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Biological Engineering Society

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EDUCATION, TRAINING AND CAREERS IN BIOMEDICAL ENGINEERING IN THE 1980's

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C O N T E N T S

THE KIND OF BIOENGINEER WHO I WOULD LIKE TO HIRE.

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Bioengineers do, of course, come in all sorts of intellectual shapes and sizes, the term is no more descriptive of a homogenous set of individuals than that of physicist or chemist.

My own laboratories are very largely concerned with the invention, design and development of new instruments or devices, some of them intended for commercial exploitation, others to solve a 'one off' problem. The range of application is very large stretching from spacecraft equipment, through a wide variety of clinical diagnostic devices to deep-sea diver monitors and technical aids for the disabled.

Most of the work is concerned with true engineering, that is the creation of a working piece of equipment which is reliable and robust which can be constructed economically and quickly, and which can be reproduced. Much less of it is concerned with biological or medical research on the presumption that good bioengineers who really feel engineering are scarce, whilst well qualified biological research or medical workers are not. This does, of course, not preclude considerable co-operation during design, involvement in proving trials, and subsequent collaboration with the user clients; but biological research is not in itself allowed to become an objective. I feel very strongly that professional bioengineering is not a soft option for individuals with an engineering training who are not good enough to survive in a proper engineering environment.

By this I do not mean that they are unable to learn the right equations, but more that they lack the flair to translate a required function or purpose into the optimum hardware configuration.

The attributes I look for in recruitment are described in greater detail below. I do not pretend that I can assess all of these in the course of the normal sequence of references, interview, curriculum vitae, though with young staff some in-service assessment is possible by judicious use of sandwich periods, holiday jobs and short-term contracts (months) · association with a particular project.

1. Ingenuity or inventiveness.

This would manifest itself in being able to conceive several alternative solutions to a problem, at least some of which would not be linear descendants of previous work. People with lots of ideas are preferable to those who have original ideas only rarely, because they can afford to be less protective towards their brain children and are thus able to afford a more objective approach towards the selection of the apparently optimum solution.

2. Being able to recognise a good idea out of context.

The ability to steal concepts from other perhaps quite unrelated pieces of equipment is a very useful ability which is most often associated with general curiosity, about how things work. The acquisition of a library of conceptual sub-assemblies should be a continuous process as active on a Sunday morning when passing a toy shop or mending a vacuum cleaner, as on a formal visit to a exhibition or a conference.

3. Manual dexterity.

I have the firm conviction that within very wide limits a member of my staff should be able to manufacture anything he is asked to design and develop. He may not be as good at any one procedure as the specifically trained individual, but being required to do it provides for an interaction between hand and brain, which I believe is genuinely superior to pure cerebration. It also counteracts excessive complexity of design.

4. Ability to work with a medically or biologically trained partner.

There are two components to this.

A. Semantic compatability: in other words being prepared to make an effort to understand and be understood in terms of what the words mean.

B. Being able to grasp the biological problems, and by reading or other means to acquire sufficient knowledge quickly to make a contribution to successive stages of definition of what actually has to be achieved.

5. Sympathy with the aims of industry.

A lot of creative bioengineering ought to be concerned with the design of devices which can ultimately be turned into products which are commercially viable. This requires an understanding of how industry works and the willingness to make the considerable effort involved in the transfer from the laboratory to the manufacturer.

6. Most important perhaps, though dangerous without at least some of the above qualifications, is enthusiasm. Work should also be fun, to be left with reluctance rather than alacrity: that new piece of equipment should almost seem to be a present and one's colleagues should appear to be the nicest people in the workd.

Perhaps I am being unrealistic!

THE ROLE OF A PROFESSIONAL SOCIETY IN THE TRAINING OF BIOENGINEERS.

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The Biological Engineering Society is in the midst of a transition from being a learned Society to becoming also a Professional Society. In its former role the major concern was the dissemination of information through conferences and publications. One logical development in this was the appearance of the Society's own journal, Journal of Biomedical Engineering now in its third year.

In one sense the journal is symptomatic of the transition since the desire to achieve high standards in scientific publication is strongly related to the maintenance of high standards of professional practice. The Society is now committed strongly to its second role. It is, therefore appropriate to consider the reasons for this and the consequences.

The Purpose of a Professional Society.

The importance of a high level of competence possessed by all who are involved in health care cannot be over emphasised. The days are now surely gone when a medical specialist had a proprietorial interest in an engineer who did odd jobs for him. Medicine has become increasingly dependent on the physical scientist for diagnosis and treatment. In the year of the disabled it is appropriate to remember that rehabilitation medicine depends heavily on a high level of engineering understanding. This may be extended to include sophisticated methods of biofeedback measurement in rehabilitation of stroke patients as well as the provision of orthoses and prostheses.

Partnership as equal members of the health care team has now largely become normal practice. This lays obligations on the bioengineer in terms of competence and ethical standards. The former implies that education training and practical experience should be adequate, the latter that the application of these will be carried out conscientiously and with integrity. In its booklet on Professional Conduct the Royal Society of Chemistry states "There may well be a tendency for members of a learned profession, such as the profession of chemistry, to become so deeply engrossed in the technical aspects of their work that the ethical aspects are sometimes overlooked or given insufficient attention. It must therefore be emphasized that the requirements with regard to conduct are fundamental and those who claim professional status must also undertake to adhere strictly to professional ethics. This means unequivocal acceptance of a standing obligation to go well beyond the bare fulfilment of legal requirements and to act at all times in a manner consistent with a position of trust and special responsibility."(1) Later in the same publication it is emphasised that for chemists in the Health Service "many of the ethics which apply in medicine therefore apply equally to the clinical chemist"(2).

The Biological Engineering Society is committed to the view that it should endeavour to uphold these principles in order to promote the highest levels of health care, to improve collaboration and partnership with members of other professions and to improve the status of its own members. This has been the reason behind latest developments.

Accreditation of Bioengineers

There is an increasing trend internationally for schemes whereby those practising biomedical engineering or clinical engineering in one country may be acceptable in another. The IFMBE will shortly be publishing proposals for registration of Clinical Engineers.

The Biological Engineering Society has now published its own regulations both with regard to training and registration of the individual, but also for the accreditation of centres which will be recognised by the Society as being suitable for such training. (3).

At present the regulations relate only to graduates. This is part of our approach to the Council of Engineering Institutions (C.E.I.) for affiliation.

Recognised qualifications are an appropriate first degree in Engineering and Physical Sciences or other examinations as specified. A period of structured practical training for a minimum period of four years is also required and two of these should be carried out in a recognised establishment. Various provisions are written into the regulations and should be studied in detail for each individual case.

The establishment of accredited centres is clearly an important part of this. Again detailed reference should be made to the regulations for the definitive statement. The Accreditation procedure includes submission of an application to the Society and a visit by members of the Professional Section Committee. The centre must demonstrate it's suitability for training in at least two areas from the following.

Biomechanics/Mechanical Engineering
Biomaterials
Medical and Related Electronics
Data Processing and Computers
Rehabilitation Engineering
Physiological Measurement
Biological Measurement
Other areas as determined by the Society.

The principles of assessment are based on two points:

a) the positive accreditation of Centres for Training through a rigorous process of visitation and adherence to the appropriate criteria.

b) the individual certification of those who have been trained in a Centre as above defined. The discipline of Bioengineering is so diffuse that the Society does not see at the moment any other way than individual certification based upon the candidate submitting his training programme, experience and, where appropriate, the outcome of his research.

The Society sees a continuous development in this direction throughout the next decade. Technology and Science have invaded the health service. It may be that the cost effectiveness has not always been as great as had been envisaged, in terms of better care for patients and better utilisation of hospital facilities. Developments may not always have been in the most appropriate direction and the glamour of a new technique may have produced emotional responses rather than rational decisions. It is imperative for the future that those involved in decision making about the direction taken in health care should be fully professional. The aim of the Society is to help to provide these individuals.

1. Professional Conduct Guidance for Chemists. Royal Institute of Chemistry, London, 1975. page 2. Soon to be re-issued from the Royal Society for Chemistry.

2. Op cit. page 24.

3. Training, Assessment and Accreditation in Bioengineering and Biomedical Engineering. Biol. Eng. Soc. London, 1980.

EDUCATION, TRAINING AND CAREERS IN BIOMEDICAL ENGINEERING - MATCH OR MISMATCH?

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In the United Kingdom, as in many other countries, the term Bio(medical) Engineer is applied to include those who work in industry producing equipment for therapy, diagnosis and life support, those in Universities carrying out research on biological and engineering systems, and those in hospitals engaged in providing the technical support for day to day patient management.

The formation and development of bioengineers can be considered by analogy with the simple circuit shown in Fig.1. The education process is essentially dynamic, producing a driving signal while the bioengineer's career may be likened to a complex and changing impedance. The matching network which enables source to be connected effectively to the load, is training.

Education. Educational patterns in bioengineering have been set for some time and the U.K. has many first and higher degree courses which provide a formal educational base from which an aspiring bioengineer can start. Postgraduate courses in bioengineering have continued to expand over the last two decades and there are now seven available to students. However, current cutbacks in university funding may inhibit the establishment of further courses and may force those already in existence to modify their approach to meet consumer demand more closely.

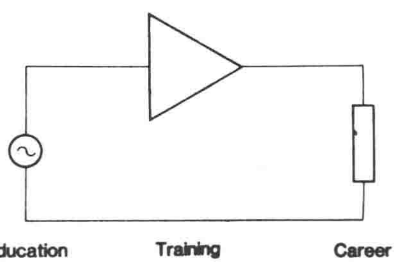

Figure 1: The formation of bioengineers.

Training. Until recently little or nothing has been offered in terms of training for bioengineering and the physical scientists are the only major group working within the health care system who require no form of professional training or certification to practise[1]. This does little to enhance the position of the scientist and engineer in health care and the lack of any training means that the signal generator illustrated in Fig.1 is often applied unmatched to the load. Sometimes the impedance match has been good and careers have flourished. More often, the match has been poor resulting in a very ineffective transfer of energy and a poorly developed career. This is wasteful, and it is timely that thought is now being given to the need for proper training.

An examination of the BES membership register reveals the inequality of professionalism in bioengineering as practised both inside and outside the National Health Service. Of the BES's membership who are qualified in the physical and engineering sciences, the proportion working outside the Health Service who are chartered engineers is 52%, while of those working within the NHS only 12% are chartered (Fig.2). This difference may only in part be explained by the smaller proportion of engineers working in the NHS and it suggests either that the NHS demands a lower standard of professionalism for its staff, or that those working within the NHS can see little point (or are unable through lack of adequate training and experience) to aspire to professional engineering status. As the need for bioengineers increases, the training given to engineers working in the Health Service will need raising to a standard compatible with that applied outside.

In establishing the pattern of the training process, two somewhat differing approaches are being pursued by the learned societies most closely identified with the field. Although different, certain features of the two schemes are similar and as both schemes develop it may well be that some coalescence will take place in the long term.

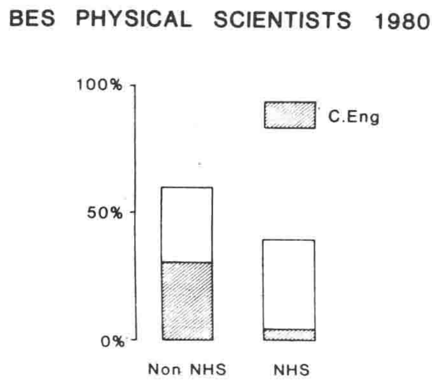

Figure 2. Distribution of Chartered Engineers in Bioengineering.

The BES's approach to training requirements has in part been dictated by precedents already established for the chartering of professional engineers by the Council of Engineering Institutions, and in part by the Society's belief that to be fully effective in bioengineering an individual must have an adequate training in his primary discipline. The paths that can be followed under the BES scheme are illustrated in Fig.3. Three options are open, the shortest of which is the path shown in the centre where a candidate undergoes a basic training in his primary discipline and then higher training in bioengineering. This short training path is for four years, but a candidate must additionally show evidence of being in a position of responsibility before being suitable for registration. The higher training in bioengineering must be carried out at an accredited training centre, the establishment of which is described in detail elsewhere in these proceedings.

The other national training scheme is being run by the HPA. Although also of four years' duration, comprising two basic parts each of two years, it differs substantially from the scheme proposed by the BES. Firstly, there is no proposal to provide a basic training in the primary discipline, there is no declared intention to use accredited training centres, and there is as yet no declared intention to use the satisfactory completion of the scheme as a step towards registration as a physical scientist (though this would be a simple extension once the scheme got underway). The question of the use of accredited training centres is overcome in the HPA scheme by the requirements for the trainees to undergo both a written and an oral examination during, and at the completion, of their training period. The BES prefers to examine the trainers before examining the trainees. The fundamental difference between the schemes lies in the nature of the basic training.

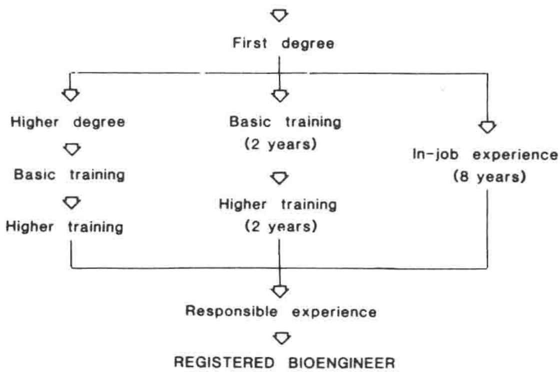

Figure 3. Pathways to registration.

Career. For any aspiring bioengineer an all-important question is, "what jobs are available to me?". The total U.K. market is difficult to assess precisely, but some measure may be gained from an examination of advertisements which appear in the Journal of Medical Engineering & Technology and New Scientist, and those advertised in the HPA's job placement circular and by the BES.

An examination of only one source might, if it were the Journal of Medical Engineering & Technology, give the impression of total stagnation, with job opportunities for graduates falling from 18 in 1974 to 0 in 1980. An examination of the New Scientist reveals that in 1974 there were 57 scientific posts available and in 1980 only 30.

An HPA survey revealed that the recruitment to the Senior Physicist grade (which would include both those working in bioengineering and radiation physics) rose from 1 in 1960 to 14 in 1970. In 1980 the HPA advertised 40 Senior Grade posts. These figures indicate that although there has been a real fall in job opportunities in the U.K. since the BES's last Education Conference those in the hospital service have continued to expand despite the current economic decline. However, of the 40 posts advertised by the HPA, only 15 (37%) were in the field normally associated with bioengineering. This figure compares well with the figure taken from all grades from basic to top, where of the 126 vacancies advertised, 48 (38%) were for activity in bioengineering. This number is not too dissimilar from the total posts advertised in the New Scientist and the Journal of Medical Engineering & Technology, and would suggest that the real number of job opportunities in 1980 probably did not exceed 50. Indeed, it could be argued that with the current output of all the U.K.'s M.Sc. courses running at over 50 per year, the current supply would appear to be in danger of outstripping the demand. Some encouragement, however, may be gained from an inspection of the job vacancies by grade. Of those posts advertised at Basic level, 27 (47%) were for work associated with bioengineering, while at the Principal level only 5 out of 22 posts advertised were seeking bioengineers. Since the contraction or expansion of any existing service is most readily achieved (particularly in times of economic stringency) by the distribution of new junior posts, one can look at the recruitment to the various grades as a reflection of the changing pattern of activity. Recruitment to the top and principal grades is largely dictated by the effects of planning which occurred several years ago, that to the senior and basic grades, planning which is going on at present. Once could, therefore, use the figures to look forward and conclude that the proportion of recruitment to bioengineering activity is likely to increase over the next decade, hopefully to the levels in the early 70's.

Conclusion. What then is needed for the 1980's? In 1975 the Department of Health stated[2] that, "adequate training arrangements and education facilities are an essential requirement for a properly organised scientific service". Five years later training is being examined in detail. However, the resources are slim and it seems most unlikely that money will be made available to implement anything approaching that ideal training scheme. At the same time, the viability of some postgraduate courses may well be called into question if they are seen to be mismatched to consumer needs.

Bioengineering is a dynamic subject. Its needs and skills will change over the next decade as resources are shifted from the acute to the non-acute areas of health care. If we are to make the most effective use of available resources, the pattern must change and there must be a closer integration between education and training. This integration must, however, go further than merely involving the NHS with the Universities. It must also integrate the U.K. medical engineering industry, much of which is currently in danger of disappearing. By insisting on adequate training in the primary discipline, job mobility between industry, research institution and hospital should be freed of at least one impediment and should foster collaboration between all three.

Career opportunities, although they may appear fewer now than five years ago, will undoubtedly increase. However, they will result, not from continued mediocrity, but from demonstrated excellence. Properly integrated and consumer-oriented education and training will help to establish and maintain this excellence and achieve the most effective match between education, training and career.

References:

1. Roberts, V.C. (1980), "Training and certification in the hospital scientific service". J.Med.Engng.Technol. 4, 113.

2. Consultative Paper: Implementing Organisational Aspects of the Zuckerman Report. DHSS (1975).

BIOENGINEERING EDUCATION: THE PAST FIFTEEN YEARS AND THE FUTURE

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In the United Kingdom Bioengineering education for the professional has generally been treated as a post graduation subject and also as a post graduate subject with very few exceptions. The minor trend in North America towards undergraduate biomedical engineering education has not taken place here.

The Bioengineering Unit at the University of Strathclyde initially enrolled candidates for research degrees, both masters and PhD, firstly under the umbrella of the Mechanical Engineering Department and, subsequently, as a feature of a separate unit when it was set up. Subsequently a formal masters course involving instructional work and a research project reported by thesis was introduced and a total of 268 students is available for statistical analysis. It seems appropriate therefore to consider this data base in respect of the orientation of the education, the first discipline of those participating, the degrees obtained and the careers entered into. Similarly, attention will be paid to the qualifications and training of those involved in the conduct of these exercises.

In the first instance the question arises "Is Biomedical Engineering Education necessary ?" There is no doubt that qualified scientists and technologists can and do enter employment where their basic expertise is adapted towards design, production or marketing of devices or systems for the Health Care industry. Similarly, others go from first discipline into units related to the health care environment, such as hospital physics, clinical research units and educational establishments. Nevertheless, there seems little doubt that as far as the students are concerned and as far as prospective employers are concerned, the widening of knowledge and experience and the adaptation of their primary skills to the medical field makes the university postgraduate leaver a more attractive recruit. It might be held that a special course or series of courses should be developed for the basic undergraduate education and career training of the recruits to these work areas. Unfortunately however, although there is a brisk market for the output of the current bioengineering university level courses in this country, there must inevitably be those who will find their career opportunities in conventional science or technology. Similarly, it would