BIOMEDICAL ENGINEERING FOR THE FUTURE

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The term medical engineering or biomedical engineering has now become fashionable. There is, however, considerable divergence of opinion as to the precise meaning of the term. It has been generally accepted to mean some combination of the life sciences and the physical sciences. Under this rather loose interpretation, there could be included the fermentation engineer, the environmental engineer, the engineer working on medical instrumentation only, those in bionics, human factors, and biomechanics. One could not exclude those engineers who at different times have helped to solve some particular problem for the physician.

Such efforts have a long history. The prototype of the engineer must have worked with the physician during early Egyptian times to develop skull trepanning techniques. Surgical tools found in Pompeian and Roman ruins indicate some knowledge of metallurgy and tool design. There were even crude attempts made to devise prostheses. In later periods the skill of the armorer was applied to creating artificial arms and legs. In the development of many of the tools of modern science, the microscope, the ophthalmoscope, the string galvanometer and others, often demonstrated an interdisciplinary effort.

It required a World War and the attempts to conquer space, however, to emphasize the interdependence of the physical and life sciences, engineering, and medicine. The creation of new and sometimes exotic environments, the high altitude airplane, the submarine, the tank, and the space capsule revealed to the engineer his dependence on the physiologist and psychologist as well as the medical scientist. Conversely the new technologies that made these environments possible revealed to the life scientists vast new potentials in the continuing struggle against disability and disease.

This awakened recognition of the mutual interdependence of life and physical science has created a demand for a professional with such interdisciplinary background. This demand has been reinforced by generous outpourings of funds from government resources for the training of such professionals. Engineering schools have reacted to this in a variety of ways.

A limited number of schools, Pennsylvania, Johns Hopkins, and Rochester, had instituted courses in Medical Engineering in the late 1950's. These courses perhaps in the beginning concentrated on medical electronics to the neglect of the potential of other engineering disciplines in the solution of medical problems. These schools were followed by others, among which were Case Western Reserve, Northwestern, Michigan, Drexel, and Rose Polytechnic, which interpreted the need in a variety of ways. Many schools initiated courses without adequately prepared background or staff. And a number of schools, California and New York University among them, had been engaged in medical engineering research for the past 20 years without consideration to educational programs.

This new demand poses a problem for engineering schools. Their primary responsibility is to turn out well-trained engineers and engineering scientists, and in fact, this is their main responsibility to the medical or biomedical programs. The question is—how are they to accomplish this in view of the already crowded curricula that prevail in so many engineering schools today?

Certain schools, such as Johns Hopkins, offer a graduate course of four or more years, in which the School of Medicine, the Faculty of Philosophy (especially the departments of Biophysics and Biology), and the School of Engineering Sciences participate. Such a program does not require all the engineering courses that a Ph. D. in Engineering might be expected to take, but makes it possible for those who wish to do so.

Northwestern, on the other hand, offers programs at three levels: An undergraduate program in Bio-Medical Engineering, leading to a B.S. degree; a program for individuals with a B.S. degree in the life sciences, or an M.D. degree; and a Ph. D. program for those with appropriate background.

Case Western Reserve University has organized to offer interdisciplinary education at the graduate level in Bioengineering, and in Medical Engineering which they differentiate. The courses fall into three categories:

1. Engineering and supporting courses in chemistry, physics, and mathematics offered at Case.
2. Bioengineering courses offered by the Engineering Division at Case.
3. Life Science courses offered at Western Reserve.

The second category are courses not ordinarily available either in an engineering or medical school, but have grown out of a combination of the two.

The University of Michigan is developing a program for degrees at the Master's and Doctor's level. This will incorporate courses from many of the schools of the university and will be available to students with B.S. degrees in the various sciences provided they prepare themselves according to an established set of standards.

Certain schools, such as the University of Washington, offer courses in the medical curriculum. More universities offer courses in the curricula of the Schools of Engineering, and in a majority of these, they more properly could be labeled courses in Medical Electronics.

At New York University, we are not yet committed to a formally structured program. The program is at the graduate level leading to Master's and Doctor's degrees and is jointly sponsored by the School of Medicine and the Electrical Engineering Department of the School of Engineering. There are courses being offered in Biomechanics, and there is research going on in several areas properly belonging to Biomedical Engineering, such as heart assistive devices and prosthetics and orthotics.

There is yet no basis for determining which if any is the correct approach. Are we to create a well-trained engineer with interest in medical problems? Are we to train a scientific generalist with less training in the engineering sciences compensated by more training in the life sciences? Or are we eventually going to create a new discipline that will draw from existing knowledge but organize it in a new fashion?

Assume that we have these answers, we are faced with another problem; how many are to be trained and where will they be absorbed? So far only a limited number have been graduated, so that no definite conclusions may be drawn. Some of these have gone to other universities to take up teaching and research activities. Some have gone to government agencies principally to the National Institutes of Health. A few have gone into industrial situations.

Eventually some order will derive out of what at present is disorder. In the meanwhile engineers are contributing to the attacks being made on medical problems. The nature and breadth of their contribution has been more elaborately developed in the article by Renato Contini, which appears in this issue; and in another contribution to this issue by Appoldt and Bennett the nature of one such research program is gone into in detail. Other articles show how much work is being done in prosthetics and orthotics.

Regardless of the present confusion, the engineer has a contribution to make in the field of medicine. The contribution will become better defined as the interplay between the engineer and physician increases. The Engineering Schools will then be ready to provide such qualified engineers.