Bio-engineering — A Perspective

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SUMMARY

Bio-engineering is a general term used to describe the application of engineering techniques to the study of medical problems. Some fields of bio-engineering research are described, and the suggestion is made that a bio-engineer be included in the clinical team. The question of regularising the position of bio-engineering within the medical and supplementary professions is raised.

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The rapid increase in technology has entered the practice of medicine, as it has almost all other aspects of modern life. The truism that medicine is both an art and a science tends to be distorted in the attempt to rationalise all normal and pathological processes and to establish more firmly their scientific foundation. Similarly, the care of the critically ill patient involves the use of scientific monitoring and therapeutic apparatus of a high degree of sophistication. Professor J. F. Brock, in his address to the 1973 medical graduates of the University of Cape Town, pleaded strongly for the preservation of the balance between clinical medicine and laboratory investigation. Current attempts at medical curriculum reform are faced with the insoluble problem of an increasing body of scientific knowledge seeming to overwhelm the more traditional 'arts', which can only be acquired slowly, and largely by example from gifted clinical teachers.

The realisation by medical practitioners that more knowledge and skill are required to be of maximum benefit to patients than one individual is capable of, has led to the establishment of clinical teams. Some such teams include a physical scientist, who may be designated variously as a bio-, biomedical, medical, rehabilitation or orthopaedic engineer.

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WHAT IS BIO-ENGINEERING?

This is an extremely difficult question to answer. As an evolving discipline, it would be a disservice to it to limit its scope by too narrow and rigid a definition. A fair, working description may be that 'bio-engineering comprises the application of engineering techniques to the study of medical problems'.[1] However, those already doing this type of work accept its interdisciplinary nature, and those institutions which undertake to train bio-engineers (at least in the UK) are prepared to accept candidates with a medical or biological background and to modify their courses appropriately.

Possibly a better comprehension of the scope of bio-engineering may be gained from some examples of the type of work undertaken. If groupings roughly equivalent to the divisions within engineering are used, the following are some of the fields of interest.[2]

Mechanics

The first accurate, quantitative analysis of the forces transmitted by the hip joint during normal walking was undertaken by a mechanical engineer when asked by a group of orthopaedic surgeons to design a better nail for fractured necks of femur. The study was made because the surgeons could not answer the elementary engineering question of what forces the nail had to carry, and the engineer felt incapable of producing a good design without such fundamental information. This work has been continued, and now full engineering analyses of the forces at knee and ankle are available, which have been checked by different experimental methods. These findings form the basis for design work on artificial joints and for the study of natural joint lubrication. Tribology, the study of friction and lubrication, is becoming important in the fundamental study of the arthropathies.

There is also an intimate working relationship between engineers and clinicians in the closely related fields of prosthetics and orthotics. The design, manufacture and introduction to clinical use of the modular systems of lower-limb prostheses have depended largely on the interest of engineers. Similarly, the development of effective upper-limb prostheses, spurred on by the aftermath of thalidomide, has reached a high level as a result of co-operation between mechanical and control engineers and the clinicians responsible for the care of amelic patients.

Considerable work on the mechanics of the spine is also being carried out.

Techniques of a more diagnostic nature are also being developed. This is being done, for example, in response to surgeons who feel that a quantitative assessment of gait is desirable in order to judge more accurately the degree of disability before performing lower-limb joint surgery and to gauge its effectiveness postoperatively. Such techniques could also be used to evaluate the effectiveness of medication in the conservative treatment of arthritic conditions. The balance which needs to be struck, however, as in all such refinements, is between a very complicated, time-consuming and expensive, yet highly accurate, laboratory investigation and subjective, quick, clinical evaluation with poor correlation between independent observers and no true record with which to compare later observations.

Chemistry

Chemical engineers, chemists and fluid-mechanics engineers are collaborating in the design of devices for the exchange of substances between the body and the environment. The prime example is the artificial kidney, where there is great room for improvement in the efficiency of the conventional devices and a huge potential for the development of small, safe, disposable devices. Both the membrane itself and its support, together with its ancillary porting, pumps, etc., are amenable to better design. Extensions of this work include replacing the filtering function of the liver (as in extracting paracetamol in cases of overdosage) and perfecting membrane oxygenators for incorporation in heart-lung bypass machines. All the work done on prosthetic heart valves, cardiac-assist devices and, in the long run, artificial hearts, may also be considered in this group.

Because of the necessity for biocompatibility of the membranes in these devices with blood, these workers have become interested in the whole problem of biocompatibility of synthetic materials with the human body. This enables them to collaborate with those designing implant devices on the aspect of materials to be used or a biocompatible coating to be applied prior to insertion into the body.

Materials Science

The behaviour of the tissues of the body at gross and microscopic levels is of great interest.

A fairly early bio-engineering project arose from the posing, by an eminent plastic surgeon, to a structural engineer specialising in materials, of the problem of why skin could stretch more in one direction than in another. This, of course, especially affects the design of flap-grafts. An instrument was constructed to measure the strain (extension per unit original length) produced for a given stress in skin all over the body. The results are usually presented as a diagram of the body covered with ellipses, representing strain for given stress, with long axes generally running craniocaudally, and the proportion of long to short axis is generally greatest on the dorsal surface of the body over the joints. These workers expanded their studies to include tendon and other collagenous structures and articular cartilage. The mechanical properties of these tissues are tested on orthodox engineering test-rigs, suitably modified for *in vitro* conditions, to ascertain their gross behaviour. Their microstructure is also studied, using both light and electron microscopy, and an attempt is made to account for their properties on this basis.

This branch of work is fairly basic in nature, although it does have direct bearing on the design of safety equipment such as crash helmets and safety harnesses. The cartilage studies are extremely relevant to joint lubrication investigations.

Electronics and Data Analysis

Many of the body's functions can be monitored by displaying the very low voltage signals which they generate (ECG, EEG, EMG), or by transducing a mechanical action into an electrical signal to be more conveniently displayed and recorded. Any direct recording from the body involves an interface between it and the apparatus. Such a junction is always a source of interference, especially electrical 'noise' with direct electrical recordings. Such a connexion is also a source of potential danger to the patient if there is any malfunctioning of the earthing circuits. Equally, from the medical point of view, it is preferable to avoid invasive diagnostic techniques if sufficiently accurate information can be obtained by other methods.

Thus electronic and mechanical engineers are developing non-invasive and, if possible, even non-contact techniques of monitoring various body functions. The ballistocardiograph and displacement cardiograph are two examples of such devices where highly sophisticated engineering techniques have been used to perfect devices whose principle has been long known.

Much work on diagnostic and therapeutic ultrasound is also being carried out in various centres.

In many instances the analogue signal detected in the body contains a great deal of superfluous information or even just noise. In order for the observer to appreciate the significance of the analogue signal, it needs to be processed in some way. It may also be necessary for the analogue signal to be converted into numerical values (digitised) so that calculations may be performed. Such signal processing is most easily carried out by computers. Computer scientists understanding the biological significance of the signals are needed to advise on the analyses required, its reliability and statistical validity, and to programme and operate the computer. It is advisable to consult data analysts who also have statistical training in the planning stage of investigations, to ensure the greatest economy of effort and a maximum of reliable information.

The foregoing fields of interest relate almost entirely to pure research carried out in the laboratories of an expensive research institute. The question arises whether there is a place for the bio-engineer in the ordinary hospital environment.

Hospital Practice

Hospital engineers' departments exist to deal with the maintenance of hospital buildings, structural alterations to these and the supply of main services, power, heating and ventilation. Some institutions also have workshops staffed by highly competent technicians where the more sophisticated equipment used, such as ventilators, monitors, ECG machines and electrotherapeutic physiotherapy apparatus, can be serviced. It would seem, however, that there is a place in the larger hospital for an engineer with knowledge of medical problems. He should be immediately available to the clinician to help and advise him on technical matters, be it in the purchase of new or the modification of existing equipment, or in the design of an experiment. Such an individual cannot be an expert in all technical matters but would, at least, be in an excellent position to know where to turn for advice and to explain a medical problem to the technical expert in the language he understands—thus helping to bridge the communications gap.

INTEGRATION WITH MEDICINE

If the premise is accepted that there is a need, and therefore a place, for bio-engineers in present and future medical practice and research, then the problem of establishing their position in the field of medicine and supplementary health services must be solved. As such, personnel would deal directly with patients, and the establishment of a register for bio-engineers by the relevant authority (e.g. the South African Medical and Dental Council) would seem essential to protect both patients and medical practioners who refer them to bio-engineers for some procedure.

The establishment of such a register would necessitate some definition of a 'bio-engineer' in order to classify those registrable and those not. There are very few orthodox training courses for bio-engineers and they therefore come from a diverse field of basic trainings, so that their competence in any particular field is difficult to assess. It may be necessary to incorporate in such registration ethical rules requiring safety checking in matters affecting patients by someone professionally registered in the field concerned, if it is not that of the bio-engineer himself. Thus the design of, say, a mechanical device by a medical bio-engineer should be checked by a suitably qualified mechanical engineer.

CONCLUSION

In the past, fruitful co-operation between medical practitioners and engineers occurred on a rather haphazard, personal basis. The maximisation of benefit to medicine from advanced technology can best be achieved by formalisation of the links between them. There are engineers interested in medical problems and anxious to apply their knowledge and skills directly in the alleviation of human suffering. There are also medical men who realise that a better knowledge of what technology can offer their patients is an asset, and who then acquire a technical training. Members of both these groups may be called bio-engineers and their contributions to the future development of the technical aspects of medical practice can be very great.

A greater awareness by the medical profession of what bio-engineering has to offer will be to the mutual benefit of all concerned.

REFERENCES

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2. Kenedi, R. M. ed. (1973): *Perspectives in Biomedical Engineering*. London: Macmillan.