September 1954

Artificial Limbs

A Review of Current Developments

ADVISORY COMMITTEE on ARTIFICIAL LIMBS

National Academy of Sciences
National Research Council

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Artificial Limbs

BRYSON FLEER, *Editor*

VOL. 1 SEPTEMBER 1954 NO. 3

A publication of the Advisory Committee on Artificial Limbs, National Academy of Sciences—National Research Council, issued three times a year, in January, May, and September, in partial fulfillment of Veterans Administration Contract VAm-21223.

CONTENTS

ADVISORY COMMITTEE on ARTIFICIAL LIMBS

NATIONAL ACADEMY OF SCIENCES—NATIONAL RESEARCH COUNCIL

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Bioengineering—Blueprint for Progress

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THE limbs of man move in space and time, in response to systems of internal and external forces, and in accordance with the laws of mechanics. To restore to any satisfactory extent the functions lost through amputation of an extremity therefore requires intimate knowledge not only of the structure, form, and behavior of the normal limb but also of the techniques available for producing complex motions in substitute devices activated by residual sources of body power. Since adequate replacement of a natural limb with an artificial one requires successful integration of the human mechanism with a toollike device, the biomechanical features of the stump and the physical characteristics of the prosthesis must be wedded as nearly as possible into a single, functional entity.

Two-sided as this problem would now obviously appear, it is only in comparatively recent years that the medical sciences of surgery, anatomy, and physiology and the physical one of engineering have been brought together in a unified attack upon the whole problem of amputee rehabilitation. Until recently, surgeons, with few exceptions, had little or no understanding of engineering problems. And heretofore the design and construction of artificial limbs has been conducted mostly by artisans who, however ingenious they may have proved to be, were mostly without formal education in engineering or anatomy. Besides this, except in isolated instances the two worked separately and alone. All of which no doubt accounts for the fact that, as late as World War II, the available artificial limbs fell far short of the standards of accomplishment attained in other fields of research and invention.

In the research program coordinated by the Advisory Committee on Artificial Limbs, National Research Council, there have been brought together in harmonious working relationship the individual skills of surgeon and engineer in a sort of mutual bioengineering to produce truly functional artificial limbs. As a result, there has been in the field of prosthetics perhaps more progress during the past decade than in all the preceding 2000 years of limbmaking.

Because the lower limb is more essential to human activity than is the arm,

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and also doubtless because the basic functions of the leg are easier to replace than are those of the arm, progress in artificial arms and hands has from the earliest times always lagged far behind developments in artificial legs. This circumstance was reflected in the fact that, when the Artificial Limb Program was established in 1945, much more had already been accomplished in replacements for the lower extremity than in those for the upper. And consequently developments in the ACAL program to date have been most noticeable in upper-extremity prosthetics, despite extensive engineering studies of normal and amputee locomotion and refinements in the techniques of lower-extremity fit and alignment.

In any case, the development of prosthetics had necessarily to follow the pattern of developments in surgery, and conversely the surgeon's philosophy with regard to "sites of election" and other matters was necessarily dictated by the character and availability of such prostheses as there were. Since the science of amputation surgery and the art of limbmaking proceed as one, the standards and practices in one field dictate standards and practices in the other, and vice versa. That each of these has now been brought to understand more fully the problems of the other may be looked upon as a major achievement in the art of prosthetics.

In the following pages of this issue of ARTIFICIAL LIMBS is to be found substantial evidence that the engineering profession, working with the amputation surgeon, has provided new thoughts, new ideas, and new approaches to the problem of providing adequate functional replacements for the limbless. In the whole Artificial Limb Program there exists no better example of cooperation toward progress than is demonstrated here. In the first of two articles, a surgeon and an engineer collaborate in describing the latest devices and techniques arising from systematic research and the influence which these developments ought rightly to exert upon the philosophy of modern amputation surgery. In the second, an engineer outlines the methodology required in investigation of the normal limbs and in the design of useful replacements. Only through such teamwork in biomechanics can truly great advances in the field of prosthetics be expected. The development of the thirty Veterans Administration and other civilian orthopedic and prosthetic appliance clinic teams has resulted in the better distribution of new knowledge toward improved fitting and alignment of artificial legs and in the design and construction of improved artificial arms.

The program of research coordinated by the Advisory Committee on Artificial Limbs involves the participation of government, university, and industrial laboratories. The Veterans Administration, the Army, and the Navy provide the necessary funds for the operation of their own establishments, while the VA provides the contractual authority with the funds necessary for work in the universities and in industrial laboratories. Out of this cooperative effort there have come within recent years improved functional prostheses for almost every level of amputation, particularly for those special amputee cases heretofore considered unsuited for an artificial limb. With the mutual cooperation of surgeon and engineer, there has resulted a cross-fertilization of ideas and a new set of modalities in the rehabilitation of amputees.

Nevertheless, the presently available devices, though anthropomorphoid in form, are far from anthropomorphoid in function. Unfortunately, no artificial limb, however elaborate, can ever serve as an ideal substitute for a natural member unless it incorporates some of the features of sensory and muscular control characteristic of the limb it replaces. Therein lies the challenge of the future—to devise mechanisms which not only simulate the motions and the functions of normal limbs but which also provide appropriate feedback of information such as occurs in natural arms and legs. In our present state of knowledge, the ultimate goal of the limb designer is still a long way off. Further progress depends largely upon the continued cooperation of surgeon and engineer, of prosthetist and therapist, and of the amputee himself.

Prosthetics Research and the Amputation Surgeon

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EUGENE F. MURPHY, Ph.D.[2]

Except in abnormal circumstances, man is born into his world with four mobile members which extend from his trunk like branches from a tree. These so-called "limbs" he uses in manifold complex patterns, first to serve his immediate personal needs and second to shape his own environment as best he can. Although in early life man reveals the history of the race by crawling about on all fours, he shortly assigns to two of the limbs chiefly, but not exclusively, the functions of supporting the body and of moving it from place to place. The "legs" thus become the principal weight-bearing members and the generally accepted means of locomotion.[3] To the more versatile "arms" man assigns most of the more complex functions of daily living and of creative activity. No doubt to this "division of labor" can largely be attributed the rather remarkable development of art and science and literature and industry and most of the other creative manifestations of human life.

Because, however, the limbs extend from the body proper, they are particularly susceptible to damage, either from lack of nutrition and disease or by external forces of one kind or another. Since the limbs are not "vital" organs in the same sense as, say, the heart or the liver, it is possible under favorable conditions to remove one or more without loss of the whole living organism, especially since the advent of modern surgery, anesthesia, and the newer drugs and blood substitutes. That is to say, a man has a chance of living on, though a natural member be discarded. We thus have as a result of war, accident, and disease a sizable number of individuals lacking part or all of one or more limbs, and to these must be added those persons born with malformed or missing limbs. All these people, now known generally as "amputees," are obviously handicapped, to greater or lesser degree, in the performance of all those functions ordinarily carried out by the arms and legs, and in extreme cases there may be no residual function at all. To restore lost functions in as great a measure as possible has long presented a challenge to certain people, mostly, as might have been expected, to amputees themselves.

The Background

Early amputations undoubtedly were more often than not traumatic events leading to a prompt death. Occasionally, however, history records amputees who survived their bloody and painful experiences. One famous example was Hegesistratus, who, captured and chained by the Spartans, amputated his own foot in order to escape (*73*). With the slow development, over the centuries, of surgery in general, amputations came to be performed more frequently. Typically they were desperate efforts to save life. Such works as those of Paré (*69*), of the sixteenth century, described the techniques. In some cases, a tight tourniquet was applied and left intact until the distal portion was lost by spontaneous amputation. In others, the amputation was conducted with

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[3] It should be recalled that with a little practice man can walk on his hands, but it is not a very comfortable behavior or one that can long be continued.