at the British Ministry of Health's Limb Fitting Centre in Roehampton, England, discarded their prostheses within six months after leaving the hospital environment.

In our clinic it has been found that use of a temporary or preparatory artificial leg, for both above-knee and below-knee cases, is helpful in prognosticating the likelihood of prosthetic use by the amputee. These devices have never been popular in the United States. Kirk *(2),* who used fiber sockets on jointless pylons, was for many years the only strong proponent of preparatory prostheses. Their helpfulness in hastening stump shrinkage was not generally appreciated. The vaulting or circumduction caused by a jointless above-knee pylon as long as the normal leg, or the gimp, with shift of center of gravity over the device in the stance phase if the pylon is made shorter, fostered poor gait patterns which were difficult to overcome after the patient received an articulated leg. There is some objection to such pylons on aesthetic grounds. They are not pretty. Furthermore, pylons for above-knee cases stick out in the aisle of a bus or theater, creating a certain amount of confusion and embarrassment to the wearer.

Our Canadian and English contemporaries were much more enthusiastic. LeMesurier in 1926 *(3)*, Verrall in 1940 *(6)*, and Key and Pennell *(1)* in 1958, strongly advocated pylons. Since the advent of various types of articulated temporary, or preparatory legs, they have enjoyed much wider use in our country. Today many clinics espouse them, particularly for above-knee amputees. Elephant boots, or stubbies, for bilateral above-knee amputees have been more generally accepted because their efficacy was usually unquestioned.

Almost all recent amputees, regardless of age or condition of decrepitude, want prostheses. They are sure that if they just had an artificial leg they could walk. The reasons are several. Some patients are unable to alter the body image they have had for so long. They cannot acknowledge to themselves the loss of a part which will render the body incomplete. An artificial leg obviates the necessity of making such admission. Sometimes grandpa just wants something to fill the trouser leg as he sits in his wheelchair. Among some amputees the desire for a prosthesis is fear that without one they will appear at a disadvantage, be handicapped socially, or that they will be less able to carry on with their business, thus suffering financial loss.

We know that many amputees 55 years of age or older cannot use such a device. In the combined Veterans Administration-Los Angeles County General Hospital study the number of VA patients who received prostheses was small, as shown herein:

Ages 55-64	50
65-74	23
75-84	11
85+	0
Total	84 (of 450)

Of 267 patients who became amputees at the Veterans Administration Hospital during the period 1961 through 1964, 152 were not considered for prostheses, 38 were considered but not prescribed for (Table 1). Only 69 received permanent prostheses.

TABLE 1. 267 PATIENTS WHO BECAME AMPUTEES AT THE VA HOSPITAL DURING 1961-1964

	Amp. Level	Age at Amp.		Not Seen Amp. Clinic	Seen but No Prescription	Permanent Leg Given
		55+	54−			
Above-knee	177	153	24	118	25	34
Bilateral above-knee	30	27	3	12	9	3
Below-knee	41	26	15	14	0	27
Bilateral below-knee	8	5	3	3	2	3
Above-knee/below-knee	7	3	4	3	1	2
Hip-disarticulation	2	1	1	1	1	0
Knee-disarticulation/above-knee	2	1	1	1	0	0
Totals	267	216	51	152	38	69

REVIEW OF 110 CASES

We have recently reviewed 110 unselected cases in which the patient had been ambulated initially on a preparatory leg. Most of them were fitted in recent years, but two originally wore our 1948 model. All were followed and examined a year or more after amputation. All amputations were at or proximal to the ankle.

SINGLE BELOW-KNEE AMPUTEES

There were ten single below-knee amputees who were 55 or older. Of the ten:

Four had conventional preparatory legs.

Six had PTB-type preparatory legs.

Nine were diabetics. (We feel very strongly that below-knee amputation in diabetics is often feasible.)

Four had some medical problem which made us doubtful that they could use prostheses. They showed us they could, and were given permanent legs that each wore for three years or more.

Three definitely benefited from the stump shrinkage and improved alignment afforded by provisional legs.

One, the only woman, wore her permanent PTB leg for two years, then died of a coronary thrombosis.

Two men did not want to walk. No permanent legs were furnished them.

BILATERAL BELOW-KNEE AMPUTEES

None of the bilateral below-knee amputees was over 54.

SINGLE ABOVE-KNEE AMPUTEES

Forty-three of the single above-knee amputees were 55 or over.

Causes of amputation were:

Arteriosclerosis	25
Diabetes	17
Trauma	1
Total	43

Two were given temporary suction-socket legs, while the remaining 41 had pelvic suspension. They wore the pylons for three to 17 months.

Six of the single above-knee amputees died within a year: two from malignancy, one from a coronary, and three just faded away.

Three patients did not do well. One man who had had an iliofemoral endarterectomy could not tolerate any pressure over the femoral triangle, and so had to abandon prostheses. Another had a coronary six months after obtaining his permanent leg and has been confined to a wheelchair ever since. The third was not motivated and did not walk, and so no permanent leg was given to him.

One man became a bilateral amputee after walking for two years on a single conventional leg and did not walk thereafter.

Four were given hydraulic mechanisms, but none was benefited thereby.

Eleven men received the Chupurdia leg,[2] which will be described later.

Thirty-four walked on their permanent legs with varying degrees of vigor, depending on their motivation and general physical condition.

The average time this group of geriatric people used their permanent prostheses was one year.

BILATERAL ABOVE-KNEE AMPUTEES

We were conspicuously unsuccessful in making our six geriatric bilateral above-knee amputees ambulatory. Five were diabetic. One just did not want to walk, and three died before obtaining full-length legs. The fifth, age 72, lost both extremities within a month. He walked well in boots. Nine months after the amputations, the boot sockets were placed on Berkeley adjustable legs. One year after the amputations, he was given conventional prostheses. He walked outside to some extent, went to church and lodge meetings, and wore the prostheses all day for several months. He then lost interest and stopped walking a year after he was given prostheses.

A 66-year-old retired admiral had an above-knee amputation for arteriosclerosis five and a half years before being seen by us. He walked on a suction socket for three and a half years and then became a bilateral above-knee amputee. He was furnished elephant boots and, later, articulated suction-socket legs, but he had no real gait training. The boots were cumbersome, and the prostheses were malaligned. None fit very well. Twenty-three months after his second amputation he was given new boots and

[2] Named for Roddy Chupurdia, C.P.O., Chief, Prosthetic-Orthotic Service, Veterans Administration Center, Wilshire and Sawtelle Blvds., Los Angeles, Calif. 90073.

gait training. He was a determined, well-motivated gentleman who wanted to walk. He used total-contact sockets with pelvic belt and Hydracadence for about a year. It then became too much trouble to put on the prostheses. He reverted to the wheelchair and stubbies. These people invariably develop a pronounced lordosis which makes walking more difficult.

ABOVE-KNEE/BELOW-KNEE AMPUTEES

Two of the 110 patients whose cases were reviewed were above-knee/below-knee amputees and over 55 years of age. Both were diabetics.

One, a 65-year-old unemployed man, walked on a conventional below-knee device for two years prior to his opposite above-knee amputation. He walked on his old prosthesis and crutches to show us his ability to move about. He then walked on a temporary above-knee device for two months before receiving a permanent leg. He walked a maximum of one block with a four-point gait on two canes and died four years later.

The other, a 62-year-old bartender, walked on a suction-socket leg five years before he lost the opposite extremity below the knee. He demonstrated his ability to use a temporary conventional device, and walked on the permanent prostheses for two years. He then deteriorated, stopped walking, and died three years after the second amputation.

LOS ANGELES VETERANS ADMINISTRATION HOSPITAL AMPUTEE CLINIC PROCEDURE

In the Los Angeles VA amputee clinic the postoperative regime is as follows: Stump conditioning and shrinkage commence the first postoperative day on the orthopaedic service. General muscle strengthening is encouraged, and prevention of flexion contractures is stressed. The patients are ambulated between parallel bars and on crutches as quickly as feasible.

The tendency to use wheelchairs is a problem. The nurses like these patients to get into their chairs to go to the bath, toilet, mess hall, and the recreation area. It is easier to put them in a chair than fuss with crutches, and patients find it requires less effort. At home the family feels sorry for the aged amputee, and so they wait on him in his wheelchair, instead of encouraging him to get up and do for himself.

When the patient demonstrates his ability to walk 100 yards on crutches he comes to the amputee conference. (This program is modified for those amputees who are fitted with plaster sockets before leaving the operating table.) One of the duties of the clinic team is to determine whether or not a particular patient will or will not be able to use an artificial leg.

From the review of previous cases, criteria have evolved which are helpful in making a decision for or against the prescription of an artificial leg.

The general criteria follow:

1. The physiological age of the patient. He must be strong enough to activate and control the device. He must be mentally alert and capable of learning to walk.
2. He must have good neuromuscular coordination and balance if he is to learn to shift his weight rhythmically to each leg and develop a smooth gait.
3. He must have sufficient vision to see where he is going, to climb steps and curbs, and to ambulate on even ground.
4. His general health must be good. If he could not walk before amputation, he will not afterward. Any chronic debilitating cardiac condition, hemiplegia, Parkinson's disease, ataxia, etc., precludes use of prosthesis. If amputation was done for malignancy it is wise to wait six months for signs of recurrence or metastases before prescribing.
5. Circulation of the opposite extremity must permit walking on it for at least 100 yards.
6. Motivation is the most important prerequisite. The patient who lives at home with his family, is self-supporting and self-respecting, who has vocational and avocational interests, such as church or fraternal groups, and who was an active person before amputation, will probably use an artificial leg.
7. The patient must not expect too much of the leg. Sometimes patients expect the leg to "walk" them. They have to accept the fact that *they* must learn to "walk" the leg and put out the energy necessary to do so.

Another decision relative to prosthetic prescription for the elderly amputee is the degree of rehabilitation the team can hope to attain in each individual. Geriatric patients can generally be placed in one of four groups:

1. Those whose condition precludes walking, and who desire a prosthesis for cosmesis only. They want something to look natural in the wheelchair. We do not prescribe purely cosmetic legs.
2. Those who want something they can rely on to permit getting about the house and out to the car. These are the debilitated people who lack the strength to walk more than a short distance, but who retain some pride and want to be independent of the wheelchair.

For this rather small group of people, we have a special device, the Chupurdia leg, which will be described later in this article.

3. Those who want to attend social functions, to go to the grocery store and post office, to do a little puttering about the house and in the garden, and to take care of their own daily needs. Most of the geriatric amputees fall into this category. For these we usually supply a conventional-type prosthesis.

4. Those who will return to full activity and to work. These are rare among geriatrics.

In our modern society, much ambition has been stifled, much self-respect lost, and much dependence fostered. Veterans' benefits, Social Security, Medicare, and a multitude of other welfare measures have unfortunately resulted in making it more profitable for many patients, particularly geriatrics, to sit at home or out in the sun and let the world pay them, rather than to be productive.

We put *all* amputees, 55 or over, on preparatory legs initially. Any other patients whose motivation and ability are doubtful also receive preparatory devices.

To obviate the undesirable features of jointless pylons, we commenced in 1947 to use a temporary device with an open-end, leather, lace-up, thigh corset, inserted into a double-bar long leg brace, with knee and ankle joints (Fig. 4). Later we discarded the leather socket for one made of plastic. These temporary legs were helpful aids, but they were awkward, and the unsteady patient was fearful of their instability. He developed rather poor gait patterns. It became evident that the preparatory device should, as nearly as possible, approximate the

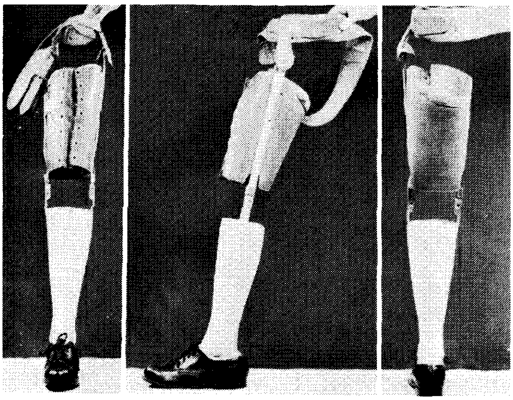

Fig. 4. Early model of the temporary leg.

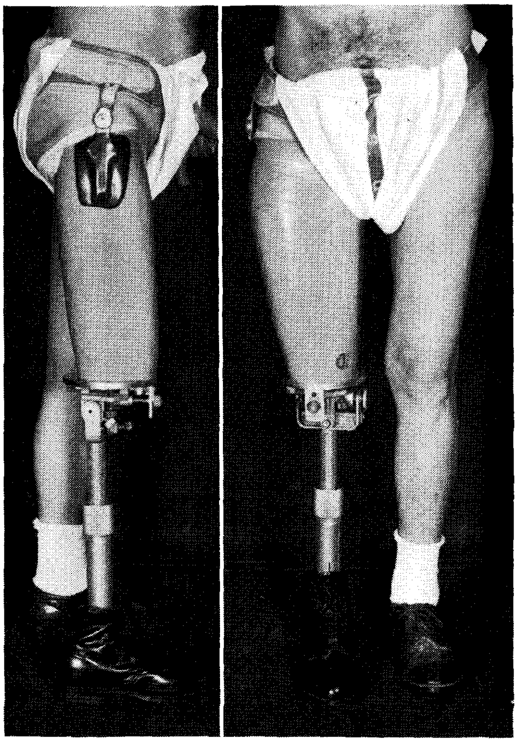

Fig. 5. The Berkeley adjustable leg. The knee can be rotated, displaced in any direction, and adjusted for desired varus, valgus, flexion, or extension. The foot can be adjusted in all planes, and the height of the shin can be changed as indicated.

anticipated permanent one. Not until the advent of the Berkeley adjustable leg did we have the needed tool (Fig. 5). For a number of years we have been making a socket of the type we think the patient will wear permanently, and putting this on the Berkeley leg. We follow the same procedure for both above- and below-knee amputees (Fig. 6). The patients wear this device for varying lengths of time, as indicated for the individual case.

Most learn to use the temporary device and are provided a permanent leg. Some convince us and themselves that they cannot use a permanent leg.

A preparatory leg not only aids stump shrinkage, but is also of infinite help in attaining the most efficacious alignment, especially for below-knee amputees.

Gait training commences as soon as the patient ambulates on a preparatory prosthesis.

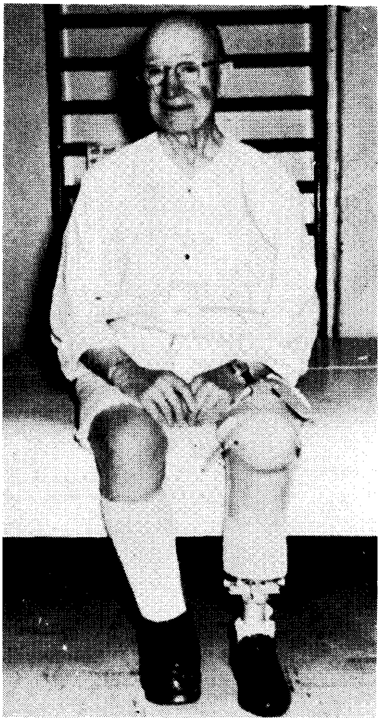

Fig. 6. Below-knee model of the Berkeley adjustable leg.

Adjustments in alignment are made as indicated.

While the geriatric patients are wearing the provisional leg, deficiencies not previously detected may become evident. Latent weakness of the opposite extremity, because of circulatory deficiency or a neuromuscular condition, can adversely affect balance, coordination, or sustained walking. Cerebral arteriosclerosis may so impair the memory that these patients simply cannot learn to use the artificial leg. Muscle weakness prevents locking the knee in a few. Where this occurs we replace the Berkeley mechanism on the provisional leg with the Hosmer knee-locking type, and put a French lock in the permanent prosthesis.

The conventional-type socket rather than the suction socket is prescribed for the elderly amputee for the following reasons:

1. Old people have neither the strength nor the patience to pull themselves into a suction socket.
2. The fit in a suction socket is more critical. These people are more comfortable wearing a sock. They like its cushioning effect.
3. The sock absorbs perspiration, and the socket stays cleaner.
4. They feel more secure with the pelvic belt.
5. Amputees who have worn a conventional socket for many years are not happy with suction sockets.

We do not use hydraulic knees because:

1. Geriatric amputees do not like the inherent friction of this knee.
2. They walk slowly and the swing-control feature is not needed.
3. They have a shuffling gait. They do not quickly flex the knee 20 deg. at push-off to activate the toe pick-up. The hydraulic mechanism does not help them.

For much the same reasons, PTB prostheses are not used routinely.

1. The fit is more critical in a PTB, and many patients like the cushioning effect of two socks.
2. Instability of the knee occurs more often in the oldsters, and so they need outside knee joints.
3. Those who have short stumps also need the external knee stability.
4. People who are accustomed to conventional sockets do not readily adapt to the PTB-type gait or socket.

BILATERAL ABOVE-KNEE AMPUTEES

All the bilateral amputee patients at the Los Angeles VA Center are given stubbies, or elephant boots, initially. On these, the patients learn balance and enjoy a certain degree of independence and mobility. The boots get the patients out of the wheelchair, thus helping to prevent flexion contractures, and they aid in muscle development and stump shrinkage. Boots are also useful in permitting the patient to get about his home at night (Fig. 7).

Rocker-bottom stubbies are no longer used at the Los Angeles VA Center. Plastic, total-contact, rectangular sockets, with pelvic band and belt, are placed on a modified-type SACH foot.

A cushion heel is used instead of a rocker bottom. It is lighter. It acts as a shock absorber on heel strike. It assists the patient in maintaining balance. The fear of falling backward is eliminated.

The trochanter-knee-ankle (TKA) line, which is the center of gravity, hits the posterior end of the solid part of the foot, for stability. (In a rocker foot the center of gravity is in the center of the flat space on the rocker bottom.)

If the stump is flexed, the socket must be, too. Then the foot is placed to the rear in rela-

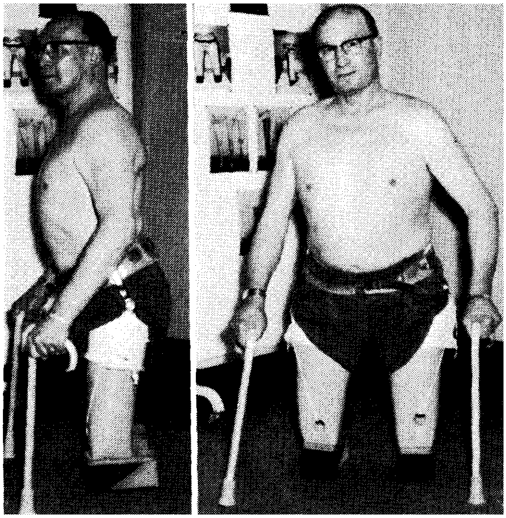

Fig. 7. Elephant boots, utilizing the principle of the SACH heel.

tion to the socket in order to keep the TKA line in its proper relationship for balance.

THE CHUPURDIA LEG

Many single, above-knee, geriatric amputees want to walk, but, because of a chronic debilitating condition, are not able to use a conventional (or suction-type) above-knee device. These are persons whose sense of balance is impaired, whose muscular control is uncertain, whose reaction time is slowed, and whose eyesight is poor. They need a stable knee. They do not want to be confined to a wheelchair, they want something to fill the empty trouser leg, and they want something on which they can walk for short distances.

The Chupurdia leg (Fig. 8) fulfills these criteria. A French-type knee lock provides stability. Backing into a chair releases the lock, and the patient may sit. On rising, the knee locks when fully extended.

The original Chupurdia leg was lighter than a conventional prosthesis because the blade-like shin was lighter than the conventional shin (Fig. 8). However, the bearing surface of this shin proved to be too small. It did not stand up under the hard use some of the wearers gave it, and we had to sacrifice the saving in weight. Now we use a conventional leg with total-contact socket, pelvic band and belt, single-axis knee with French-type knee lock (posterior lock) and a SACH foot (Fig. 9).

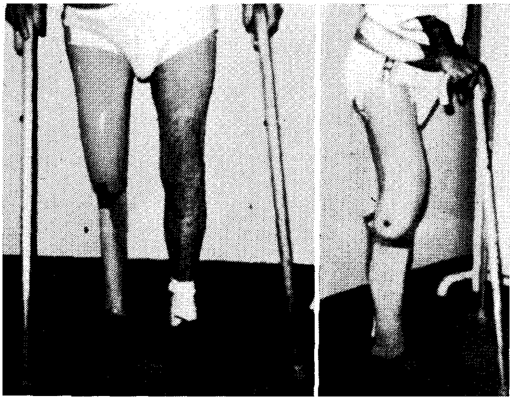

Fig. 8. The Chupurdia leg with French-type knee lock and rudder-type shin.

Fig. 9. The new Chupurdia leg with single-bolt knee and French-type knee lock.

Eleven patients have been provided with the original model. It permits patients who would not otherwise be mobile to get about the house unaided, to go out, to enter a car, and to walk with confidence. They use two canes outside and walk haltingly, but they walk.

Those patients were between 59 and 74, averaging 66 years of age. Nine were diabetics' and two were arteriosclerotics. One of them died of malignant melanoma, but he used the

Chupurdia leg for nine months. Another walked on his leg for one year before the opposite leg was amputated. He did not walk thereafter. One man discarded the Chupurdia leg after using it for 20 months, because it was too heavy.

One patient failed quite rapidly after the Chupurdia leg was ordered, and is not strong enough to use it.

One man lives with an indulgent sister and enjoys his invalidism. He can walk but prefers not to.

The other six have used this device for periods of one to four years.

The newer Chupurdia leg (Fig. 9) has been used on four patients with equally satisfactory results. This device fills a definite need in a small group of enervated people who would not walk in a prosthesis without a knee lock.

DISCUSSION

A combined study of 1,770 lower-extremity geriatric amputees by the amputee clinic teams of the Los Angeles County General Hospital and the Veterans Administration conducted several years ago revealed several illuminating facts:

1. The mortality rate among these people is appreciably higher than that of the general population of similar age during the first postamputation year. If the amputee survives this year, his probability of survival is virtually the same as that of nonamputees.
2. The outlook for longevity of diabetic amputees and nondiabetic amputees is similar.
3. The diabetic is more likely to become a bilateral amputee.
4. More than half the amputees who received artificial legs discarded them within six months.

This study and a more recent review of 267 amputees disclosed that not quite one-third of the amputees received prostheses.

From these studies and the experience in our amputee clinic, criteria have evolved which are believed to be helpful in assaying the probability of prosthesis use by a particular amputee.

The desirability of employing preparatory legs was demonstrated by a review of 110 patients, sixty-one of whom were 55 or older. Temporary devices are useful to promote stump shrinkage, obviate or decrease joint contractures, ascertain optimum alignment of prosthesis, permit earlier gait training, and demonstrate whether or not the patient can handle an artificial device. All bilateral above-knee amputees should initially ambulate on elephant boots. All geriatric amputees who are being considered for prosthetic prescription should be ambulated on a provisional leg first.

Nine of the ten geriatric below-knee amputees of the 110 reviewed were diabetic. It is believed that amputation in this area in diabetics is feasible and highly desirable.

A small group of decrepit above-knee amputees are best served by a lightweight, articulated leg with a French-type knee lock. Geriatric patients, with few exceptions, prefer a pelvic belt to suction socket, and many prefer a conventional leg to the PTB below-knee leg. The hydraulic mechanism is not helpful to the geriatric amputee.

In our experience bilateral above-knee amputees rarely use their artificial legs, and unless single above-knee amputees are carefully chosen and skillfully trained, many will discard their legs within six months. However, of the well-chosen and trained, most do use their prostheses effectively for longer than a year.

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Orthotics Measurement Board for Tibial Torsion and Toe-Out

HANS R. LEHNEIS, C.P.O.[2]

COORDINATED function of the brace-anatomical complex is dependent upon the configuration and fit of the brace with the patient's anatomical structure. Brace alignment should be consistent with individual variations in toe-out and tibiofibular torsion. The process of accomplishing such proper alignment depends, first, upon the anatomical measurement technique and, second, upon the orthotic fabrication technique.

Since, in conventional orthotics practice, individual tibial torsion and toe-out accommodations are rarely made for lack of precise measuring devices and techniques, an orthotics measurement board was devised at New York University.[3] The measurement board was designed to obtain individual measurements of tibial torsion and toe-out as well as to serve as a tracing board. In addition, a technique was developed by which the measurements obtained through the use of the orthotics measurement board can be utilized to make appropriate accommodations for tibial torsion and toe-out in the patient's brace.

[1] This article appeared originally in the September 1965 issue of the *Orthopedic and Prosthetic Appliance Journal,* having been prepared at the request of the Committee on Advances in Prosthetics and Orthotics of the American Orthotic and Prosthetic Association. It is being republished in *Artificial Limbs* in the belief that the device and procedure described will be of interest to our readers. The research and development were conducted under the sponsorship of the Vocational Rehabilitation Administration of the Department of Health, Education, and Welfare.

[2] Director, Orthotics Department, New York University Medical Center, Institute of Rehabilitation Medicine, 400 East 34th St., New York, N. Y. 10016.

[3] The measuring device is obtainable from the Pope Foundation, 197 South West Ave., Kankakee, Ill. 60901.

DESCRIPTION OF MEASUREMENT BOARD

The measurement board (Fig, 1) consists of two hinged masonite boards, an adjustable footrest permitting vertical adjustment as well as rotational adjustment on the goniometer, and two malleolar pointers mounted on the footrest, which is slotted to allow antero-posterior adjustability of the pointers. Mediolateral adjustability is provided by a set screw locking the malleolar pointers in the desired position.

MEASUREMENT PROCEDURE

Prior to positioning the patient on the measurement board, the medial and lateral malleoli are marked on the patient's skin to serve as landmarks for the determination of tibiofibular torsion. On the assumption that the ankle-joint axis runs through the centers of the malleoli as viewed in the sagittal plane, the width of each malleolus is palpated and its center indicated by a mark approximately one-half-inch long.

PATIENT PLACEMENT

Placement of the patient on the measurement board is one of the most critical parts of the procedure. The patient must be seated on a hard-surfaced table with both knees flexed approximately 90 deg. over the edge of the table and with the measurement board placed under the involved extremity (Fig. 2). The popliteal areas should be pressed firmly against the hinge of the measurement board on the affected extremity and against the edge of the table on the sound leg. This ensures that the knee axis runs parallel to the hinge of the board. The space between the knees in this position should not be excessive, for this would influence the accuracy of the measurements. At this point, the footrest should not touch the pa-

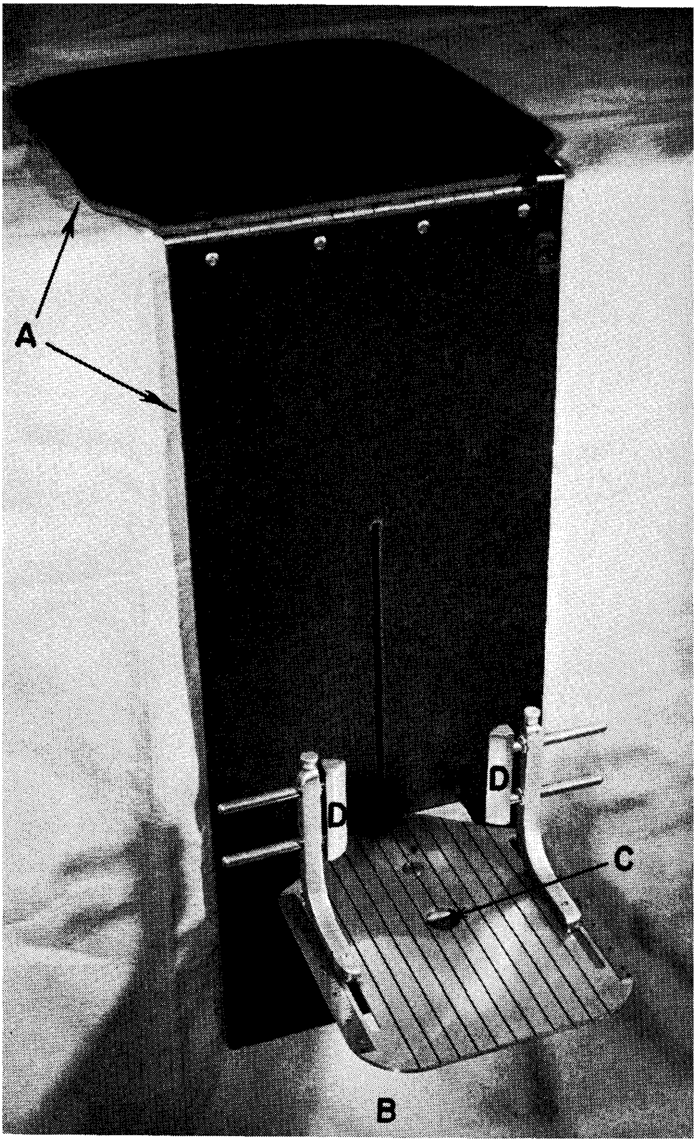

Fig. 1. Device developed at New York University for measurement of tibial torsion and toe-out. Components are two hinged masonite boards *A*, an adjustable footrest *B*, permitting vertical adjustment as well as rotational adjustment on the goniometer *C*, and two malleolar pointers *D* mounted on the footrest *B*, which is slotted to allow anteroposterior adjustability of the pointers.

tient's foot; thus the weight of the shank is allowed to orient the knee axis horizontally in the frontal plane.

TIBIAL TORSION

The procedure described does not involve any angular measurement of tibial torsion, because the relative anteroposterior distance between the medial and lateral malleoli in the transverse plane is a simpler measure for orthotics application.

Following the proper placement of the patient on the measurement board, the f ootrest is brought against the patient's foot. Care must be taken that the foot is not distorted in any way as the footrest approaches the foot; that is, the foot should not be everted or inverted. To measure the amount of tibial torsion, the goniometer setting must be at the zero mark. This places the adjustment slots in the footrest at right angles to the surface of the masonite board. With the back of the patient's heel pressed against the board, the malleolar pointers are individually adjusted to coincide with the landmarks previously indicated on the patient's skin (Fig. 3). The scale on either side of the footrest measures the distance of the medial and lateral malleoli from the back of the heel. These two measurements are then recorded on the orthotics measurement form (Fig. 4). (See Appendix A.)

TOE-OUT

Toe-out is measured by carefully lifting the patient's foot slightly away from the footrest

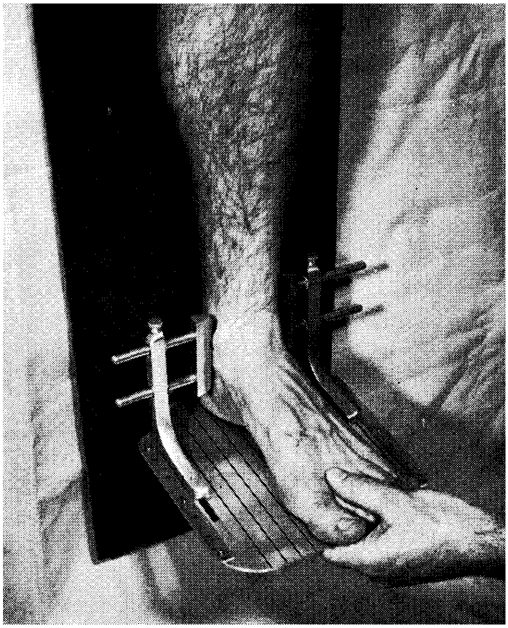

Fig. 3. Measuring tibial torsion.

so as to permit the footrest to rotate about the goniometer. The footrest is adjusted until one of the longitudinally inscribed marks coincides with the medial border of the foot (Fig. 5). It should be noted that the orthotics measurement board does not measure the degree of toe-out as related to the long axis of the foot; rather, it measures the angular relationship between the medial border of the foot and the knee axis. This measure is also recorded on the orthotics measurement form.

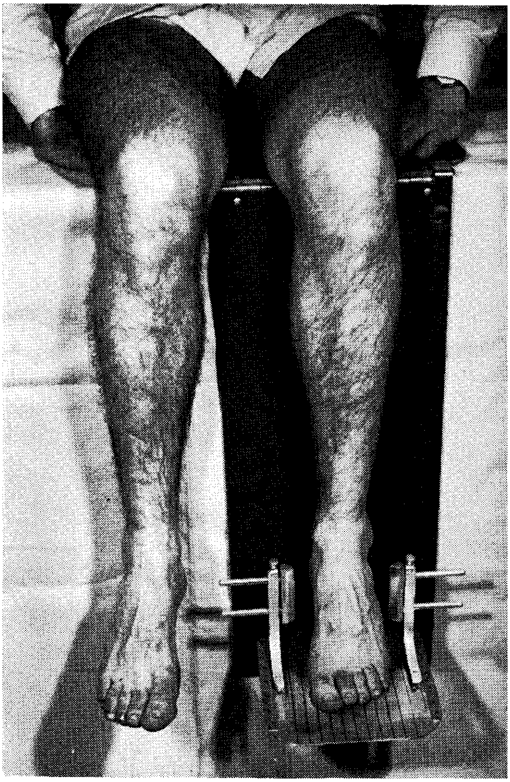

Fig. 2. Positioning patient on orthotics measurement board.

FABRICATION PROCEDURE

TIBIAL TORSION

From the measurements obtained, it is a relatively simple procedure to introduce tibial torsion into the brace. The difference between the medial and lateral malleolar measurements simply indicates the amount of offset needed between the medial and lateral brace ankle joints. If, for example, the medial malleolar measurement is 3 in. and the lateral measurement is 2 in., the difference is 1 in. Therefore, the medial ankle joint is offset anteriorly with respect to the lateral ankle joint by 1 in. plus % in. for a total of l^fj in. (Fig. 6). The purpose of the additional }/% in. is to allow for the usual clearance needed between the malleoli and the brace ankle joints.

Generally, the offset is made on the medial bar if the difference between the malleolar measurements is 1 in. or less because, normally, the medial malleolus is anterior to the midline of the leg as viewed in the sagittal plane. Should the difference of the malleolar measure-

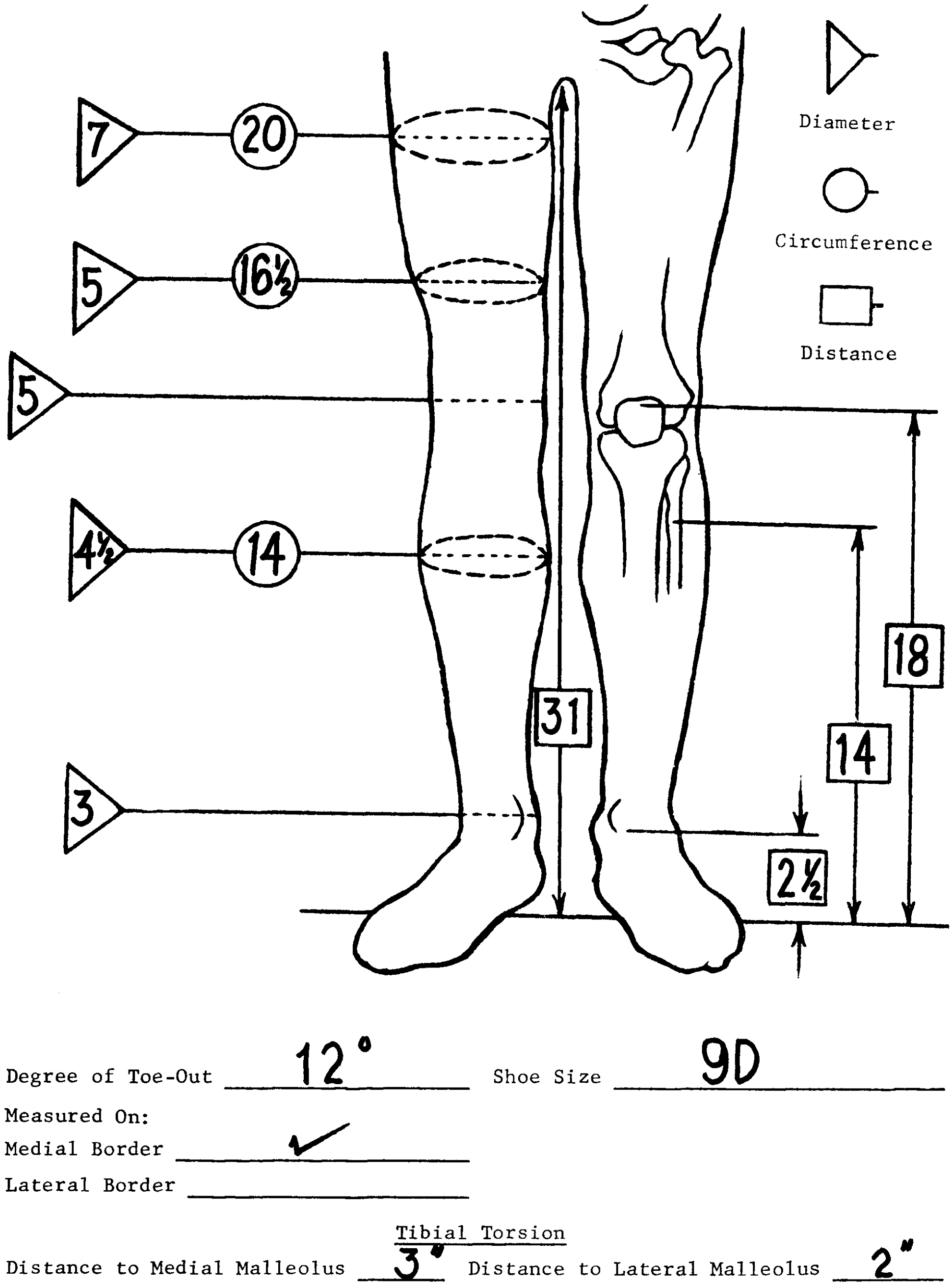

Fig. 4. Lower-extremity orthotics measurement form.

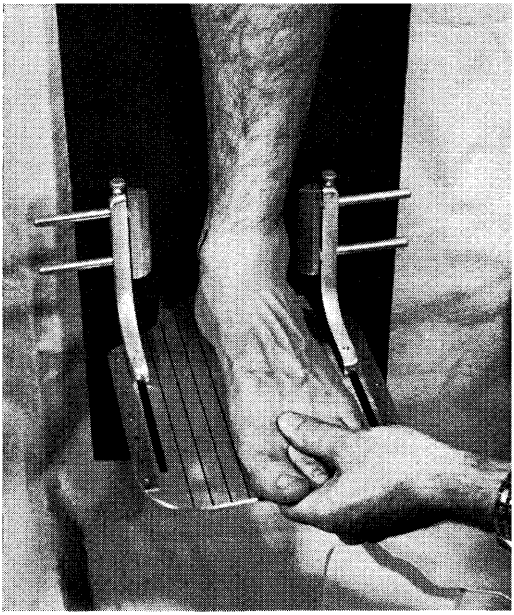

Fig. 5. Measuring toe-out.

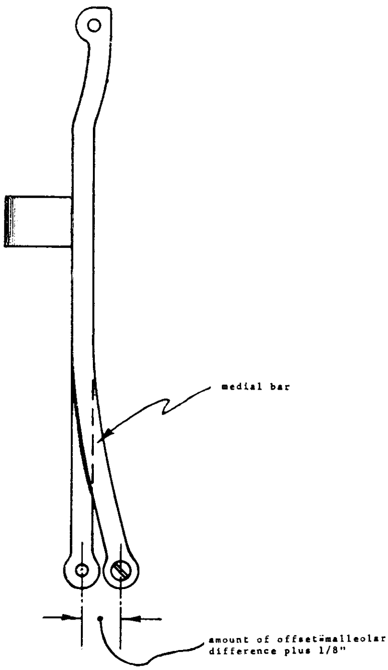

Fig. 6. Accommodation for tibial torsion on the medial bar of the leg brace when the difference between malleolar measurements is 1 in. or less.

ments exceed 1 in., the excess is accommodated by posterior deflection of the lateral ankle joint. After offsetting the ankle joint, both joint surfaces must be realigned parallel to each other (Fig. 7).

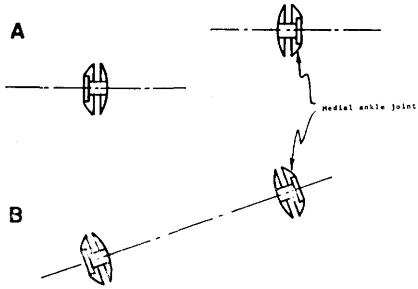

Fig. 7. Accommodation for tibial torsion by anterior deflection of the medial ankle joint of the leg brace. When the difference between the malleolar measurements exceeds 1 in., the lateral joint is posteriorly deflected by the excess over 1 in. *A,* Before parallel realignment of joint surfaces; *B,* after parallel realignment of joint surfaces.

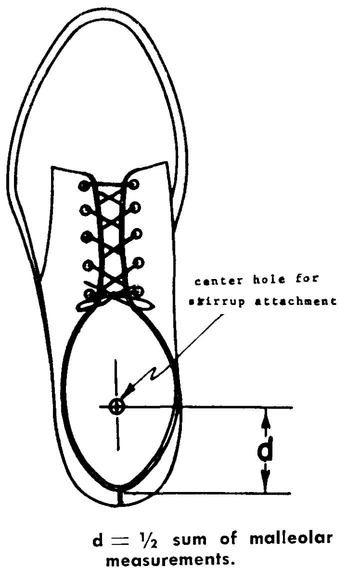

Fig. 8. Accommodation for toe-out. A hole is drilled through the sole of the shoe at a point in front of the counter, equal to one-half the sum of both malleolar measurements.

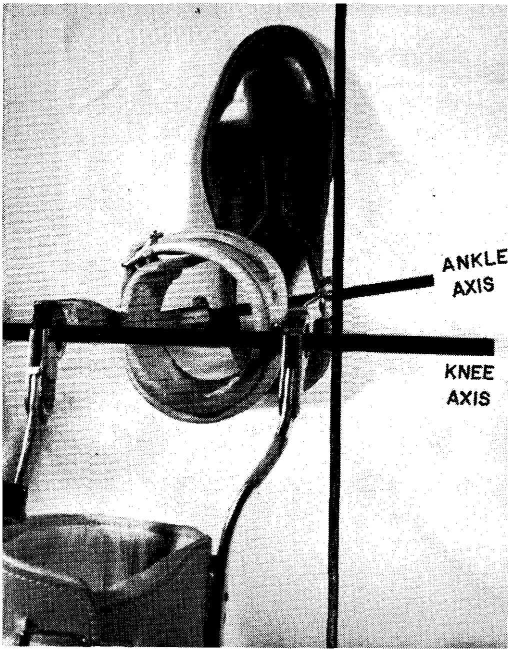

Fig. 9. Relating toe-out to the knee axis of the brace.

TOE-OUT

Toe-out accommodation is the final step in brace fabrication. This requires assembly of the stirrup to the leg brace frame. To determine the proper anteroposterior position of the stirrup on the shoe, a hole is drilled through the sole of the shoe at a point in front of the counter, equal to one-half the sum of both malleolar measurements (Fig. 8). The stirrup is then attached to the shoe with one rivet through the center of the stirrup to permit rotation of the shoe on the stirrup to match the degree of toe-out recorded on the orthotics measurement form. As described in this article, toe-out is measured as the angular relationship between the knee axis and the medial border of the foot. Consequently, in brace fabrication the medial border of the shoe must be related to the brace knee axis (Fig. 9). Two or more additional rivets may then be used to fix the shoe on the stirrup in the desired position.

SUMMARY

The measurement board described is designed to measure the relative distance of the medial and lateral malleoli from the back of the heel in the transverse plane. It is also used to obtain an angular measurement between the medial border of the foot and the knee axis.

Following the procedure described, the orthotist may produce a brace which more nearly corresponds to the patient's individual anatomical structure. Although the accommodation of tibial torsion is of diminished consequence when limited-motion ankle joints are used, its routine introduction in the brace is relatively simple and, of course, of utmost importance with free-motion ankle joints. Conversely, toe-out accommodation is not dependent on the type of ankle joint but is an individual measure with equal importance in all cases.

ACKNOWLEDGMENTS

The project described was conducted under the general supervision of Dr. Sidney Fishman and Mr. Norman Berger. I am most grateful to Dr. Fishman and Mr. Warren Springer for their review of the manuscript.

Bibliography on the Physical Properties of the Skeletal System[1]

F. GAYNOR EVANS, PH.D.[2]

JL HIS bibliography on the physical properties of the skeletal system is an outgrowth of one originally prepared in connection with my own research in this area and the writing of a book on the subject. The bibliography includes references to research on the physical properties of bone considered as a material, as well as to research on intact bones and parts of the skeleton. There are also a few references to the physical properties of intervertebral disks and of articular cartilage.

Most of the references deal with properties at the gross rather than the molecular level. While these properties are usually considered as "mechanical" rather than "physical," the term "physical" properties was believed to be a better choice for our purpose because it is more generally understood by those who are not specialists in the field of materials testing.

No claim is made that the present bibliography is a complete one. However, we believe that it contains references to most of the important publications on the subject. Except in special cases, for example, Russian and Japanese, each reference is cited in its original language. To the extent permitted by time and facilities, each reference has been carefully checked for accuracy. Many references not included in the present bibliography are filed and, it is hoped, will be reviewed and added at some future time.

We believe the bibliography will be useful to individuals working in many different areas. Some of these areas are orthopaedic surgery, trauma surgery, neurosurgery; physical medicine and rehabilitation; the design and manufacturing of prosthetic and orthotic appliances; safety engineering in the automotive and airplane industries as well as in the space program; the manufacture of crash helmets and other safety gear; anatomy, physical anthropology, and other areas of investigation within the basic sciences.

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[2] Professor of Anatomy, University of Michigan, Ann Arbor, Mich. 48104. In the preparation of this bibliography, Professor Evans was assisted by Antoinette R. Catron, M.A., Department of Anatomy. University of Michigan.

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Review of Visual Aids for Prosthetics and Orthotics, *Continued*

PROSTHETICS (GENERAL)

"Bilateral Hip Disarticulation: Casting, Fabrication and Training," Prosthetic-Orthotic Education, Northwestern University, 1967, 27 min., color, sound, 16 mm.

Summary: Presents a young man with transverse myelitis who underwent bilateral hip disarticulation for the purpose of increasing mobility. The picture shows a suspension-casting technique and a step-by-step progression in fabricating and fitting the plastic socket. Limbs are attached to the socket by mechanical hip joints. Demonstrates training activities, such as balance exercises; ambulation, using parallel bars; negotiation of stairs, curbs, and inclines; and falling and recovery. Pylons are replaced with articulated prostheses incorporating manual knee locks. The patient is seen at the conclusion of the rehabilitation program walking along the street using crutches.

Evaluation: This is a technically excellent film in which the prosthetics techniques and the training procedures are clearly portrayed. A minor exception concerns positioning for the hip joint, where further clarification is needed. It should be noted that the remarkable results obtained by this patient can be attributed largely to the fact that he is highly motivated and possesses superior neuromuscular coordination and strength. The film, which presupposes some knowledge of the subject, would be particularly useful for prosthetists and physical therapists who might be working with this type of patient.

Distributor: Prosthetic and Sensory Aids Service, Veterans Administration, 252 Seventh Ave., New York, N.Y. 10001.

Rental Fee: None.

"Rehabilitation of the Quadruple Amputee" Baylor University—Texas Institute for Research and Rehabilitation, 1967, 15 min., color, sound, 16 mm.

Summary: Presents a young man who became a quadruple amputee as the result of electrical burns. The below-elbow and below-knee stumps are shown before and after surgical revision. Patient is shown donning the prostheses, walking, negotiating stairs, and performing several other activities of daily living.

Evaluation: The film shows some activities that this type of quadruple amputee is able to perform in a clinical situation. The approach is very general in that only results are shown, without reference to methods of training, time required for training, and professional partici-

[1] This review, a continuation of the review appearing in the Autumn 1965 and the Autumn 1966 issues of *Artificial Limbs,* was compiled by the Subcommittee on Prosthetic-Orthotic Educational Materials of the Committee on Prosthetic-Orthotic Education. Members of the subcommittee are Mrs. Geneva R. Johnson (Chairman), Director, Physical Therapy Curriculum, Case Western Reserve University, Cleveland, Ohio; Mrs. Joan E. Edelstein, Associate Research Scientist, Prosthetics and Orthotics, New York University, New York, N.Y.; Mr. Herbert B. Hanger, Prosthetic-Orthotic Education, Northwestern University, Chicago, 111.; Mr. Frank W. Harmon, Atlanta Brace Shop, Atlanta, Ga.; Miss Jamie L. Lisle, Chief, Division of Physical Therapy, Medical College of Virginia, Richmond, Va.; Miss Phyllis Porter, Assistant Professor, Rehabilitation Nursing, College of Nursing, University of Bridgeport, Bridgeport, Conn.; Mr. Clark Sabine, Assistant Professor, Richmond Professional Institute, Richmond, Va.; Augusto Sarmiento, M.D., Division of Orthopaedics, University of Miami Medical School, Miami, Fla.; and Miss Muriel E. Zimmerman, Associate Chief, Occupational Therapy, NYU Medical Center, New York, N.Y. Mrs. Barbara R. Friz, Executive Secretary, Committee on Prosthetic-Orthotic Education, serves as secretary of this subcommittee.

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pation. Vocational achievements would have been of interest, inasmuch as the patient returned to work on a farm. The technical quality of the film is good. The film might be useful to acquaint a patient, a family, or an interested group with the potential rehabilitation of this type of patient.

Distributor: Texas Institute for Research and Rehabilitation, 1333 Moursund Ave., Houston, Tex. 77025.

Rental Fee: None.

Purchase Cost: $85.00.

"Surgery and Immediate Prosthetic Rehabilitation of the Peripheral Vascular Disease Amputee," University of Miami, 1967, 16 min., color, sound, 16 mm.

Summary: Describes amputation surgery, immediate prosthetic fitting, and rehabilitation of a 62-year-old man who underwent a below-knee amputation for severe arteriosclerosis. Points stressed in surgical procedure include transection of the tibia and fibula at the same level, unattached sectioned muscle groups, and the use of interrupted sutures, rather than drains. A plaster-of-Paris socket that leaves the knee unrestricted is attached to an adjustable pylon with foot. Weight-bearing is on a graduated basis. Also briefly presented is a 79-year-old diabetic fitted with the expandable PTB-Syme's prosthesis.

Evaluation: The film outlines clearly the steps and procedures followed in this approach to immediate postsurgical fitting. The subject matter is well organized and effectively handled. The technical quality of the film is excellent in all respects. It is of interest primarily to physicians and prosthetists. Although gait training is not included, physical therapists would be interested in the film for background information, as would other professional personnel working with patients who have undergone this procedure.

Distributor: American Academy of Orthopaedic Surgeons, 29 East Madison St., Chicago, 111. 60602.

Rental Fee: $3.00.

Purchase Cost: $130.00.

"Surgical Approach to Syme's Amputation," University of Miami, 1965, 13 min., color, sound, 16 mm.

Summary: The patient is a 22-year-old woman with spina bifida who required amputation of a foot because of infection. Illustrates surgical procedures, which include transection of bone to allow surfaces to be parallel to floor, removal of bone flares for improved cosmesis, and closure of wound with interrupted wire sutures. A SACH foot is attached to the plaster pylon and the patient becomes fully weight-bearing after the stitches are removed and the second cast is applied. The permanent appliance, which is usually delivered two months following amputation, has an inner wall of expandable plastic which eliminates the need for the side window and supracondylar cuff. Also shows a 79-year-old man satisfactorily wearing this type of prosthesis two years after amputation.

Evaluation: This is a well-organized, technically excellent film, presenting a modification of the Syme's amputation and prosthetic fitting. The prosthesis is described, but fabrication is not detailed. Some of the surgical procedures are shown without much explanation, so presumably they would be completely understood only by surgeons, to whom the picture is actually directed. Other professional groups would find the material valuable for orientation to this approach to the Syme's amputation.

Distributor: American Academy of Orthopaedic Surgeons, 29 East Madison St., Chicago, 111. 60602.

Rental Fee: $3.00.

CHILD PROSTHETICS

"The Child with an Acquired Amputation," Prosthetic-Orthotic Education, Northwestern University, 1967, 29 min., color, sound, 16 mm.

Summary: Summarizes current practices in the care of the child with an acquired amputation. Stresses behavioral and physiologic differences between children and adults. Presents statistics related to etiology and sites of amputation, outlines principles of surgery, and discusses prescription of prosthesis and principles of training as related to age of child. Emphasizes team approach and involvement of family.

Evaluation: This film provides an excellent vehicle for the philosophy underlying the medical management of these children. The subject is thoroughly covered, well organized and well documented. Continuity is maintained and the final summary constitutes an effective teaching device. The superb photography, animated illustrations, and musical background contribute to the technical excellence and appreciation of the film. The narration is not particularly well paced, and the statistics could be presented more effectively. The film is directed primarily to a physician (orthopaedic-pediatric) audience; however, it would also provide excellent orientation to the program for any professional person involved in the treatment of these children. Selected members of a family might profit by seeing it.

Distributor: American Academy of Orthopaedic Surgeons, 29 East Madison St., Chicago, 111. 60602.

Rental Fee: $3.00.

Purchase Cost: $150.00.

ORTHOTICS

"Balanced Forearm Orthosis in Muscular Dystrophy" Highland View Hospital, 1967, 14 min., color, sound, 16 mm.

Summary: Two patients with Duchenne's muscular dystrophy demonstrate how the balanced forearm orthosis (BFO) increases their independence. Film explains some principles underlying the function of the BFO and shows assembly of the device and method of making adjustments to aid or prevent specific motions. One patient demonstrates his ability to use the electric typewriter.

Evaluation: The material is clearly and simply presented and the demonstrations of increased function are effective. The technical quality is good. The presentation presupposes some knowledge of orthotic function, although terminology is often expressed in layman's terms. It would be of particular value to orthotists and occupational therapists interested in the use of this device.

Distributor: Highland View Hospital, 3901 Ireland Dr., Cleveland, Ohio 44122.

Rental Fee: $5.00.

Purchase Cost: $50.00.

"The IRM Electric Arm Orthosis," Institute of Rehabilitation Medicine, New York University, 1966-67, 8 min., color, sound, 16 mm-

Summary: Explains mechanism of motorized device and demonstrates use of the IRM electric arm orthosis for quadriplegic patient with C4-5 cervical lesion. Demonstrates prehension of the hand, pronation and supination of the forearm, elbow flexion and extension, and shoulder flexion, extension, abduction, and adduction.

Evaluation: The film introduces a new device. The technical quality is adequate for this purpose. Activation of motion should have been explained early in the film and needs clarification. The film was designed primarily for research orthotists and engineers, but is informative to any one interested in developments in this area.

Distributor: Institute of Rehabilitation Medicine, New York University Medical Center, 550 First Ave., New York, N.Y. 10016.

Rental Fee: None.

Purchase Cost: $30.00.

"The RIC Plastic Tenodesis Splint," Rehabilitation Institute of Chicago, Department of Occupational Therapy, 1967, 24 min., color, sound, 16 mm.

Summary: Shows how patient with minimal wrist function can use this device effectively. Describes components of the splint which possesses no mechanical joints. Discusses criteria for useful wearing. Demonstrates application and removal of splint, steps in training, and use in a number of activities, such as shaving, writing, and cutting meat. The last portion of the film demonstrates the steps in fabrication and fitting. The advantages of the splint are listed.

Evaluation: This is an outstanding instructional film, exemplifying the highest technical and professional qualities in production. Photography and narration are exceptionally good. Subject matter is well organized and presented clearly and concisely. Physicians, orthotists, occupational therapists, physical therapists, and nurses will be interested in the film, particularly the first half; the second half is specifically directed to the orthotist.

Distributor: Rehabilitation Institute of Chicago, 401 East Ohio St., Chicago, 111. 60611.

Rental Fee: $10.00.

Purchase Cost: $175.00.

News and Notes

Seventeenth Meeting of CPRD

The Seventeenth Meeting of the Committee on Prosthetics Research and Development was held in the National Academy of Sciences Building, Washington, D.C., on October 21, 1967. The Chairman of CPRD, Dr. Herbert Elftman, presided. The Vice Chairman of CPRD, Colin A. McLaurin, was present. Other members of CPRD attending the meeting were Dr. George T. Aitken, Dr. Cameron B. Hall, Dr. Robert W. Mann, Alvin L. Muilenburg, Professor J. Raymond Pearson, Professor Charles W. Radcliffe, Dr. Allen S. Russek, Professor Robert N. Scott, Howard R. Thranhardt, and Bert R. Titus. Drs. John Lyman and James B. Reswick, past members of CPRD, were present. Dr. Herbert E. Pedersen, who, as Chairman of the Committee on Prosthetic-Orthotic Education, is a liaison member of CPRD, was present. The Children's Bureau was represented by Dr. Charles P. Gershenson, the Veterans Administration by Anthony Staros, and the Social and Rehabilitation Service by Joseph E. Traub.

Others attending the meeting were Colonel Peter M. Margetis, Director of the Army Medical Biomechanical Research Laboratory; Dr. Fred Leonard, Scientific Director of AMBRL; Drs. Edward A. Kiessling, Claude N. Lambert, Yoshio Setoguchi, and Warren G. Stamp; Mrs. Barbara R. Friz, Executive Secretary of CPOE; S. M. Charlesworth, Assistant Executive Secretary of the Division of Engineering, National Research Council; A. Bennett Wilson, Jr., Executive Director, Committee on Prosthetics Research and Development; Hector W. Kay, Assistant Executive Director, CPRD; and James R. Kingham, Staff Editor, CPRD.

Dr. Elftman convened the meeting and invited Mr. Charlesworth to speak on behalf of the Division of Engineering. Mr. Charlesworth explained that because of other commitments it was not possible for the Executive Secretary of the Division of Engineering to be present. Mr. Charlesworth extended a hearty welcome to CPRD from the Division and then dwelt briefly on the uniqueness of the National Research Council in its capabilities for interdisciplinary endeavors; for example, the opportunities to work with the Materials Advisory Board (within the Division of Engineering) in the area of new materials for application in prosthetics.

Professor Pearson, Chairman of the Subcommittee on Fundamental Studies, reported on the plans of the subcommittee to arrange for a conference on the human foot, probably in the spring of 1968.

Mr. McLaurin, Chairman of the Subcommittee on Design and Development, gave an overview of the work of the various workshop panels and said that, in the future, the subcommittee will probably be more closely involved in the details of panel activities. He then called upon those panel chairmen present to comment on the work of their panels.

Professor Radcliffe reported that it was planned to hold the next meeting of the Workshop Panel on Lower-Extremity Components in Miami during December 1967. Problems confronting the panel included: prosthetic feet, modular prostheses for above-knee amputees, reconsideration of knee controls, and built-in alignment devices. He said that consideration would also be given to scaled-down models for children.

Mr. Staros briefly mentioned a number of orthotic devices and techniques under consideration by the Workshop Panel on Lower-Extremity Orthotics and said that there is increasing interest in lower-extremity orthotics. Two major developments of the panel were: stimulus for a proposed workshop on the problems of the human foot; a proposed survey of lower-extremity orthotics practices in the United States. He said that the panel is also working on nomenclature. It seemed likely that the next meeting of the panel would beheld during the late spring of 1968.

In the absence of the panel chairman, Mr. Wilson spoke briefly on the activities of the Workshop Panel on Lower-Extremity Prosthetics Fitting. He said that the last meeting of the panel was at Duke University under the chairmanship of James Foort, and that the highlight of the meeting was the emphasis on methods for the measurement of pressures between stumps and sockets. Considerable interest has been stimulated in this problem.

Mr. Traub said that the last meeting of the Workshop Panel on Upper-Extremity Prosthetics Fitting, Harnessing, and Power Transmission was chiefly concerned with the UCLA project for rewriting the *Manual of Upper-Extremity Prosthetics,* a project which was going well. It was believed that the panels on fitting and components should be merged. Considerable interest had been stimulated in the problem of the interface between the amputee and the prosthesis.

Dr. Lyman, who served as a co-chairman with Mr. McLaurin at a combined meeting of the Panel on the Control of External Power and the Panel on Upper-Extremity Orthotics in New York during May 1967, briefly reported on the meeting. He said that the report of the meeting might be considered as a statement of what is new since the report of the Conference on the Control of External Power in Upper-Extremity Rehabilitation held in Warrenton in 1965.

Mr. McLaurin recommended the continued support of the panel sessions, and there was general concurrence in his recommendation.

Mr. Thranhardt, Chairman of the Subcommittee on Evaluation, reported that a meeting of the subcommittee had been held during August 1967. He said that extensive clinical evaluations had been performed on two items (Engen hand orthosis and VAPC PTB brace) during the past year.

There was a general discussion of evaluation. Dr. Aitken commented that the final outcome to be expected from the pilot study being conducted by CPRD was unclear. Dr. Elftman said that, in his opinion, the distinction between testing and evaluation sometimes tended to be hairsplitting. Mr. McLaurin said that two laboratories—AMBRL and VAPC—had indicated their willingness to perform what might be termed laboratory or engineering testing of items under development, a proper function of design and development. In Mr. McLaurin's opinion, the rather limited work done so far by CPRD on the pilot evaluation program was excellent. Professor Radcliffe observed that CPRD was not really set up to do extensive testing in areas outside the capabilities of AMBRL and VAPC. Mr. Thranhardt commented that the engineers in design and development perform certain initial evaluation; following this comes the clinical field testing, which requires considerable staff effort. He questioned whether this was actually an appropriate staff activity. Professor Radcliffe said that he believed that there is a burden on a developer to prepare a set of clear, teachable instructions for the application of a new device or technique. Moreover, laboratory-type evaluations should be carried out by the developer and documented. Mr. Kay commented that, in his opinion, independent evaluation is still an essential part of the process.

Mr. Wilson then commented that CPRD had been operating for some 15 months on its pilot evaluation program. There had been excellent cooperation. He believed that far-reaching decisions should not be made until draft reports of the pilot program could be made available.

Dr. Aitken noted that NYU was still serving as an independent laboratory for the child prosthetics program. He added that very soon there would be some highly sophisticated externally powered devices which would require skilled professional evaluation.

Dr. Mann cited his experience with the development of an externally powered upper-extremity prosthesis in which several groups—the Board of Directors of Liberty Mutual, MIT, and Massachusetts General Hospital—all had an interest and served to check on each other.

Dr. Aitken observed that CPRD does not possess an in-house capability to test. He considered that the alternatives confronting CPRD were either to develop such a capability or to encourage an independent institution to acquire this capability. It appeared to him that a university would be a logical institution.

Professor Radcliffe said that the University of California would not be interested in operating an evaluation laboratory. He added that the actual testing of the PTB prosthesis and the adjustable casting brim was done by San Francisco Bay Area prosthetists.

Professor Scott said that a distinction should be made between informal and formal evaluation.

Mr. Staros expressed the view that it would be appropriate for SRS to undertake evaluation, in a manner similar to VA.

Mr. Traub said that, eventually, SRS probably would have its own laboratory. Quite possibly, when the present contract for the CPRD pilot evaluation project expired, SRS would seek to continue the program on an interim basis.

Dr. Aitken, Chairman of the Subcommittee on Child Prosthetics Problems, reported that there had been two meetings of the subcommittee since the last meeting of CPRD.

At Dr. Aitken's request, Mr. McLaurin demonstrated an electrically powered, coordinated arm developed at the Ontario Crippled Children's Centre and showed projection slides depicting the arm fitted to a child bimanually.

Dr. Aitken then said that at the most recent meeting of the subcommittee a matter had come up which required action by the parent committee. A number of highly sophisticated, externally powered devices had come into existence, and there was a need for the establishment of specialized centers to fit these devices to severely handicapped children. Within the United States there is a continuing population of perhaps 1,500 to 2,000 such severely handicapped persons. Moreover, it was probable that externally powered arms such as the one Mr. McLaurin had demonstrated would always be in a fluid state of development.

After some discussion, CPRD approved the proposal of the Subcommittee on Child Prosthetics Problems to establish an *ad hoc* committee to develop a detailed plan for the establishment of a specialized prosthetics fitting center for severely handicapped children.

Dr. Mann, Chairman of the Subcommittee on Sensory Aids, said that the subcommittee had sponsored a two-day conference on sensory aids during March 1967, and he distributed copies of a draft report of the meeting to the members of CPRD.

Dr. Mann urged that a separate Committee on Sensory Aids be established, and Mr. Staros commented that from the point of view of the Veterans Administration there might not be sufficient funding available to support such a separate committee.

Dr. Gershenson said that there were two matters of importance that CPRD should be aware of. The first was the establishment of the Social and Rehabilitation Service within the Department of Health, Education, and Welfare. The five major agencies within SRS are: the Rehabilitation Service Administration, the Children's Bureau, the Administration on Aging, the Medical Service Administration, and the Assistance Payments Administration. The first three agencies are primarily concerned with services, and the last two with payments. Dr. Gershenson added that further changes are under way, with an overall trend toward moving authority and responsibility away from Washington to Regional Commissioners. Changes in the organization of the Public Health Service were also in the offing.

The second matter of importance, Dr. Gershenson said, was the present austerity in the expenditure of public funds. Because this situation existed, it was important that CPRD make its needs known at the highest levels and that programs be set up in terms of five-year increments. Proposed programs should be translated into economic terms.

Mr. Traub reiterated the importance of the need for five-year planning mentioned by Dr. Gershenson. He added that, in this respect, the report of the CPRD Conference on Prosthetics and Orthotics held during December 1966 had been of considerable assistance. He suggested that it might be desirable to hold a small conference each year for the purpose of bringing the report up to date.

In discussing the relationship of the Veterans Administration with CPRD, Mr. Staros also emphasized the need for awareness of the current philosophy of austerity and the importance of five-year plans. He concurred in the recommendation made by Mr. Traub that annual conferences on prosthetics and orthotics be held for the purpose of updating recommendations.

Mr. Staros concluded his remarks by saying that Dr. Robert E. Stewart, Director of the VA Prosthetic and Sensory Aids Service had asked him to convey congratulations to CPRD for its work. In Dr. Stewart's opinion, CPRD was the architect of the entire program.

Dr. Pedersen, as the new Chairman of the Committee on Prosthetic-Orthotic Education, introduced Mrs. Friz as the new Executive

Secretary serving CPOE and paid tribute to the work of Dr. Glattly over the years.

Dr. Pedersen said that there seemed to be some overlap in the surveys of current orthotics practices currently under way; he trusted that, with proper coordination, duplication of effort could be avoided.

Colonel Margetis and Dr. Fred Leonard showed samples and projection slides illustrative of a method for fabricating a transparent prosthetic socket suitable for investigative purposes.

Dr. Leonard demonstrated an electromechanical hand developed by AMBRL. He said that a number of models were being built for experimental fittings within the program.

Dr. Leonard also showed a plastic leg brace developed in Israel. Dr. Reswick briefly described a method developed in Russia for the treatment of stroke cases. It involved the replaying of electrical stimulating signals from the recording of normal activities and was reported to be highly beneficial.

Dr. Reswick also mentioned that Case Institute was producing, for experimental purposes, a limited number of electrodes suitable for implantation in human beings.

Mr. Wilson reviewed plans for a conference on the foot and ankle, noting that it now appeared that a workshop panel would be held, rather than a seminar. Tentatively, the meeting would be held during February or March 1968, but plans were still fluid. It was hoped that the outcome of the meeting would be a document recording present knowledge.

Mr. Wilson said that there had been a great demand for copies of the report of the Conference on the Geriatric Amputee held during 1962. He was certain that many of these copies had found their way into the teaching programs. However, despite the continuing demand, he was hesitant about ordering reprints because the report had been overtaken by events and was in need of updating. He hoped that it might be possible to convene a small conference for the purpose of reviewing the previous publication and bringing it up to date.

Dr. Pedersen concurred that much in the previous publication was now erroneous.

Dr. Aitken said that a conference of the type proposed would be premature. Another year or more was required to understand the meaning of immediate postsurgical prosthetics fittings for geriatric patients. He believed that the orthotics portion of the publication would be relatively small.

Dr. Pedersen said that, in his opinion, the most important single problem with respect to peacetime amputees is the care of geriatrics. He considered it essential to get the latest correct information out to the physicians involved.

Mr. McLaurin observed that the problem probably belonged within CPOE.

Dr. Russek said that he was presently arranging a regional conference on geriatric amputees in the New York City area, probably to be held during the first week of December 1967. He said that the conference was necessary because of divergences and the need for agreement or disagreement. He said that confusion exists in New York concerning this subject.

Dr. Hall said that he was not yet in a position to comment. Material concerning immediate postsurgical fittings was still being gathered in the Los Angeles area; as yet, there was no well-formulated opinion. It appeared to him that Dr. Pedersen, as Chairman of CPOE, had a more immediate interest.

It was decided by CPRD to recommend that CPOE assume the responsibility for organizing a conference and preparing an up-to-date document on the treatment of geriatric amputees.

Mr. Wilson said that until more is known about the effect of pressures and shears on human tissues there was very little chance of achieving breakthroughs. He said that, in his opinion, the whole area should be explored.

Mr. McLaurin concurred and added that he could think of nothing that might be more significant. He believed that a conference would be helpful.

Dr. Elftman observed that physiologists have information that has yet to be passed to clinicians.

It was decided by CPRD that a conference on the effect of pressures and shears should be organized and held.

Mr. Staros briefly mentioned the activities of the North American Subcommittee on Prosthetics and Orthotics and the International Committee on Prosthetics and Orthotics. He said that countries other than the United States are represented at the international conferences by impressive exhibits. If CPRD would participate, VA and SRS would be brought together in organizing an exhibit for the XI World Conference of the International Society for Rehabilitation of the Disabled to be held in Dublin during 1969.

It was decided by CPRD that the Committee would participate in organizing an exhibit for the XI World Conference.

Mr. Kingham briefly reviewed the activities of the recently established United States National Committee on Engineering in Medicine and Biology, which he serves as Staff Executive in addition to his regular duties as Staff Editor of CPRD. He said that the National Academy of Engineering had more recently established a Committee on the Interplay of Engineering with Biology and Medicine, and that the National Institutes of Health had signed a $250,000 contract for the support of the new committee. However, little was known about the new committee, since it had not yet held its first meeting.

There was a brief general discussion of systems management, during which Dr. Reswick said that he considered that, using VA as a model, SRS would do well to develop an in-house capability to monitor contracts, *etc.*

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 Joseph Henry Building (which is leased by the National Academy of Sciences) in Washington, D.C, on October 20, 1967. The Chairman of the Subcommittee, Dr. George T. Aitken, presided. Members attending the meeting were Dr. Sidney Fishman, Dr. Claude N. Lambert, Dr. Fred Leonard, Dr. Newton C. McCollough, Colin A. McLaurin, and Dr. Yoshio Setoguchi. The Children's Bureau of the Social and Rehabilitation Service was represented by Drs. Arthur J. Lesser and Charles P. Gershenson.

Others attending the meeting were Albert B. Colman, Roy Katsuren, and Lloyd Salisbury, staff scientists of the Army Medical Biomechanical Research Laboratory; C. B. Taft and C. Dolan, staff members of New York University; Bert R. Titus, of Duke University Medical Center; Dr. Donald S. Pierce, of Massachusetts General Hospital; Dr. Herbert Elftman, Chairman of the Committee on Prosthetics Research and Development; A. Bennett Wilson, Jr., Executive Director of CPRD; Hector W. Kay, Assistant Executive Director of CPRD; and James R. Kingham, Staff Editor of CPRD.

The Chairman convened the meeting and extended a special welcome to the two new members of the Subcommittee, Drs. Leonard and Setoguchi.

Dr. Aitken noted that a serious problem confronting the Subcommittee was the need for a speed-up in the application of special devices to severely handicapped children. A major item of business before the Subcommittee would be consideration of a plan for the solution of this problem.

At the invitation of the Chairman, Dr. Lesser spoke briefly on the general prospects of government funding of child prosthetics program activities during the coming year. Dr. Lesser said that at the present time Congress had not yet passed an appropriation act for the fiscal year already begun. The various governmental agencies were operating under monthly resolutions which enabled them, each month, to operate at the same fiscal level as one year ago. New projects could not be undertaken. Because of the proposed surtax and the expenditures for the Vietnam conflict, there was a strong drive for economy. The major general emphasis in the Deparment of Health, Education, and Welfare was on the poverty program and family planning. Because of the uncertainty of the level of the funding that might eventually become available, it would be highly desirable for the subcommittee to develop rather specific programs; for example, one to provide special arms for severely handicapped children.

Dr. Gershenson, whose office is concerned with research grant funds, confirmed Dr. Lesser's comments regarding the tightness of funds. He said that this was also a period of change in the setting up of priorities and reorganization.

Dr. Gershenson recommended that the subcommittee think in terms of five-year increments of overall strategy. The subcommittee should identify specific problems and determine what progress might be made, how many people were affected by the problems, and what the costs (overall and per capita) would be for programs to alleviate the problems. It would be desirable to develop a rational strategy, with a justification for this particular strategy. Such an approach would have an appeal to those responsible for the expenditure of government funds. There should be no surprises, although the possibility for dramatic breakthroughs would be recognized.

Dr. Gershenson said that the subcommittee's plans should be thought out in terms of both a bioengineering framework and a psychosocial framework. Help should be sought from the behavioral sciences.

Dr. Gershenson said that the spirit of the times called for "cutting fat" from the budget. Therefore, the cost of research must be recognized. In general, research possessed three characteristics: it was costly; it was time-consuming; it often did not bring results. Congress demanded results, and the political realities must be taken into consideration.

In concluding his remarks, Dr. Gershenson said that the efforts of the Children's Bureau should be strengthened as a result of the reorganization of the Social and Rehabilitation Service, and a joint funding of projects should be feasible. Within the Children's Bureau, the child prosthetics program was a high-priority area.

The Chairman expressed his concern with the inability of the subcommittee to expedite the transition from development to patient application of certain items that could be highly beneficial to severely handicapped children. Since these items were continually being redesigned, they probably would never have commercial appeal. Some of these items were components, some were complete systems. Meanwhile the children who could be benefited were becoming older.

In the United Kingdom, centralized fitting laboratories have been effective in serving the severely handicapped. But in the United States there was not a single centralized laboratory for this purpose. Dr. Aitken suggested that perhaps one or more fitting centers, with complete capabilities to do a skilled job, should be established. Thus, when a child outgrew some highly specialized item, the item should be recovered, refurbished, and reissued to another child.

Dr. Fishman estimated that approximately 15 per cent of the child amputee population might be considered to be severely handicapped; that is, in need of sophisticated devices. He said that perhaps there were 1,500-2,500 such children in the United States.

Mr. McLaurin observed that if these children were to receive optimal service they could not be cared for by various local clinics all over the country. He briefly discussed the experience of the children's centers in Toronto and Edinburgh, saying that in both centers acute problems can be attacked directly because the developers were in close contact with the clinical situation.

Dr. Lesser then briefly discussed certain special-project funds of the Children's Bureau which might be used in support of care for out-of-state children at regional centers. He believed that the idea of centers serving geographic and demographic areas had merit.

Mr. McLaurin expressed the view that the engineer staff at such centers should be there for the sole purpose of developing special equipment.

Dr. Fishman said that he did not believe that the establishment of one or two centers alone would solve the problem. There would be a need for continuing monitoring over the years between the children's visits to the major centers. Therefore, training and orientation should be given to the local clinic personnel, also. Besides, he said, there were severely handicapped adults to be served.

Dr. Leonard requested clarification of the problem. In response, the Chairman cited the MCCC electric feeder arm as an example. He said that this device should be manufactured in sufficient volume so that children throughout the country would benefit.

Dr. Leonard then inquired whether the core of the problem was: How to get these devices manufactured?

The Chairman said that more than that was involved. Would some of his M.D. colleagues be willing to give up some of their prerogatives and refer their patients to specialized centers? He believed that centralized control was necessary.

Mr. McLaurin said that maintenance of the devices would be no problem. By using air express, devices requiring major repairs could be sent to a central facility. The using centers need not *develop* devices but simply *apply* whatever was available.

The Chairman mentioned as an example that the MCCC electric feeder arm could benefit children between the ages of three and six. He then referred to a map of the United States which depicted the participating child amputee clinics and said that those clinics—all of them—were treating only about 12 bilateral upper-extremity amelics in this age group. In the proposed plan the participating clinics could send their extremely handicapped children to a special center. Such a program would involve all three areas of interest to the Children's Bureau and the Subcommittee on Child Prosthetics Problems: research, development, and service.

Dr. Lesser said that a number of questions occurred to him; for example: Is the central problem research or manufacturing? Would all the centers be centers of technical excellence? Would the items be made on contract or by the center? What would be the mechanism for distribution? How would the follow-up be handled? How would the children be selected? How would fitting, supervision, and replacement be handled? How much time would be allotted to training? In his opinion, these details were important and should be resolved.

The Chairman said that one problem would be to say in advance how much money would be required, since the items involved might not be fully known at the beginning of any fiscal period. In any event, there was a definite need to develop a plan to present to the appropriate government agency for funding.

It was the consensus that an *ad hoc* committee should be established to develop a detailed plan for the establishment of a specialized center or centers for the fitting of devices to severely handicapped children.

At the request of the Chairman, Mr. Kay briefly summarized the current situation with respect to the cooperating child amputee clinics. He said that there were some 26 full-fledged participating clinics in the program and some 18 or 19 additional clinics with which fairly close contact was being maintained. Of these 18 or 19 additional clinics, six were close to meeting the qualifications for regular membership status. There should be an increase in the number of participating clmics within one year or perhaps one and one-half years. No concerted effort had been made to recruit clinics. Mr. Kay pointed to a map on which the locations of clinics were indicated and said that there were large gaps in areas having considerable populations. He suggested that perhaps some recruiting effort should be made.

Dr. McCollough said that, although specific figures were not available, he was certain that many child amputees were not being adequately cared for. He said that there was a need for more young physicians to become interested in the program.

Mr. Wilson suggested that, at the next symposium of the Committee on the Skeletal System, a presentation might be made on the desirability of more children's clinics throughout the country. The chief concern of the symposium would be residency training programs.

Consideration was then given to a draft of the proposed revised criteria for participating clinics. Mr. Kay pointed out major changes being made in the criteria. After some discussion, it was decided that further revisions should be made by the *ad hoc* committee concerned and that copies of the draft should then be submitted by mail to the members of the subcommittee for their consideration.

The Chairman said that for some time it had been customary to hold the annual meeting of the chiefs of the participating clinics in conjunction with the annual meeting of the American Academy of Orthopaedic Surgeons, but for various reasons there were objections to this. Dr. Aitken said that it appeared that funds would be available to finance a meeting of the clinic chiefs during the spring of 1968.

Dr. Fishman stressed the importance of holding meetings of the clinic chiefs fairly frequently.

It was decided that an *ad hoc* committee would be established to plan for a meeting of the clinic chiefs to be held during the spring of 1968.

It was the consensus that an important item of business at the meeting of the clinic chiefs would be consideration of the plan for the establishment of regional specialized centers for severely handicapped children.

Mr. Kay reported that the *Inter-Clinic Information Bulletin* was now in its seventh year. Referring to figures on circulation prepared by NYU, he said that 2,000 copies were now being printed of each monthly issue and that more than 1,900 copies were distributed to addressees in the United States and abroad. He said that present scheduling extended through 1968 and called for articles by two clinic chiefs per issue.

Mr. Kay reported that 1,000 copies of *Normal and Abnormal Embryological Development* had been printed and that distribution was in progress.

Dr. Lambert inquired how extensively the nomenclature for congenital skeletal limb deficiencies developed by consultants to the subcommittee *(Artificial Limbs,* Spring 1966) had been accepted.

Dr. Fishman said that the Cameron Hall nomenclature was being taught at UCLA, the Frantz-O'Rahilly nomenclature at Northwestern University, and the new nomenclature at NYU. He added that the Lindemann-Marquardt nomenclature was in use in Germany, and said that the matter of developing a common nomenclature would be brought to the attention of the International Committee on Prosthetics and Orthotics, of which Dr. Knud Jansen is Chairman.

It was the consensus that it was unfortunate that three different nomenclatures were being taught in American universities. After some discussion, it was decided that a statement should be made to the University Council on Orthotic-Prosthetic Education, via CPRD, suggesting the desirability of coordination between schools with regard to instruction in nomenclature for congenital limb anomalies.

It was understood that Dr. Fishman would supplement the CPRD statement by informal discussions with the universities.

Dr. Fishman and Mr. Dolan briefly summarized experiences with the AMBRL porous laminate PTB prosthesis. They said that the initial reactions were generally favorable, the weight reduction and porosity being regarded as advantageous. Data on durability were insufficient to make a definite statement, but the available data were generally positive. It was stressed that the handling procedures set forth by AMBRL should be closely adhered to. During fabrication, the prosthesis required more meticulous craftsmanship and more time on the part of the prosthetist.

It was decided that the new AMBRL technique for stress-bearing application of porous plastic laminate prostheses should be referred to UCOPE for inclusion as part of the instruction in the armamentarium.

Dr. Fishman reviewed a field applications study made of five Michigan electric feeder arms fitted to seven children during the period July 1965 through June 1967, and Mr. Taft summarized an extensive report. In general, the device appeared to be satisfactory. Films depicting children using the device were shown to the subcommittee. Dr. Fishman said that an important question was the next step that should be taken, pointing out that the report recommended several small improvements that could be made fairly readily and some major design improvements that would require considerable work.

The Chairman said that 11 of the devices—suitable for children from two and one-half to six years of age—existed.

Dr. Lambert said that the device represented a satisfactory method for treating children with severe disabilities.

After further discussion, it was decided that efforts should be made by the developer to obtain 20 of the improved models of the MCCC electric feeder arm (10 right and 10 left), and that the recommended changes be reviewed by the CPRD Subcommittee on Design and Development.

Mr. Titus gave a brief, informal report on his experiences with the AIPR pneumatic prosthesis. He showed projection slides depicting a young girl-fitted with the prosthesis and demonstrated the arm itself. He said that the prosthesis had also been fitted to a nine-year-old child. The prosthesis had given very little trouble, and the younger child, particularly, had derived great benefit. Mr. Titus said that, in general, he had been very favorably impressed by the AIPR prosthesis.

It was the consensus that the subcommittee was interested in the AIPR device and that the developer should be encouraged to proceed.

Dr. Fishman said that a proposal had been submitted to the Children's Bureau for the support of a study by NYU of electrical components and controls. Mr. Dolan summarized some brief preliminary experience with the items. Mr. Salisbury demonstrated a number of AMBRL switches, including a strain gauge switch capable of working at two levels and a joystick switch. It was understood that AMBRL would supply elbows, hands, and switches required for the NYU study.

Mr. McLaurin said that the Prosthetics-Orthotics Research and Development Unit of the Manitoba Rehabilitation Hospital would streamline the design of the ankle unit available for the OCCC swivel walker *(Artificial Limbs,* Autumn 1966) and make the ankle unit available through some appropriate organization in the United States.

Mr. McLaurin submitted a draft brochure on the OCCC open above-elbow socket. Copies of the brochure would be distributed to the clinic chiefs after review and editorial revision by NYU.

Dr. Leonard showed a plastic brace fabricated in Israel, a rigid long leg brace, and a flexible drop-foot brace. He said that fabrication of the plastic braces would be taught to VAPC with a view toward a limited applications study. He said that the resilient hand was being modified, and that AMBRL was working on an all-electric hook, a powered wrist unit with pronation, supination, and flexion, and a shoulder unit.

Consideration was given to the Northwestern University linear actuator. Essentially, the item consists of an electric motor attached to a cable system to amplify cable excursion and power available from body sources. A limited number of patients had been fitted with the device. It was decided that the item would be dropped from the subcommittee agenda but would be followed by the staff.

A commercial prototype No. 1 hand developed by the D. W. Dorrance Co. was shown. The item would sell for $125 and was expected to be in production by early 1968. NYU was to purchase two hands (one right and one left) and make a limited test.

Consideration was given to a proposed form for use in connection with a juvenile amputee census to be conducted by NYU. It was decided that the study should proceed.

Consideration was given to a draft memorandum and questionnaire prepared by NYU for the purpose of conducting a survey of juvenile amputees engaged in competitive sports. Dr. Fishman pointed out that completion of the questionnaire would require considerable effort on the part of the clinic chiefs. It was the consensus that the survey should be deferred, and it was suggested that Dr. Fishman might simply write letters to the clinic chiefs asking them to supply information on sports participation that might be readily available.

Mr. Dolan briefly reported on the current status of an NYU survey of immediate postsurgical fittings of prostheses to children. He said that 120 amputations were performed by the participating clinics during 1966. Of these, somewhat more than 19 were immediate fittings and 39 were early fittings. He said that, generally, there appeared to be sufficient amputations and sufficient interest to warrant a field study.

Dr. Fishman commented that the study was assuming importance for a number of reasons and would be a major undertaking involving special courses of instruction.

Mr. McLaurin demonstrated a number of items under development at the Ontario Crippled Children's Centre, including a preschool, coordinated electric arm fitted with a three-finger terminal device. He showed slides depicting a boy who had been fitted with the arm bimanually. Mr. McLaurin estimated the unit cost of the arm to be approximately $1,000 and said that steps were being taken to have the arm manufactured in any quantity required.

The members of the subcommittee were very-much impressed by the arm and accepted it as a very promising and unusual developmental item. At the request of Dr. Leonard, Mr. McLaurin agreed to make drawings of the arm available to AMBRL, where a number of the arms would be made up for study.

Meeting of CPRD Subcommittee on Design and Development

The Subcommittee on Design and Development of the Committee on Prosthetics Research and Development met in the Hotel Jefferson, Washington, D.C., on October 20, 1967. The Chairman of the subcommittee, Colin A. McLaurin, presided. Subcommittee members attending the meeting were Dr. Fred Leonard, Dr. John Lyman, Professor Charles W. Radcliffe, Dr. James B. Reswick, and Anthony Staros.

Others attending the meeting were Arthur B. Colman and Lloyd Salisbury, staff scientists of the Army Medical Biomechanical Research Laboratory; Dr. Edward A. Kiessling, American Institute for Prosthetic Research; Joseph E. Traub, Social and Rehabilitation Service, Department of Health, Education, and Welfare; Dr. Herbert Elftman, Chairman of the Committee on Prosthetics Research and Development; Howard R. Thranhardt, Chairman of the Subcommittee on Evaluation, CPRD; A. Bennett Wilson, Jr., Executive Director, CPRD; Hector W. Kay, Assistant Executive Director, CPRD; and James R. Kingham, Staff Editor, CPRD.

After convening the meeting, Mr. McLaurin noted that the membership of the subcommittee had remained intact for several years and requested comments concerning new trends to be encouraged when new members were selected.

It was suggested that an important function of the subcommittee was to define problems that require work. To do this, the membership should be kept small.

There was discussion of, but no general agreement on, the possibility of appointing a production engineer to membership.

The activities of the workshop panels were briefly reviewed.

At a meeting of the Workshop Panel on Lower-Extremity Orthotics held in Santa Monica earlier this year, it was suggested 'that a special workshop on the problems of the human foot be convened. It appeared that, under the auspices of the Subcommittee on Fundamental Studies, such a workshop, consisting of some 15 to 30 persons, would be convened during March 1968. It seemed likely that the next meeting of the Workshop Panel on Lower-Extremity Orthotics would be held during the late spring of 1968.

The last meeting of the Workshop Panel on Upper-Extremity Prosthetics Fitting, Harnessing, and Power Transmission was chiefly concerned with the UCLA project for rewriting the *Manual of Upper-Extremity Prosthetics.* An effort was made to stimulate further research on the interface between the amputee and the prosthesis. It was also thought that the upper-extremity fitting and components panels should be merged.

It was pointed out that in upper-extremity fittings no serious work has been done in biomechanics and instrumentation, comparable to that which has been done in lower-extremity fittings. The need for accurate fitting in upper-extremity cases is perhaps not as great as it is in lower-extremity cases, but the same kind of man-machine interface problems should be pursued. It was recommended that this be done when enough people were interested.

The next meeting of the Workshop Panel on Lower-Extremity Prosthetics Components would be in Miami during December 1967. Problems confronting the panel were: prosthetic feet; modular prostheses for above-knee amputees; reconsideration of knee controls; three special problems (knee-disarticulation cases, hip-disarticulation cases, and geriatric cases); and built-in alignment devices. Consideration would also be given to scaled-down models for children.

The comment was made that lower-extremity amputees and paralytics constitute the majority of the potential beneficiaries of the prosthetics and orthotics program. However, it seemed that a major part of the development effort was being put into upper-extremity devices.

The Workshop Panel on Lower-Extremity Fitting had been active in promoting and discussing pressure measurements in sockets. Although the data so far obtained were somewhat crude for use in studies of stump circulation and related problems, it was believed that the data did add validity for the redesign of sockets.

It was suggested that one of the future panel sessions be devoted entirely to socket instrumentation.

The combined meeting of the Workshop Panel on Control of External Power and the Workshop Panel on Upper-Extremity Orthotics held in New York City during May 1967 was considered to have been successful in providing an active interchange of technical data and philosophy among those working in the field. There had been advances since the conference held in Warrenton in 1965.

Several persons active in the design of upper-extremity prosthetic and orthotic components were in attendance at the meeting in New York. But there seemed to be little interplay between them and the control group. Consequently, it was thought that the next meeting should be restricted to problems in control. The problem of relating progress in this field to practical design and to the eventual benefit of the patient remained to be solved.

The view was expressed that it would be desirable for the Social and Rehabilitation Service to develop a technical corps of persons qualified to make contract awards, in much the same manner as VA, NASA, and the Army. It was also believed that the sponsoring agencies should possess in-house laboratories.

Mr. Traub assured the subcommittee that SRS is gradually developing the capabilities described.

Mr. McLaurin requested comments concerning the desirability of creating an engineering office to facilitate the flow of design items into production.

It was suggested that one approach might be to employ consultants.

Others expressed the view that the present *ad hoc* method should be continued.

Mr. Wilson said that differentiation should be made between upper-extremity and lower-extremity items. In the case of lower-extremity items, there is sufficient volume to warrant the interest of commercial concerns, whereas this is not the case for many upper-extremity items.

Mr. McLaurin said that the subcommittee required laboratories to conduct performance testing of hardware for functional specifications and durability; cyclic testing, for example.

Mr. Staros, on behalf of VAPC, and Dr. Leonard, on behalf of AMBRL, said that their respective laboratories would gladly handle any such tests that were within their capabilities.

Mr. McLaurin invited comments as to future meetings of the subcommittee.

The view was expressed that meetings of the subcommittee should be held at least three or four times per year, and it was thought it would be desirable to hold the meetings at major research and development centers. It was the consensus that the next meeting should concern itself with items from the panel meetings.

CPRD Subcommittee on Child Prosthetics Problems Publishes Proceedings on Embryology

Normal and Abnormal Embryological Development, National Academy of Sciences Publication 1497, the proceedings of a symposium held in Chicago during January 1966 under the auspices of the Subcommittee on Child Prosthetics Problems of the Committee on Prosthetics Research and Development, an 82-page, illustrated report, has attracted widespread interest in medical circles.

The theme of the publication is stated by Dr. Charles H. Frantz, former Chairman of the Subcommittee on Child Prosthetics Problems, in his Foreword: "Our clinical endeavors are focused on child amputees and on children with limb malformations. Utilizing advanced prosthetic techniques, our goal is the restoration of limb function, in the hope that these handicapped children will be afforded the opportunity of assuming some degree of economic independence in the future. We are all aware that the patterns of these limb malformations are set during the embryonic period of pregnancy. . . . We hope that in the future ways and means may be found to modify or alleviate some of the common abnormalities. To arrive at a better understanding of the mechanisms at work, we must turn to our contemporaries in research."

Major papers in the publication are "Normal Development of the Human Embryo," by Ronan O'Rahilly, M.D., Chairman of the Department of Anatomy at St. Louis School of Medicine; "Control of Growth Patterns in Limb Development," by John W. Saunders, Jr., Ph.D., Marquette University; "The Contribution of Histochemistry to our Understanding of Limb Morphogenesis and Some of Its Congenital Deviations," by John Milaire, Ph.D., Professor of Anatomy at the University of Brussels; and "Environmental Factors in Human Teratology," by Sidney Q. Cohlan, M.D., Professor of Clinical Pediatrics at New York University Medical Center.

Report of CPRD Conference on Prosthetics and Orthotics in Demand

Prosthetics and Orthotics, the report of a conference sponsored by the Committee on Prosthetics Research and Development at the National Academy of Sciences during December 1966, a 41-page publication of the National Academy of Sciences, has had to be reprinted because of widespread demand. The conference reported on was held at the request of the Vocational Rehabilitation Administration (now the Social and Rehabilitation Service of the Department of Health, Education, and Welfare) for the purpose of developing information for use in planning research and development activities in prosthetics and orthotics for the next five years and longer.

In her Foreword to the publication, Miss Mary Switzer, Commissioner of the Vocational Rehabilitation Administration, says: "In many ways the field of prosthetics and orthotics has developed a model national program of research, training, and service to people. We are proud of the part we have been able to play in the development of this program. . . . This report is the result of the work of many people who have a vital interest in and broad knowledge of the field. The message within the pages of this report will impress one with the great variety of knowledge and skills that combine to produce advances in the tools, techniques, and hardware of prosthetics and orthotics. The conference outcome is an outstanding synthesis of the formidable tasks which we must attack."

In its conclusions, the conference found that great progress had 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 report makes a number of specific recommendations in the fields of lower-extremity and upper-extremity prosthetics.

With respect to orthotics, the conference found that, although persons in need of braces are much more numerous than those requiring prosthetic replacements, only minimal progress has been made in providing orthotic devices capable of giving functional rehabilitation. 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 was 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. Such a survey would also disclose the need for new devices and lead to their design and development.

Veterans Administration Publication on Immediate Postsurgical Prosthetics Fittings

Immediate Postsurgical Prosthetics in the Management of Lower Extremity Amputees, by Ernest M. Burgess, M.D., Principal Investigator, Prosthetics Research Study, Seattle, Wash.; Joseph E. Traub, Director, Prosthetics Research Study, Seattle, Wash.; and A. Bennett Wilson, Jr., Executive Director, Committee on Prosthetics Research and Development, is **a** 51-page, illustrated publication of the Veterans Administration's Prosthetic and Sensory Aids Service, available from the U.S. Government Printing Office for 45 cents. Because of widespread demand, a second printing was necessary.

In his Foreword to the publication, Dr. Robert E. Stewart, Director of the VA Prosthetic and Sensory Aids Service, says: "The preparation and dissemination of this handbook represent a milestone in an amputee management program that has been of great interest to the medical community and to all people concerned with the prosthetics restoration of the lower extremity amputee. . . . We appreciate greatly the efforts of the Committee on Prosthetics Research and Development of the National Academy of Sciences—National Research Council in helping advance this exciting program of amputee management, by stimulating the undertaking of similar research programs in other areas of the country, and by arranging for the valuable exchange of information among the several projects."

Annual Assembly of AOPA for 1967

The annual assembly of the American Orthotic and Prosthetic Association was held at the Hotel Fontainebleau, Miami Beach, Fla., October 7-10, 1967. The President of the Association, George H. Lambert, Sr., of Baton Rouge, La., presided. Registered attendance numbered 458. Exhibitors were well represented.

Preliminary activities before the formal opening of the assembly included a meeting of suppliers to the Veterans Administration, presided over by Dr. Edward Peizer, Chief of the Bioengineering Research Service at the VA Prosthetics Center in New York City. The chief purpose of this meeting was to discuss a proposed revision of the standards and specifications for prosthetic feet, including SACH feet. In the new standards, emphasis was to be placed upon functional characteristics.

The subject of the first technical session of the AOPA assembly was The Immediate Postsurgical Procedure, at which Richard G. Bidwell was scheduled to preside. Because of Mr. Bidwell's illness, however, Mr. Lambert, President of AOPA, presided. Panelists included Dr. Frank L. Golbranson, Dr. Alfred E. Kritter. Dr. Frank W. Clippinger, Jr., Dr. Augusto Sarmiento, Bert R. Titus, William F. Sinclair, and Fred J. Eschen. A feature of the session was the showing of a film on below-knee amputations primarily, followed by prosthetic fitting. The film had been prepared by Dr. Sarmiento at Jackson Memorial Hospital, Miami, under the sponsorship of AOPA. The film emphasized the contribution of the prosthetist in the procedure. Dr. Clippinger spoke on the Syme's amputation in immediate postsurgical fitting, and Dr. Golbranson spoke on the above-knee amputation. Dr. Golbranson also showed slides illustrating the type of amputee being treated as an outcome of the conflict in Vietnam. Dr. Kritter spoke on the application of immediate postsurgical fittings to upper-extremity amputees.

Among the salient points in the presentations was Dr. Sarmiento's stress on the value of the rigid dressing. In his opinion, it is the prime factor in the efficacy of immediate postsurgical fitting. Dr. Golbranson indicated that it is more difficult to apply immediate postsurgical procedures to above-knee amputations.

The subject of the second technical session was Insensitive Limbs. Featured was a presentation by Dr. Paul W. Brand, who is noted for his work with victims of Hansen's Disease at the Public Health Service Hospital in Carville, La.

In all, there were nine technical sessions, and it was the consensus that they were of superior quality throughout, reflecting credit upon Mr. Bidwell, who arranged the technical program.

Alvin L. Muilenburg, of Houston, Tex., was installed as the new President of the Association for 1967-1968. Serving with him are President-Elect Michael P. Cestaro, of Washington, D.C.; Vice President William L. Bartels, of Portland, Ore.; and Secretary-Treasurer Durward R. Coon, of Detroit, Mich.

The American Orthotic and Prosthetic Association maintains its national headquarters at 919 18th St., N.W., Washington, D.C. 20006. Executive Director of the Association is Herbert B. Warburton.

Meeting of North American Subcommittee of International Committee on Prosthetics and Orthotics

The North American Subcommittee of the International Committee on Prosthetics and Orthotics, International Society for Rehabilitation of the Disabled, met at the Hotel Fontainebleau, Miami Beach, Fla., on October 6, 1967. Anthony Staros, Chairman of the subcommittee, presided. Members present for the meeting were A. Bennett Wilson, Jr., Executive

Secretary; Dr. Miles Anderson, James Foort, Colin A. McLaurin, Alvin L. Muilenburg, Dr. Eugene F. Murphy, Professor Charles W. Radcliffe, Dr. Allen S. Russek, Charles Scott, Howard R. Thranhardt, William A. Tosberg, and Charles E. Yesalis.

Others present for the meeting were J. Morgan Greene, Hector W. Kay, Dr. Cameron B. Hall, Dr. Edward Peizer, Dr. Pierre Labelle, and Joseph E. Traub.

In his opening remarks, Mr. Staros said that the North American Subcommittee is now one of several regional subcommittees formed to give the parent International Committee larger representation. Latin America and the Far East now have such subcommittees, and additional subcommittees are planned for South Asia, the Middle East, Eastern Europe, and possibly Africa.

Mr. Staros then reviewed actions taken by the International Committee at its September 1966 meeting in Wiesbaden, Germany. There it was proposed that the International Committee be strengthened by adding associate members and honorary members. The associate membership would be composed of persons active in the fields of prosthetics and orthotics, and the honorary membership of persons who have been active but who have retired. Members of the regional subcommittees would be asked to serve as associate members if they were not already members of the International Committee or semiretired. Mr. Staros then requested each member of the North American Subcommittee to submit to him nominations for an additional associate membership.

Consideration was given to the format for the international catalog of components, as developed by Mr. Scott. It was agreed that Mr. Staros would review the Suppliers' Directory published by the American Orthotic and Prosthetic Association. It was believed that this list could serve as a source of information for the catalog itself and perhaps it, or a part of it, might be included as an appendix to the catalog.

Mr. Staros reviewed the history of the International Courses, most of which had been conducted at Copenhagen at various times during the past ten years, and stated that the International Committee had decided that it would be appropriate now to establish regional schools. From now on, the educational endeavors in Copenhagen would serve to assist the faculties of the regional schools.

The International Committee planned to organize a special seminar on educational standards during July 1968 for the purpose of providing guidelines for regional training centers and other special training programs.

The members of the North American Subcommittee agreed that it would be highly desirable for the International Committee to sponsor, either before or after the seminar on educational standards, a meeting to plan an international conference on prosthetics and orthotics research. It was noted that many of the participants in the proposed seminar are deeply involved in research.

The North American Subcommittee endorsed a proposal that an exhibit depicting research, education, and service as carried out in North America be prepared for showing at the XI World Conference of the International Society for Rehabilitation of the Disabled to be held in Dublin during 1969.

Professor Radcliffe reported on his recent visit to Scotland as a Fulbright Scholar, working at the University of Strathclyde with Professor R. M. Kenedi. Professor Radcliffe's primary function was to assist the well-established bioengineering unit there to set up a prosthetics-orthotics unit. He had also been able to visit Italy and follow up on work he had instituted there on a previous visit. He also reported on the Prosthetics Conference held in Dundee during June 1967, which he considered quite successful.

Change **of Command at Navy** Prosthetics Research **Laboratory**

Captain Frank L. Golbranson, MC, USN, recently retired from the Navy upon completion of 20 years' service. From November 1963 until his retirement, Dr. Golbranson was Medical Officer-in-Charge, Navy Prosthetics Research Laboratory, U.S. Naval Hospital, Oakland, Calif.

Dr. Golbranson has made many notable personal contributions to the care and management of amputees. During the period that the

Captain Frank L. Golbranson, MC, USN (Ret.)- From 1963 until his recent retirement from the Navy, Dr. Golbranson served as Medical Ofhcer-in-Charge, Navy Prosthetics Research Laboratory, U.S. Naval Hospital, Oakland, Calif. He is now in private practice as an orthopaedic surgeon in Livermore, Calif.

Lieutenant Commander D. W. Rohren, MC, USN. Dr. Rohren, who has been certified by the American Board of Orthopaedic Surgery, is now serving as Medical Officer-in-Charge of the Navy Prosthetics Research Laboratory in Oakland, Calif.

immediate postsurgical prosthetics fitting procedure was being introduced into the United States, he served as Chairman of the *Ad Hoc* Committee on Immediate Postsurgical Prosthetics Fitting of the Committee on Prosthetics Research and Development.

Dr. Golbranson received the degree of B.A. at the University of Maine and the degree of M.D. at Yale University School of Medicine. During the Korean conflict, he served with the Military Sea Transportation Service, Pacific. Other important assignments have been at naval hospitals at Bethesda, Md., and Bremerton, Wash. He is a member of the American Academy of Orthopaedic Surgeons and the American College of Surgeons.

Dr. Golbranson is now in private practice in Livermore, Calif.

Lieutenant Commander D. W. Rohren, MC, USN, relieved Dr. Golbranson as Medical Officer-in-Charge of the Navy Prosthetics Research Laboratory. Dr. Rohren had previously served at the U.S. Naval Hospital in Bremerton; the U.S. Naval Air Facility, Monterey, Calif.; the U.S. Naval Hospital, Portsmouth, Va.; and the U.S. Naval Hospital, Yokosuka, Japan, He has been certified by the American Board of Orthopaedic Surgery. Dr. Rohren received the degree of B.S. and the degree of M.D. from the University of Nebraska.

Board on Medicine Established by National Academy of Sciences

The capacity of medical research and practice to meet national needs will be the concern of a new high-level group within the National Academy of Sciences.

In announcing the formation of the Board on Medicine, Dr. Frederick Seitz, President of the National Academy of Sciences, said, "This new Board, which will report directly to the Council of the Academy, reflects the growing concern on the part of the Academy, members of the medical profession, and a number of Federal agencies as to how our rapidly expanding biomedical knowledge can be more effectively applied in response to critical human needs. We have asked the Board to range broadly in identifying urgent problems, to be imaginative in seeking solutions, and innovative in recommending public policy."

Specifically, the Board might consider such problems as how to shorten the interval between the acquisition of new knowledge and its application in clinical medicine; how to improve the quality and delivery of medical care; how medical knowledge gets used, refreshed, and taught; the ethical and legal implications of human experimentation; and the role of medical schools and other biomedical institutions in attacking the problems of rural and urban slums.

Because many of the questions are not purely biomedical but involve the entire spectrum of social and political institutions, a substantial portion of the Board's membership of 21 is drawn from nonmedical fields. Additional members probably will be named to the Board as its mission develops.

Dr. Walsh McDermott, Chairman of the Department of Public Health, Cornell University Medical College, will serve as Chairman of the Board on Medicine.

Serving with Dr. McDermott are: Ivan L. Bennett, Deputy Director, Office of Science and Technology, Washington, D.C.; Charles G. Child, III, Chairman of the Department of Surgery, University of Michigan Medical School; Julius H. Comroe, Jr., Director, Cardiovascular Research Institute, San Francisco Medical Center, University of California; John T. Dunlop, Professor of Economics, Harvard University; Rashi Fein, Senior Staff, Brookings Institution; Robert J. Glaser, Dean of the School of Medicine, Stanford University; Mrs. Lucile Petry Leone, College of Nursing, Texas Woman's University; Irving London, Chairman, Department of Medicine, Albert Einstein College of Medicine, Yeshiva University; Colin N. MacLeod, Vice President for Medical Affairs, Commonwealth Fund; Samuel M. Nabrit, Executive Director, Southern Fellowships Fund; Irvine H. Page, Cleveland Clinic, Cleveland, Ohio; Henry W. Riecken, Vice President, Social Science Research Council, Washington, D.C.; Walter A. Rosenblith, Professor of Communications Biophysics, Massachusetts Institute of Technology; Ernest W. Saward, Medical Director, Permanente Clinic, Portland, Oregon; James A. Shannon, Director,. National Institutes of Health; Eugene A. Stead, Jr., Professor of Medicine, Duke University Medical Center; Dwight L. Wilbur, President-Elect, American Medical Association; Bryan M. Williams, M.D., Dallas, Texas; Adam Yarmolinsky, Professor of Law, Harvard University; Alonzo S. Yerby, Head, Department of Health Services Administration, Harvard University School of Public Health.

Serving as Executive Secretary of the Board will be Joseph S. Murtaugh, currently Director of the Office of Program Planning, National Institutes of Health, who will retire at the end of November 1967 after 20 years of government service.

Dr. McDermott, the Board's Chairman, has not only made important contributions to medical research, but has also been able to further the applications of such research through participation in the highest advisory councils of governmental agencies and international organizations.

Early in his career, Dr. McDermott investigated the pharmacological properties of a number of antimicrobial drugs, including oral penicillin, work which proved invaluable in the treatment of syphilis and pneumonia. Since then he has become a world authority on the chemotherapy of tuberculosis, and is perhaps best known for organizing the successful program to control this devastating disease among the Navajo Indians.

This project brought him to the attention of Washington, and in 1960 he was appointed Chairman of the Development Assistance Panel of President Eisenhower's Science Advisory Committee, a post he continued to hold under the Kennedy administration. During these years he developed an abiding interest in the applications of science to the problems of developing nations and has subsequently served on research advisory committees of the Agency for International Development, the World Health Organization, and the Pan American Health Organization. Dr. McDermott is presently engaged in research on microbial persistence and on the broad problem of instituting modern public health measures in developing countries.

Report on Programs of Medical Research Issued by National Institutes of Health

The Advancement of Knowledge for the Nation's Health, a 202-page report recently issued by the National Institutes of Health, describes the current research efforts directed toward the major disease problems of the nation through the research programs of NIH. The status of these problems, the nature of present and planned investigative efforts, and the opportunities for further research are set forth by the individual Institutes having responsibility for their respective disease areas.

An impression of the scope of the NIH programs is conveyed in the preface of the report: "A national consensus to mount a major attack upon important health problems developed and first found expression during the 5-year period following World War II. This decision was embodied in the series of legislative enactments establishing the complex of research institutes that now comprise the National Institutes of Health. Through generous budgetary support from both the Executive and Legislative Branches of the Government, these programs now involve an annual expenditure on the order of $1 billion."

The major NIH organizations whose reports are contained within the overall report are the National Institute of Allergy and Infectious Diseases, the National Institute of Arthritis and Metabolic Diseases, the National Cancer Institute, the National Institute of Dental Research, the National Heart Institute, the National Institute of Mental Health, the National Institute of Neurological Diseases and Blindness, the National Institute of Child Health and Human Development, the National Institute of General Medical Sciences, and the Division of Biologies Standards.

The report is informative and well written in language readily comprehensible to the layman. It is enhanced by appendix tables and charts showing the organization of NIH, NIH growth and functions, national expenditures for health and for medical research, sources of medical research funds, *etc.*

Copies of the report may be obtained from the U.S. Government Printing Office for **$1.25.**

Course in Biomedical Telemetry Sponsored by International Institute for Medical Electronics and Biological Engineering

The International Institute for Medical Electronics and Biological Engineering is sponsoring a short intensive course in the applications of radiotelemetry in biological research, in medical research, and in clinical medicine. The course will be held in London, England, June 26-29, 1968.

The principal lecturer for the course will be Professor R. Stuart Mackay of Boston University. This part of the course has been presented to several large groups in American cities but has not previously been given in Great Britain or Europe.

The lecture series sponsored by the Institute is being offered at the Royal College of Surgeons of England in cooperation with the Biological Engineering Society. British coordinators for the course are Dr. Dennis W. Hill, H. S. Wolff, and W. J. Perkins. One of the four days will be devoted to lectures and demonstrations by British and European scientists.

The relevance of biomedical telemetry to many fields of zoology, ecology, and animal physiology is steadily increasing owing to the subminiature size of radio transmitters that can be swallowed or implanted in animals and which can provide the means of recording behavioral patterns and physiological variables in the free-moving state. The relevance in clinical and research medicine has long been recognized, but new types of sensors and the wide range of medical telemetry instruments now available make the subject increasingly important to doctors and medical engineers.

Further information and application forms for the course may be obtained from the International Institute for Medical Electronics and Biological Engineering, 47 Boulevard de l'Hopital, Paris 13, France.

Prosthetic and Orthotic Shop Manuals Available from AOPA

Recently published by the American Orthotic and Prosthetic Association are the *Prosthetic Shop Manual* and the *Orthotic Shop Manual,* two loose-leaf publications covering in practical detail the work done at the bench in prosthetics and orthotics facilities.

Both manuals are profusely illustrated, and major sections of both manuals are devoted to "Tools," "Materials," "Work Projects," and "Glossary of Terms." The coverage is comprehensive and up to date, and the loose-leaf format lends itself readily to the insertion of revisions as new procedures are developed.

Prepared by the International Educational Services Division of the International Textbook Company, copies of the manuals may be obtained from the American Orthotic and Prosthetic Association, 919 18th St., N.W., Washington, D.C. 20006. The price is $15 for either manual separately, or $25 for both.

New Powered Limbs Research Unit Established in England

The British Medical Research Council has recently announced the establishment of a Powered Limbs Research Unit at West Hendon Hospital, London, under the direction of Dr. A. B. Kinnier Wilson.

The Unit will continue and expand the research in medical and biological engineering for prosthetics and orthotics with which Dr. Kinnier Wilson has been concerned for a number of years as a member of the Council's External Scientific Staff. The approach being made is multidisciplinary, involving aspects of medicine, biology, and engineering, and includes the study of both basic and clinical problems. The Unit will also encourage the exchange of information by holding regular informal specialists meetings and will keep in close touch with research and development in medical and biological engineering being undertaken in university departments, by clinical teams in specialist hospitals, and in industry.

Correspondence concerning work in progress at the Unit should be addressed to Dr. A. B. Kinnier Wilson, MRC Powered Limbs Research Unit, West Hendon Hospital, Goldsmith Ave., Colindale, London, N.W. 9, England.

Accreditation for Rehabilitation Facilities

Beginning in January 1968 rehabilitation facilities in the United States and Canada may voluntarily seek accreditation by demonstrating compliance with standards that have been formally adopted by the newly established Commission on Accreditation of Rehabilitation Facilities (CARF).

Initiation of the accreditation program was announced by H. G. Lytle, Chairman of the CARF Board of Trustees, at the Joint Annual Conference of its sponsoring organizations, the Association of Rehabilitation Centers (ARC) and the National Association of Sheltered Workshops and Homebound Programs (NASWHP), held in New Orleans during November 1967.

According to Mr. Lytle, the accreditation program is designed to encourage the development and improvement of uniformly high standards of performance for all facilities serving the handicapped.

Referring to a recent survey that showed at least 5,000 facilities engaged in some form of rehabilitation activity, Mr. Lytle stressed that "the process of accreditation will further serve the public interest by informing the public at large that the accredited facility has earned this recognition through its provision of consistently high-quality services as assessed by a competent and independent voluntarv authority."

Interested facilities may write for a booklet outlining the CARF program. Inquiries should be directed to the Commission on Accreditation of Rehabilitation Facilities, 645 N. Michigan Ave., Chicago, 111. **60611.**

Seventh International Conference on Medical and Biological Engineering Held in Stockholm during August 1967

The Seventh International Conference on Medical and Biological Engineering, held in Stockholm, Sweden, August 14-19, 1967, was attended by 1,044 participants, 335 of whom were Americans. Thirty countries were represented.

The 527-page digest of the conference is in English, and the papers are organized under 40 major topics, such as Artificial Organs, Current Trends in Biomedical Engineering, Education in Biomedical Engineering, Pacemakers and Defibrillation, Telemetry, Computer Analysis of Electrocardiograms, Image Processing in

Medical Data Handling, Plethysmography, Hemodynamics, Lasers and Plasma Arcs, Nucleonics, Clinical Monitoring and Intensive Care Units, Ultrasonics, Biomechanics of the Skin, *etc.* The digest is profusely illustrated and contains an index of authors.

Copies of the digest may be obtained from Almqvist and Wiksell, Booksellers, 26 Gamla Brogatan, Stockholm 1, Sweden. The price per copy is Sw Kr 95 (about $19.00).

Sponsor of the conference was the International Federation for Medical and Biological Engineering. Members of the United States delegation attending the Federation's general assembly, which was held in conjunction with the conference, were Dr. Murray Eden, Research Laboratory of Electronics, Massachusetts Institute of Technology; Dr. Edward F. Leonard, Department of Chemical Engineering, Columbia University; Dr. L. E. Flory, David Sarnoff Research Center, Radio Corporation of America; and Dr. Peter L. Frommer, Artificial-Heart-Myocardial Infarction Program, National Heart Institute. Members of the delegation were appointed by the President of the National Academy of Engineering upon nomination by the United States National Committee on Engineering in Medicine and Biology.

In commenting on the conference, the American delegates said that, on the average, the technical quality of the papers was higher than in previous meetings, but there were some repetitions and trivialities. In the area of hemodynamics the papers were particularly good, although sometimes not entirely new in their findings. The predominance of United States contributions was most apparent.

The conference facilities, including projection equipment, *etc.*, were more than adequate. The exhibits, particularly those from Japan, were of high quality. A number of pleasant social events were arranged for the conference participants.

In general, the American delegates considered the meeting worthwhile and the opportunity for active in-depth discussion with other investigators very valuable.

The Eighth International Conference on Medical and Biological Engineering will be held in Chicago in 1969.

Advanced Seminar on Lower-Extremity Prosthetics to be Held in England During April 1968

The British Ministry of Health has recently announced that an advanced residential seminar entitled The Total Management of Lower Limb Amputations and Prosthetics will be held at Bulmershe College of Education, Reading, England, April 21-26, 1968.

Arranged by the Ministry of Health's Limb Service at Roehampton, the seminar will cover such major subjects as Assessment, Biomechanics, Surgery, Rehabilitation, and Prosthetics. In addition, there will be discussion groups on Vascular Disease, Children, Stump Pain, and Education.

The faculty, comprising orthopaedic, vascular, and general surgeons, and biomechanical engineers, will include visitors from the United States and Continental Europe.

A comprehensive fee of 18 pounds sterling will cover registration and full residential accommodation for the seminar. Inquiries concerning the seminar should be addressed to Dr. E. E. Harris (Seminar), Limb Fitting Centre, Roehampton, London, S.W. 15, England.

Xerox Corporation Reproducing ARTIFICIAL LIMBS

The Xerox Corporation, on the basis of an agreement recently signed with the National Academy of Sciences, is now reproducing *Artificial Limbs* on microfilm and through xerographic copy. Current as well as back issues are available.

Requests for information should be addressed to University Microfilms, Xerox Corporation, 300 North Zeeb Rd., Ann Arbor, Mich. 48106.

Copies of Spring 1966 ARTIFICIAL LIMBS

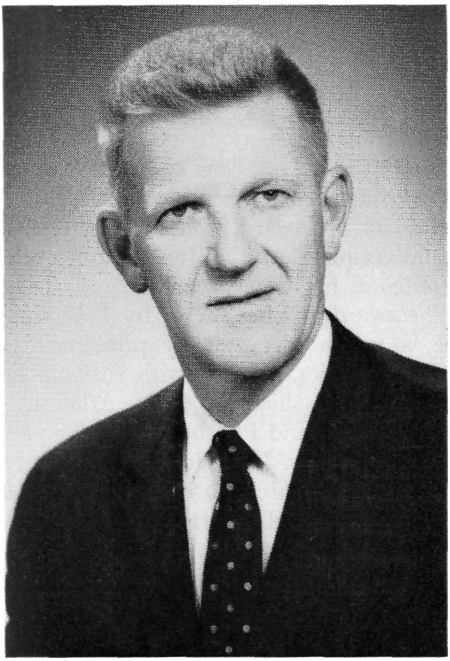
The office of the Committee on Prosthetics Research and Development is in urgent need of 40 copies of the Spring 1966 issue of *Artificial Limbs.* It will be greatly appreciated if persons having extra copies of this issue will mail them to the Executive Director, Committee on Prosthetics Research and Development, National Academy of Sciences-National Research Council, 2101 Constitution Ave., Washington, D.C. 20418.

Meeting of CPOE Subcommittee on Special Educational Projects in Prosthetics and Orthotics

The first meeting of the Subcommittee on Special Educational Projects in Prosthetics and Orthotics was held in St. Louis, Mo., on July 21, 1967. Chairman of the Subcommittee, Dr. J. Warren Perry, presided. Participants included William M. Bernstock, McCarthy Hanger, George H. Lambert, Sr., Miss Florence Linduff (now Mrs. Florence S. Knowles), and Herbert B. Warburton. Dr. Herbert E. Pedersen, Chairman of CPOE, and Mrs. Barbara R. Friz, Executive Secretary of CPOE, were also present.

The Subcommittee on Special Educational Projects in Prosthetics and Orthotics was organized for the purpose of supplementing the work of other interested agencies and organizations in developing definitive training and long-term educational programs to help meet the demands for personnel qualified to practice at various levels in the fields of prosthetics and orthotics.

At the meeting in St. Louis, the subcommittee decided there was an urgent requirement for an investigation of the manpower situation in prosthetics and orthotics. Accordingly, it was decided to conduct a survey of facility owners to pinpoint the areas of current manpower needs and to develop information on future needs. Dr. Perry appointed Mr. Bernstock, who is Assistant Chief of the Research



Dr. Herbert E. Pedersen, Chairman of the Committee on Prosthetic-Orthotic Education. Dr. Pedersen is Chairman of the Department of Orthopaedic Surgery at Wayne State University Medical School, Detroit, Mich. Before joining the faculty at Wayne State University in 1951, Dr. Pedersen served as Resident Orthopaedic Surgeon at the U.S. Veterans Administration Hospital in Dearborn, Mich. He received both his A.B. and his M.D. from the University of Michigan.

Mrs. Barbara R. Friz, Executive Secretary of the Committee on Prosthetic-Orthotic Education. Since retirement from the Army Medical Specialists Corps, U.S. Army, in 1962 with the rank of lieutenant colonel, Mrs. Friz has served on the CPOE staff. Her Army assignments included four years in the Office of the Surgeon General as Chief of the Physical Therapists Section and three years as Director of the U.S. Army Physical Therapy School. She received her B.S. at Washington State University and her M.S. at the University of Colorado Medical School.

and Development Division of the VA Prosthetic and Sensory Aids Service, and Mr. Warburton, who is Executive Director of the American Orthotic and Prosthetic Association, to work with Mrs. Friz in the development of a survey form.

Meeting of CPOE Subcommittee on Paramedical Education

The Subcommittee on Paramedical Education of the Committee on Prosthetic-Orthotic Education met at the Rehabilitation Institute of Chicago on November 6, 1967. Chairman of the Subcommittee, Colonel Ruth A. Robinson, presided. Subcommittee members present at the meeting were Miss Margaret Bryce, Miss Nancy B. Ellis, Miss Dorothy R. Hewitt, Miss Jerry Johnson, Miss Lena M. Plaisted, and Mrs. Margery L. Wagner. Others attending the meeting included Dr. Jack D. Armold and Mrs. Barbara R. Friz, Executive Secretary of CPOE.

Messrs. Charles M. Fryer and Edwin H. Bonk of Northwestern University outlined in detail a proposed educational film on the role of the nurse in the care and management of the amputee. Mr. Fryer also outlined a proposal for several films on biomechanics related to problems of the amputee and other disabled persons.

The subcommittee recommended that a two-day pilot course for nurse educators be conducted at Northwestern University. The purpose of such a course would be twofold: to provide the participants with a learning situation related to prosthetics and to teaching methods in prosthetics; and to receive from the participants ideas and recommendations on how best to meet the prosthetics educational needs of nurses.

It was announced that the *ad hoc* committee to review visual aids which had been appointed by the Subcommittee on Paramedical Education had been upgraded and was now a standing subcommittee of CPOE, to be known as the Subcommittee on Prosthetic-Orthotic Educational Materials. Miss Ellis reviewed the accomplishments of the *ad hoc* committee, which included the publication of a number of annotated bibliographies and reviews of prosthetics and orthotics films.

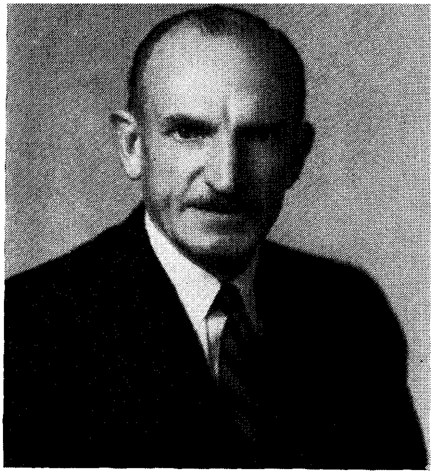
J. E. Hanger Award to Be Presented at NYU Commencement

New York University has recently announced the establishment of the J. E. Hanger Award, to be presented annually to a student completing the School of Education's four-year undergraduate curriculum in Prosthetics and Orthotics. The first award will be made in June 1968, according to Dr. Sidney Fishman, Coordinator of Prosthetics and Orthotics at NYU.

The award will be in the amount of $300 and will be granted to the full-time student having the highest grade average during the combined scholastic periods of his junior and senior years. All full-time students enrolled in the prosthetics and orthotics curriculum are eligible for the award, which will be presented to the recipient at the June commencement exercises of his senior year.

The award is being offered by J. E. Hanger, Inc., a group of nationally prominent prosthetics-orthotics facilities with regional headquarters in Washington, D.C.; Atlanta, Ga.; St. Louis, Mo.; and Pittsburgh, Pa. The award is in honor of Mr. J. E. Hanger, the founder of the Hanger organization and early pioneer in the development of improved prosthetics techniques in this country. It is intended that the award will give recognition to the increasing professional status being accorded the practice of prosthetics and orthotics through the efforts of New York University and other educational institutions.

IN MEMORIAM



Harold Willard Glattly
1902-1967

The bright October sunshine filtered through the trees as the military procession moved along the winding roads from the chapel at Fort Myer into Arlington National Cemetery. As one of the honorary pallbearers, I followed the cadence of the muffled drums as I walked beside the black caisson pulled by six black horses. We were preceded by the color guard and the drum and bugle corps, and followed by the bearer of the brilliant one-star flag, by Black Jack, that magnificent black stallion with empty saddle and boots on backwards, three platoons of Army soldiers, and limousines bearing family and friends. A Brigadier General in the Army, Dr. Harold W. Glattly, was buried with full military honors at Arlington on October 30, 1967.

THE GENERAL

How many of us really knew this Brigadier General? I want to record just enough here for us to realize how close we were to one of the military's highest-ranking medical officers. I'll begin in 1942 when he assumed command of the 12th Medical Regiment in the Philippines as Surgeon of the U.S. Luzon Force. During the Battle of Bataan on April 19, 1942, he was taken prisoner by the Japanese and was held until September 6, 1945. General Glattly was the only medical officer captured at Bataan, and for his treatment of fellow prisoners on that infamous Death March and during the subsequent imprisonment, he was awarded the Legion of Merit.

His next assignment was as Inspector General, Office of the Army Surgeon General; this to be followed in 1949 as Surgeon of the Second Army at Fort George G. Meade, Maryland. In 1951, General Glattly returned to the Office of the Surgeon General to become Chief of Personnel, and his final assignment prior to his retirement in 1957 was as Surgeon of the First Army, Governor's Island, New York.

In addition to the Legion of Merit with Oak Leaf Cluster, the General's awards included the Bronze Star Medal, Commendation Medal with metal pendant, American Defense Service Medal with foreign service clasp, and the Asiatic-Pacific Campaign Medal with one bronze star for participation in the Philippine Islands Campaign. He also held the World War II Victory Medal, the Distinguished Unit Citation with two Oak Leaf Clusters, the Philippine Presidential Unit Citation, the Philippine Independence Ribbon, and the Philippine Defense Ribbon with bronze service star.

THE DOCTOR

For those of us who knew Dr. Harold Glattly during the last decade of his life following his retirement from the military, this recital of past positions and honors seems irrelevant. For in those last ten years of his life, he became permanently and indelibly associated with the fields of prosthetics and orthotics and orthopaedic surgery.

Few of us knew that, at the National Academy of Sciences—National Research Council, he was also Executive Secretary of two other groups: the Committee on the Skeletal System and the Committee on the Genito-Urinary System. So closely identified was he with our programs that it seemed his entire life revolved around his job as Executive Secretary of the Committee on Prosthetic-Orthotic Education. CPOE and Dr. Glattly's name were synonomous and we never thought of one without the other, for he was the founder, the developer, and the champion of all its activities. Whatever fruits have sprung from its structure—and I believe the benefits are many—can be directly attributed to his vision and wisdom. We can understand now how his capability for organization and delegation of responsibility were outgrowths of his earlier professional experiences.

Dr. Glattly's personal imagination and efforts initiated important projects that began some of the collection of significant data for these fields, rallied the medical and allied health professions to the importance and need of prosthetics and orthotics in their own training programs, and prepared the "grass roots" materials that drew the attention of the medical and allied health professions to these areas. Professionalism for prosthetists and orthotists was one of his fondest goals, and his assistance in developing the Conference of Prosthetists was one of his special interests. How pleased he would be to know that a Conference of Orthotists is now in the formative stage! His leadership will be a constant source of inspiration for those who will carry on the activities of CPOE.

THE MAN

But more important to me than all his achievements in the military sphere of his life and in the prosthetics-orthotics and medical areas, was the unique quality of the man himself.

I have never known another person so charged with dynamic energy. Hal had a special capacity for getting at the structure of a problem, and he was tenacious in the forces he exerted to arrive at the best possible solution.

Hal was fun-loving, and I must confess that regional and national meetings in many fields will never be quite the same without his presence. His being there was a sort of physical force that kept a party going long after most of us had faded and withdrawn. And yet—and all who knew him well know that I speak true—he was the first one up at the next day's meeting.

A few of us had the rare privilege of knowing the members of his family, although Hal did not impose upon them many of his professional responsibilities. But I count every occasion at the Army and Navy Club with his dear wife Salita, and with Jan, and more recently with Robin, as further insight into the irresistible warmth and sensitivity of the man and his family.

The last time that I saw him was at Walter Reed Army Hospital when, with his family and closest associates, we presented him with the plaque bearing the names of all our national associations and organizations and the bound volume of letters from his friends. How proud he was of the many tributes you sent to him! And his final words spoken to me in a telephone call just two days before his death were so typical of him: "You betcha!" Well, you betcha, Hal, you have contributed much to all of us in this second career of yours with CPOE.

WThat more can we say but that we were touched and enriched by his presence, and we will always be grateful for having known this General, this Doctor, this Man.

J. WARREN PERRY, PH.D.[1]

[1] Dean, School of Health-Related Professions, State University of New York, Buffalo, N. Y. 14214.