Prelude, Prophecy, and Promise

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AT HAS become almost axiomatic to say that the effective and rational treatment of human ills is dependent upon a knowledge of the normal structure and function of the human body and its response to the abnormal. But application of this dictum to the development of prosthetic apparatus as a substitute for loss of an extremity has been long delayed, and consequently improvement in artificial limbs has been extraordinarily slow. Almost to the immediate present, design of artificial limbs has been characterized largely by empirical developments and has depended little on fundamental investigation.

The reasons for this state of affairs are many and complex. Among them might be mentioned the late appearance, in the nineteenth century, of the humanitarian movement which was to provide much of the stimulus and the monetary support from private philanthropist and, later, from the public purse. Tradition too has had its influence, for initially the development of prostheses lay in the hands of the armorer, an association reminiscent of the relationship between amputation and warfare, and thence it passed to his lineal heirs, the surgical-instrument maker and the skilled artisan, who, however ingenious, had no background either in anatomy or in physiology and little knowledge of mathematics or of engineering.

Replacement of hand and arm, the tool through which the highest endowments of the human mind have been expressed, offered no great possibility of complete success. This circumstance influenced the surgeon toward an extreme conservatism in upper-extremity amputation, and failure to achieve perfection in a prosthesis brought no greater disappointment than there were expectations. From the point of view of amputee rehabilitation, furthermore, it was recognized that in the unilateral arm amputee the left hand could be taught to perform the functions of the right, and vice versa, so that a partial restoration of function in supplying stability was all that was sought. Limitations in expectation provided limitations in objective.

In the lower extremity, the problem of restoration seemed, on superficial analysis, to be infinitely more simple. As might have been expected, initial concepts of replacement were in terms of support only, to be followed by development of a jointed support in mimicry of the human leg as a static rather

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than a dynamic mechanism. The degree of disappointment and measure of failure in these simple objectives, without change in fundamental concepts, is to be seen in the countless empirical modifications of initial designs which bestrew the literature on artificial limbs over the past hundred years and more.

Earlier optimisms were gradually replaced by indifference and the inertia of failure, as is well known to those associated with the problem of the amputee after World War I. Locomotion, as we ordinarily understand it, is impossible on a single extremity. But it was realized insufficiently that, unlike the upper extremities, the two lower limbs together constitute but a single organ—the organ of locomotion. Consequently, the complexity of locomotion in relationship to prosthetics design never really was understood, and even where designs were in question the available information was inadequate to support newer developments of principle.

Preliminary efforts in the study of human locomotion are to be found in the work, *De Motu Animalium,* of the Neapolitan mathematician and physician, Giovanni Borelli (1608-1679). As a pupil of Galileo, he was stimulated to take a mechanistic view of bodily function and to study locomotion as a problem in leverage, but his theories and those of his followers soon were reduced to absurdity in the attempt to apply the same mechanistic principles to the whole of medical practice. Continuation of Borelli's approach had to await the nineteenth century and the advent of the Weber brothers, Edward (1806-1871) and Wilhelm (1804-1891), physician and physicist respectively, who with primitive electrical apparatus made the first accurate measurements of gait and undertook its mathematical analysis. The development of photography as a method of recording enabled Etienne-Jules Marey (1830-1904) to avoid previous errors and to correct earlier ideas, and further improvements in photography led to the classical work of Christian Braune and Otto Fischer, *Der Gang des Menschen* (1895), which has constituted the main source in the formulation of principles for the construction of artificial legs, as in the well-known books of H. von Recklinghausen (1920) and Frederich Mommsen (1932). Over more than a decade (1933-1945) Elftman published the results of extensive locomotion studies. To these and many others we owe a great debt.

Despite all these investigations, at the end of World War II our knowledge of human locomotion was still quite incomplete, and such knowledge as existed was only poorly understood. Thus it was that, when approached in September of 1945 by the then Committee on Artificial Limbs of the National Research Council, the representatives of the College of Engineering and of the Medical School of the University of California could point to the necessity of the adoption of a long-term outlook which envisioned the study of the fundamentals of human locomotion, of the amputee who must wear a lower-extremity prosthesis, and of the prosthesis itself. It could be shown that the experience of 400 years in trial-and-error techniques had offered little and that a firm basis

for progress could be established only by a systematic approach. It was predicted that at least seven years of study would be required to collect the fundamental data necessary for improved design of artificial legs.

That that prophecy was not needlessly pessimistic is revealed in the fact that only today can it be said with a degree of confidence that we are about to enter a period of practical development in the evolution of a truly satisfactory lower-extremity prosthesis. Within the next two or three years we should see the appearance of sound improvements based upon the preceding nine years of pioneering work.

But the problems of the leg amputee are not wholly "prosthetic." Such a patient presents a clinical picture of considerable significance. The whole being the sum of its parts, the amputee can scarcely be looked upon as normal in the medical sense, however good general health may be. He is, indeed, quite abnormal, for from amputation of an extremity come changes in skeletal, muscular, and circulatory systems to be dealt with in the design and application of the prosthetic replacement. Complications of pain, real and phantom, and of skin disorders are other matters needing the skills and experience of the medical profession.

Taking cognizance of this situation, the Advisory Committee on Artificial Limbs, in the spring of 1953, recommended that the University of California initiate an extensive clinical program to be integrated with the work already under way in the fundamentals of locomotion and in the techniques of lower-extremity fit and alignment. Utilizing space and services afforded by the U. S. Naval Hospital at Oakland and personnel from the University of California Medical and Engineering Schools, the Clinical Study aims to apply to the practical problems of difficult amputee cases the results of the earlier work on the Berkeley Campus.

This issue of ARTIFICIAL LIMBS is concerned with two major factors in the management of the lower-extremity amputee—the solution of medical problems associated with the amputated state, and the proper application of the prosthetic replacement on the basis of established biomechanical considerations. In the first of two articles, an orthopedic surgeon and an engineer collaborate in describing the origin, observations, and objectives of the Lower-Extremity Clinical Study. In the second, an engineer develops the principles of alignment and socket fit so indispensable to comfort and function, and hence to the success, of the above-knee artificial leg. In this cooperative effort is reflected the whole basic philosophy of the Artificial Limb Program in approaching the problems of the amputee.