Excerpts from "A Survey of Research Activities in Western Europe for Selected Areas of Biotechnology"

By HILDE GROTH, Ph.D.
Department of Engineering
University of California at Los Angeles

EDITOR'S NOTE: The following excerpts of special interest to prosthetists and orthotists are reprinted by permission of the author from the report of the same name, published by the UCLA Department of Engineering. Complete copies may be obtained from the Biotechnology Laboratory, Department of Engineering, UCLA, Report 61-30.

This continuing project is conducted under the sponsorship of the Veterans Administration with coodination by the Prosthetics Research Board, National Academy of Sciences, National Research Council.

Upper Extremity Prosthetics Research

Organized prosthetics research comparable to programs in the United States apparently does not exist in the European countries visited. Personal initiative of individuals interested in prosthetic problems seems to determine both the extent and direction of developments taking place. Since most of the investigators are working either in clinical settings or for private enterprise, current developments reflect these conditions and seem to be the result of a considerable amount of trial and error "gadgeteering" rather than controlled engineering research and analysis. Lack of sufficient financial support from interested government agencies for necessary basic research apparently is another important factor contributing to the observed trends.

Implied by discussions was one rather serious reason that may contribute to the relative lack of research effort in this field. Prosthetics is considered to be a specialized handicraft and lacks status as a legitimate field for scientific inquiry. The general emphasis on hardware component developments seems to discourage capable talent among theoretical and analytical investigators and may account for the presence of a disproportionately large number of inventor-technicians with vested interest in prosthetics development.

Since man-machine-systems concepts have found far less consideration in engineering design in Europe than in the United States, it was not surprising to find the integrative systems approach missing altogether in prosthetics.

The specific influence of socialized medicine in Great Britain and quasi-socialized medicine in West Germany cannot be evaluated adequately without further study. In these countries great importance seems to be attached to factors of low cost, high reliability, and easy maintenance. This emphasis apparently exerts a retarding effect upon support and encouragement of implementing more progressive design ideas.

In the following sections, the state of the art of upper extremity prosthetics in Great Britain, France, West Germany, and Spain will be discussed in more detail.

1. GREAT BRITAIN

a. *Queen Mary's Hospital, Roehampton*

A visit with Dr. McKenzie and Brigadier Swettenham of Queen Mary's Hospital Limb Fitting Centre, Roehampton, provided first hand impressions of the present philosophy of this institution concerning artificial arm developments.

Simplicity, low cost, easy maintenance, durability, and reliability are considered the most important criteria for replacement limbs. As every amputee must be treated as a special case, developments directed toward fabrication of standardized prostheses for given levels of amputation are considered unrealistic and impractical. Whatever type of prosthesis and terminal device will fulfill an amputee's personal desires is determined, and components are supplied accordingly. For example, if the amputee indicates a preference for specialized terminal devices to a general purpose hook, his wishes are taken into consideration and a suitable armamentarium is prescribed.

Utilization of available materials for prosthesis fabrication is deemed more important than a radical shift to exclusive use of new products like plastics. Consequently, there appeared to be more leather sockets than plastic sockets in the Centre's storerooms and repair shops. The general feeling is that although leather is sweat absorbent, such sockets are more comfortable and total sweat secretion seems to be less than in plastic sockets.

With regard to external power, little need for it was seen at the Centre, which supplies most prosthetic demands in Great Britain. McKenzie and Swettenham felt that the majority of amputees have adequate strength for limb and terminal device activation. "Even if a need could be created, why would one want to create such a need?" expresses the general philosophy of the Centre.

Both investigators felt that it would be much more important to establish valid criteria for evaluating existing prostheses before deciding that the state of the art must be advanced. At present there are no well defined goals, only some vague concepts advocating a "principle of least effort" as the criterion for functional rehabilitation. Rather than embarking on new, high cost projects which show dubious prospect of success, more studies on a fundamental level are felt necessary. For example, and in close agreement with our own views, Swettenham was convinced that present technology can supply all necessary components for an externally powered arm, but the man-prosthesis interphase problem has not changed since the original U. S. IBM-Alderson electric arm. The conclusion indicated was that assessments of the sensory feedback-control input problem should receive priority attention and be solved before new hardware developments are initiated if such an arm should be developed at all.

Utilization of cineplasty tunnels for either power sources or control sites is looked on with little favor in Great Britain, and the operation is apparently no longer performed.

b. *West-Hendon Polio Centre*

Development of a simple pneumatically powered polio brace by Dr. Kinnier-Wilson and Mr. Dalrymple at the West Hendon Hospital Polio Centre in London looked very promising. Basically, the device is a modification of the CO_2 activation principle used by the West German group in Heidelberg for their pneumatically powered artificial arm. The power unit consists of a dual arrangement of two pistons and cylinders, one acting as agonist (biceps), the other as antagonist (triceps) "muscle." The storage

unit contains a sufficient amount of CO_2 for 48 full cycles of arm flexion and extension. Arm motion is controlled by pressure of a muscle bulge against a sensitive small plastic bladder. In order to hold the arm in position, the pressure against the bladder must be maintained at the given level. At present, no provision for control of movement rate is made.

The brace had not been fitted to a patient at the time of my visit; a functional evaluation had therefore not been made.

c. *St. Thomas Hospital*

Basic research for exploring the feasibility of utilizing muscle action potentials as input signals for prosthesis activation was being conducted by Dr. Nightingale at St. Thomas Hospital, Physics Laboratory, in London. The goal of the project is to make use of remaining electrical activity in the biceps and quadriceps muscles of severely paralyzed polio patients to activate a very simple functional brace. The prosthesis should enable the patient to feed himself in a special shielded hospital room. In such circumstances the device should operate free of electrical interference and adjustment and maintenance problems would be attended to immediately by hospital technicians.

No attempt was anticipated to solve problems of electrical interference outside the shielded room or to miniaturize the equipment. The muscle action potentials will be used for activating an on-off control mechanism only. No plans have been made for designing a graded control system before a well functioning on-off control has been developed and more is learned about the practical problems involved.

All projects for development of artificial arms controlled by muscle potentials were abandoned more than two years ago because of unsurmountable expenses and other difficulties.

EMG records of even severely paralyzed muscles showed action potentials of at least 30 rv above noise level indicating the basic feasibility of the polio brace project. Dr. Nightingale stated that progress was slow because of limited funds for acquisition of necessary data analysis equipment.

d. *General Conclusions*

Present research activities in Britain apparently are directed more toward the rehabilitation of polio patients than toward the arm-amputee problem. However, as there are certain similarities among the associated problems, many findings should be applicable to artificial arm developments as well.

No functional externally powered artificial limbs have so far been developed in Great Britain.

2. GERMANY

a. *University of Heidelberg*

The Orthopadische Klinik of the University of Heidelberg is the only West German center engaged in research and development of externally powered artificial arms. To the best information available at that time, Mr. Haffner, the inventor of the CO_2 powered German prosthesis, is presently working for the East German government in Thuringia. He and a large staff of technicians assertedly are engaged in extensive modifications and further developments of this prosthesis.

Regrettably, external circumstances made impossible a visit to the East German prosthetic center.

A visit of several days in Heidelberg provided a good overall view of the present state of the pneumatically powered arm—its advantages and disadvantages. The project is under the direction of Professor Lindemann and Dr. E. Marquardt, both orthopedic surgeons. A new engineer recently joined them to take over the position previously held by Mr. Haffner.

All fitting, fabrication, and repair work of the arm is currently done in the shops of the clinic. However, Dr. Marquardt feels that the prosthesis has reached a state of development where it should be turned over to a commercial firm for final engineering modifications and mass production. As planned, only research leading to functionally important modifications will be continued by the clinic.

The prosthesis has been designed as a heavy duty working arm without regard to factors of cosmesis. Sylphon bellows are preferred to pistons because of greater safety to the patient in case of explosion.

Whenever possible, Dr. Marquardt prefers the use of separate locations for single control valves to a single location for a multiple valve controlling several functions. Use of the multiple valve is indicated only for the severely handicapped where there is no alternative. Although learning to operate the sequential control has not presented a large problem, it requires an undue amount of conscious effort and attention.

Existing pectoral tunnels have been found to provide excellent body control sites for shoulder disarticulations and forequarter surgeries. Dr. Marquardt doubts that miniaturization of cineplasty tunnels could provide satisfactory control sites because of hygienic and dermatological reasons.

The hissing sound of the valves provides an important auxiliary feedback channel to the amputee and should not be eliminated before other types of satisfactory feedback devices have been developed. Research is currently being conducted on such devices.

Although all amputees learn the basic prosthesis functions fairly fast and attain a criterion level of proficiency in the clinic, it has been found that practice is often neglected in the home environment. Amputees capable of functional independence have been found to revert to old patterns of dependancy on their return home.

An important feature of the arm is the complete standardization of components permitting interchangable mechanical or pneumatic powered assemblies. In case of pneumatic system failure, a mechanical part can be applied in its place. High reliability, ease of maintenance, and good rehabilitation value are indicated by the full endorsement of the prosthesis by the agencies of the West German government in charge of veterans' care and by the compulsory medical insurance agency (Allgemcine Ortskrankenkasse).

Urgent need is seen for the development of a pneumatic hook because of its functional superiority to an artificial hand. An excellent pneumatic prosthesis has been developed for transmetacarpal amputees. The valve is operated by the dorsum of the hand and permits very sensitive finger control.

Dr. Marquardt made it possible for me to observe several amputees of various ages doing work at the clinic and in their homes. These observations clearly demonstrated the advantages of externally powered prostheses for both severely handicapped children and adult amputees.

Adoption of the suction socket fitting technique developed at the University of Munster was found to be very satisfactory. According to Dr. Marquardt, elimination of all harness straps provides maximum comfort to the wearer and facilitates donning of the prosthesis. My own observations of amputees engaged in fairly heavy labor at a machine shop indicated a good fit without slippage. All amputees interviewed expressed satisfaction and considered it a great improvement over their previous harness-type prostheses.

The use of transparent "Plexidur" for socket and brace fabrication is said to have considerable advantages for strength, weight, flexibility, and ease of molding over the resins used ordinarily. A side trip to the producer of "Plexidur," Rohm and Haas, Kunststoff-Chemische Fabrik in Darmstadt,

provided samples and brochures with detailed technical information about this material. The material is also available in the U. S.

A complete pneumatic prosthesis was purchased for the Biotechnology Laboratory for engineering and functional analysis.

b. *University of Munster*

When visiting the Orthopadische Universitats-Klinik (Hufferstiftung) in Munster, both Professor Hepp and Dr. Kuhn had left for vacation. But fortunately Dr. Manz, an orthopedic surgeon and assistant to Dr. Kuhn, was available and kindly showed the research facilities and provided an up-to-date report of their experimental work. The present facilities are limited in space, but a large new laboratory and rehabilitation building is under construction.

Little interest in external power exists at this center. Their viewpoint is that auxiliary power is not necessary and that the disadvantages of costs, repairs and associated problems will outweigh any possible advantages. Development activities were primarily of the trial-and-error, gadgeteering type.

A notable achievement is the development of a three-prong voluntary opening hook which shows the following advantages: 1) easy adjustability of spring force to specific needs, 2) facilitation for grasping and holding cylindrical and spherical objects, 3) surface friction of the hook covering approximating that of normal skin, and 4) easy replacement of hook covering. The hook has a stationary thumb and two movable fingers which spread apart during opening. The functional qualities seem to be superior to those of ordinary hooks. However, the cosmetic appearance is very poor.

The suction socket for upper extremities was developed at the Munster center. The technical details of fabrication of the suction sockets are adequately described in the literature and will be omitted here. The goal of the development was to devise a socket that would give a tight and secure fit without use of supporting harness.

Dr. Manz was able to demonstrate several BE and AE amputees with problem stumps. All of them were able to lift a 40 kg weight without slippage of the socket. Donning of the prosthesis was possible for all unilateral amputees without assistance. Removal, however, is difficult if not impossible without aid. Amputees reported that they do not feel pain or discomfort even after eight hours of manual work. Sweat production seems to be reduced significantly in the tight fitting socket.

Pain as a consequence of neuromas and bony spurs reportedly is decreased appreciably. The reason given for the beneficial effect is the constant pressure in contrast to the variable pressure distribution during movements with conventional sockets. In a few cases, allergies have been observed, but these were attributable to individual reactions to the socket material and independent of the type of socket.

A further noteworthy development was the AE socket shape where a "bank" or "shelf" in the axilla and a 1:1 height-width ratio of the opening provides a best fit.

Dr. Kuhn is opposed to corrective surgery for stump shaping which would facilitate the fitting procedures enormously. Instead, very elaborate and special methods have been developed for obtaining the mold.

c. *General Conclusions*

In comparison to Great Britain, a good amount of progressive prosthetic development is being conducted in West Germany. The search for new and better materials, radical departure from conventional upper extremity fitting techniques, and a group of researchers dedicated to the ap-

plication of external power are indices of a tendency toward more sophisticated developments.

3. FRANCE

a. *St. Cloud Hospital*

Mlle, S. Fouche, Director of the "Lique pour l'adaption du diminue physique au travail," made arrangements for a visit and conference with Dr. Lescoeur and his staff at the Centre de Reeducation Fonctionelle at St. Cloud. The conference was attended also by a representative of the French Ministry of Health. St. Cloud is one of the government centers for prosthesis fitting and fabrication, and for physical and occupational therapy.

There is little or no interest in external power projects in this center. Reasons given for this attitude were as follows: 1) Only a very limited population would benefit by it; 2) Development and production costs would be high; 3) Maintenance would be difficult; and 4) Complex mechanisms to be used by laymen would be inherently unreliable.

The group was extremely reluctant to talk about the electric hand manufactured in Paris. On response to my questioning, they indicated that they had acquired one but had never fitted it to an amputee. To an outsider it appeared that there were other motives than technical considerations underlying the rejection of the electric hand.

Cineplasty tunnels were referred to as "unnecessary mutilation," and the operation is not performed at the Hospital.

Their prosthetic armamentarium consists of German and Austrian mechanical devices which are preferred to American developments because of their greater reliability, lower cost, and readily available spare parts.

There is a French counterpart of the APRL hand, but German hooks are generally prescribed for terminal devices.

b. *F. Guillot Institute*

Development and fabrication of electric hands is conducted by Mr. W. Kegel in the F. Guillot Institute Chirurgie Orthopedie, a limb fitting shop in Paris. Mr. W. Kegel is the only member of the German team that began this development shortly after World War II in Vaduz, Liechtenstein, who remains active in this concern. The German patent on this hand is held by him, the French patent by Mr. Guillot. The Vaduz project was terminated because of lack of funds, and no further prosthetic development is conducted in Liechtenstein.

The electric hand undergoes continuous minor modifications, and the latest model (Mark V) was purchased for engineering and functional analysis in the Biotechnology Laboratory. A detailed description of the mechanism will be published as a laboratory technical report when the analysis has been completed. No descriptive material was available in France.

The hand has a good cosmetic appearance and is extremely light in weight. The complete mechanism weighs less than 100 gms, and Mr. Kegel was experimenting at that time with a new motor which was about half the size of the present one and which would reduce the weight by another 50%.

If one can judge by the sales volume, the hand seems to be popular; and again when extrapolating from the repair orders, it also seems to be fairly durable.

Function is controlled by means of muscle force exerted against an air-filled plastic bladder. Any muscle bulge is suitable, and the pressure in the bulb transducer can be regulated to permit operation in the optimum range of sensitivity. Grasp force is approximately 2 kg. Only one BE amputee wearing the hand could be observed. He showed good dexterity with it and stated his satisfaction with the device.

A mechanical light-weight nine-position elbow lock was also developed by Mr. Kegel. The appearance of this mechanism is rather crude. However, it is apparently very sturdy and reliable during operation.

Mr. Kegel does not see any need for additional external power as long as the amputee has some stump left. However, for very short AE and shoulder disarticulation amputations, he stated that he preferred the German pneumatic arm.

c. *General Conclusions*

No scientifically planned prosthetic research and development is going on in France. The official attitude seems to be to scan the international market for reliable devices of low cost rather than to support local development. Private initiative seems to be very low, and no new developments seem to be contemplated.

4. SPAIN

a. *La Casa Prim*

Dr. Cantor, the Attache for Cultural Affairs at the U. S. Embassy, had no knowledge of any developmental work of prosthetics in Spain. He kindly made arrangements for a conference with members of the Direccion General de Sanidad de Espana in Madrid. Here I received confirmation of Dr. Cantor's impression that no prosthetic developments are going on or are contemplated for the future.

Senora Clementina Juderias, Patronata des Invalidos, then arranged visits to an orthopedic and rehabilitation hospital and to a limb shop, the Establicimientos Ortopedicos Prim. Nothing of prosthetic interest was observed in the hospital.

The limb shop, owned and operated primarily for his own patients by Dr. Prim, an orthopedic surgeon, is somewhat limited. As Dr. Prim was on vacation, his private clinic was closed and activities in the limb shop were at low ebb. Apparently it is the only limb shop in Madrid, if not in Spain, and all terminal devices and other components are imported to supply it.

b. *General Conclusions*

The relatively small number of arm amputees and the general poverty of the country seem to inhibit any official initiative for a prosthetic program.

The Third International Conference on Medical Electronics in London, England

Abstract of paper by:

BRIGADIER N. A. M. SWETTENHAM, A.M.I. Mech. E.:

"Problems of Powered Limb Prostheses"

The problems to be faced in trying to apply external power sources to the operation of artificial limbs and aids for paralyzed patients are human and mechanical. With every patient there is a limit to the addition of appliances and, in general, no such added aid is acceptable unless it provides a worth-while function. The problem is different for paralyzed patients and amputees, the latter usually having residual muscle power adequate to provide movement and operation of a prosthesis.

It would seem that the most promising investigations are those dealing with aids for the upper extremity: not only has a satisfactory mechanism to be designed, but also the method of its control. Some work has been done on mechanisms, but none at present available is entirely satisfactory. Compressed gas is the first choice for investigation as a medium of powering the devices. The problem of the bulk and weight of power storage is more acute for ambulant patients than for those who are chair-borne. Existing pneumatic

motors developed in other countries suffer from inadequate power and/or "bounce," a promising new design is being investigated in this country in which two double-acting opposed pistons are used to operate the mechanisms and it is hoped that this may well provide the answer to providing adequate power without bounce.

There is a limit to the number of controls a patient can operate instinctively, and there is evidence that three such controls should not be exceeded for the average person; this means simplification of movements. With the amputee it is normal practice to train the patient to operate the prosthesis with muscles different from those normally used for the movement. With the paralyzed patient a similar problem will exist in that some active muscle will have to be used to operate the valve of the mechanism. In the first place the operating mechanism will probably take the form of either a direct pull on a valve or the use of a small air bladder which can be compressed between a muscle and some fixed member.

As a long-term project, work is being done to explore the possibility of using neuromuscular potentials. Even a clinically paralyzed muscle often exhibits some electrical response. If this could be harnessed in some way and used to operate the mechanism, the patient might not be faced with the need for gaining an acquired skill to operate the aid or prosthesis. But many difficulties have to be overcome before this idea can become a practical proposition. These difficulties exist at all stages. The type of electrode which can be worn for long periods has still to be ascertained. A method has to be worked out for interpreting the signals so as to obtain a modulated control and not merely on-off switching. Some means has to be found for cancelling out or eliminating unwanted noise and interfering signals. Possibly the requirement least likely to present difficulty is that the apparatus must be reduced to minimum bulk and weight. Finally, it must be completely reliable if it is to be acceptable.

In Memoriam

The Association has learned with deep regret of the death of Franklin Homer Page, Jr., President of Du Pa Co., Inc., Arcadia, California, who was killed November 15, 1961 as he was walking home from a Little League meeting. He was well-known for his contributions to lower limb prostheses. At the time of his death Dr. Page was in the process of writing a book on the subject.

Dr. Franklin Page was a native of Des Moines, Iowa. He was a graduate of San Diego State College where he received a bachelors degree in chemical engineering. He received Ph.D. degrees in both chemical and electrical engineering from the California Institute of Technology in Pasadena. He was a minor league director of the Coast Little League in Arcadia, Scoutmaster of Troop 125, B.S.A., a Life Member of the P.T.A. and an Elder in the First Presbyterian Church of Arcadia. Survivors include his wife, Mrs. Ruth L. Page, two children, Pamela and John Page, his mother, Mrs. Frank Page of San Diego, and three brothers.