Middle Articles

Collaborating Disciplines: Biology and Medicine—Physics and Engineering

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There is nothing new about the collaboration of the sciences. As Roger Bacon, physicist, mathematician, and philosopher, wrote in the fourteenth century: "All sciences are connected. They lend each other material aid as parts of one great whole, each doing its own work not for itself alone but for the other parts, as the eye guides the whole body and the foot sustains it and leads it from place to place."¹ Over the centuries the laws and theories of the physical and mathematical sciences in particular have been used by the philosopher-scientists to try to explain the working of the body. It is possible to mention here only a few of the great thinkers of the past who have brought the light of other sciences to bear on biological problems. Aristotle, in his treatise on animals, analysed the action of muscles in geometric terms. Leonardo da Vinci studied the anatomy of the body in great detail and used the principles of mechanics to explain balance, posture, movement, and the action of the muscles. About A.D. 1500, in his *Sul Volo degli Uccelli*, he wrote: "Instrumental or mechanical science is the noblest and above all others the most useful, seeing that by means of it all animated bodies which have movement perform all their actions."²

The founder of the science of biomechanics was probably Borelli, a pupil of Galileo. In *De Moto Animalium*³ he used the principles and laws of physics and mathematics to explain anatomical problems. Many of the early studies of the form and structure of living things showed how far these conform to physical and mathematical laws, as D'Arcy W. Thompson points out in his excellent work *On Growth and Form*.⁴ Sanctorius of Padua, the sixteenth-century physician and iatro-physicist founder of the physiology of metabolism, devised a pulse-clock, a thermometer, and a machine for weighing himself before, during, and after meals to estimate his insensible loss of perspiration. His contemporary, William Harvey, a physician at St. Bartholomew's Hospital, who can be said to be the founder of the science of physiology, demonstrated that blood moved in a circuit and not to and fro. He based his surmise almost entirely on an analogy with the performance of simple machines. It was not a doctor, but Sir Christopher Wren, architect, engineer, and chemist, and Robert Boyle, physicist, who in about 1665 conceived the idea of injecting medicines into the blood-stream. At Wadham College, Oxford, they injected an infusion of opium through a quill into a vein in the hind leg of a dog. In 1816 Laennec made medical use of the fact well known in acoustics that if you scratch one end of a piece of wood with a pin you can hear the scratch with great distinctness by putting your ear to the other end. He devised the stethoscope. Yet it took more than 14 years for his invention to be accepted by the English medical world. It was Thomas Young (1773–1829), physician, mathematician, and archaeologist, who first described

astigmatism. He also developed a theory of colour vision, the Young-Helmholtz theory. Yest engineers remember the same man mainly for providing them with Young's Modulus of Elasticity—the ratio, within the limit of elasticity, of the stress to the corresponding strain. It was a physicist, Professor Roentgen, who in 1895, at Würzburg in Germany, discovered roentgen or x rays, and so revolutionized medical diagnosis and treatment.

These are just a few of the outstanding contributions which men trained in the physical sciences have made to the advancement of biology and medicine.

But although the theory of physics had often been used to help solve biological problems, it was not until this century that applied physics and engineering methods and techniques became an accepted part of biological studies and medical diagnosis and treatment. There is now hardly an aspect of biology and medicine which does not interest the physicist. The First International Conference on Medical Physics, to be held in Harrogate in September this year, will give some idea of this wide interplay of interest. There are to be papers on artificial organs and limbs, computers and data-processing, haemodynamics, physics of cell division, solid state physics, work in artificial environments, microwaves, spectroscopy, ultrasonics, and the analysis of biological systems and instrumentation.

The latest group of scientists to have shot into the limelight as allies of medicine are the electrical engineers, particularly those working on measurement and control systems.

Electronic Devices

The more sensitive the equipment we need, the more complex becomes its design. And one thing we have gained from the military programmes of nations has been the development of tiny sophisticated electronic devices. The latest sensing equipment can record changes in pressure, temperature, and electrical activity within organs. Sensors can be fixed in the tissues, either connected to recorders by fine leads or able to transmit information to near-by radio receivers. Electronics engineers can often make a major contribution to the solution of biological and medical problems; and their special knowledge of electrical circuits and components is often essential for the design of experiments as well as the recording and interpretation of data.

In the treatment of heart-block their work has been particularly rewarding. One exciting new device is the inductively coupled cardiac pacemaker working inside the patient but with its power source outside. The pacemaker coil, potted in silicone rubber, is fixed next to the heart and connected to it by needle electrodes. The patient is able to adjust his pulse rate according to physiological needs, and the pacemaker does not have to be removed to recharge the battery. In this work Birmingham University and Joseph Lucas have combined their resources. Their collaboration helped to get the Midlands Medical Engineering Group started in January of this year. This is

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an attempt to give medical research workers freer access to the Midlands' vast store of industrial technical "know-how."

A Revolution

As for the recording, storage, and retrieval of medical data, computers are now bringing about a revolution. Elliott Automation and University College Hospital, with the approval of the Ministry of Health, have together set up a new centre to study these problems. Here computers are used to analyse clinical problems and frequent computer courses are available for medical and other workers. The Royal Air Force Institute of Aviation Medicine at Farnborough has reorganized its scientific instruments and set up a central instrumentation, computation, and recording room. This is connected to the laboratories by multichannel lines, and not only saves the research worker difficulty in collecting specialized instruments but makes it unnecessary for instruments to lie idle for long periods. Many physiological studies of a bio-engineering nature concerning the aerial performance of man and the design of the necessary equipment are undertaken here.

In radiology, physicists have for many years worked with doctors on experimental studies and engineers on design and manufacture of equipment for x-ray diagnosis and therapy. More recently, work in high-energy radiation with either a gamma source or the linear accelerator has enabled materials to be sterilized which it would have been difficult or impossible to sterilize by other means.

Artificial Limbs and Organs

Perhaps the most dramatic advances are in the field of artificial limbs and organs. Dr. Luther L. Terry,⁵ Surgeon General of the United States Public Health Service, in a speech at Georgetown University on 9 February 1965 forecast the development of artificial hearts for implantation in the human body and inexpensive artificial kidneys for home use within the next 20 years.

The orthopaedic surgeon, particularly concerned with those parts of the body which generate and transmit power, is making increasing use of artificial components for the replacement of joint surfaces and portions of bone. These buried devices may have to work upwards of 60 years without servicing, and what machine yet has been expected to do that?

The study of wear and tear and the development of biologically and mechanically satisfactory artificial joints are costly, long-term projects. The history of artificial replacement in hip-joint surgery clearly shows the need for extensive engineering studies, such as those in progress at the Hip Centre, Wrightington Hospital, in conjunction with Manchester University; and at the Institute of Orthopaedics (University of London), in association with the British Petroleum Research Centre, Deloro Stellite Limited, the Battersea College of Technology, the British Non-Ferrous Metals Research Association, and the Brown-Firth Research Laboratories. A proper understanding of how people walk is essential for the improvement of artificial legs, and an extensive programme of work on this was undertaken in the Engineering Department of the University of California, Berkeley, California, between 1945 and 1947.⁶

As for arms, in 1955 Battye, Nightingale, and Whillis⁷ described how a prototype upper-arm prosthesis could be controlled by the myoelectric currents generated by the patient's muscles. At the same time, in Heidelberg, Dr. Marquardt⁸ developed a gas-powered artificial arm. The National Fund for research into Poliomyelitis and Other Crippling Diseases assisted work on improved gas-powered motors and myoelectric controls by a Medical Research Council team at the Institute of Orthopaedics (University of London) and at the Medical School, St. Thomas's Hospital. But it was not until the thalidomide

tragedy in 1962 that strong voluntary and Government support was given to research into powered artificial limbs. Various programmes of work are now in progress at a number of centres, including West Hendon Hospital, the Research Department of the Ministry of Health's Limb Fitting Centre, Queen Mary's Hospital, Roehampton, in a special unit at the Princess Margaret Rose Hospital, Edinburgh, and at the Nuffield Orthopaedic Centre, Oxford. Meanwhile Russian scientists deserve credit for apparently perceiving the importance of the British work of 1955 and being the first to produce an artificial arm, myoelectrically controlled, which doctors could accept. Current British developments in this field now show exceptional promise.

These few examples give some idea of how many physicists and engineers are working in the biological and medical fields. Those with interests in common have established various societies, branches of existing societies, or working parties. These include the Biological Engineering Society, which is affiliated to the International Federation of Medical Electronics and Biological Engineering, the Institutions of Radio, Electrical, and Mechanical Engineers; the Physical Society, the Bio-Physical Society, the Hospital Physicists Association, the Ergonomics Research Society, the Society of Instrument Technology, the British Computer Society, and the Section of Measurement of the Royal Society of Medicine.

A Problem

One of the greatest problems is communication between individuals in various branches of the two disciplines, biology and medicine on the one hand, and physics and engineering on the other. The meetings of the various societies and groups are helping to break down the barriers. Courses have been held, organized in the main by engineers, at Imperial College, London, the Manchester College of Science and Technology, the Royal College of Surgeons of England, and at Norwood, West Ham, and Mid-Essex technical Colleges.

In the United States more ambitious training programmes have been arranged. Engineering graduates can take a four-year course leading to a Ph.D. degree in physiology, while there are courses for doctors in the physical sciences. But D. B. Pall, of the Pall Corporation, New York, told a recent Ciba Foundation discussion meeting⁹ that after some 20 years' experience in dealing with engineers at various levels he did not think that people with this double training would prove effective. He went on to say that "the task of selecting the right men to begin with, of exposing them to suitable training, and of weeding out those unable eventually to undertake responsibility requires a good knowledge of engineering in addition to skill in dealing with people. How can a medically trained director of a research institute lacking in engineering training and experience be expected to make the correct hiring and firing decisions which are so necessary to build up a successful group?"

Need for Collaboration

In Britain and the United States alike there is an increasing need for collaboration between the disciplines in both fundamental and applied studies. However there should not be created a new hybrid specialty, known as bio-engineering, with full undergraduate and postgraduate training in both disciplines. The bio-engineer could not possibly become in his lifetime a specialist in all aspects of biology and engineering—he would be an inferior jack-of-all-trades. Instead, each profession should contribute members to composite teams working in hospitals, universities, technical colleges, industrial firms, and other organizations. Status and pay should be high enough to attract people of the right calibre into a type of research and development which is exciting but often more difficult than work within a single discipline.

The University of Strathclyde has shown what can be done, by setting up, with the help of the Medical Research Council, a Chair of Bio-engineering in the Faculty of Engineering. The present holder of the chair is an engineer. Under him engineers use their skills in the solution of engineering problems in biology and medicine. Doctors and biologists are encouraged to pose problems which can be worked on either in the department or in the hospital. This imaginative scheme is likely to succeed in a city like Glasgow, where the University and hospitals are within easy distance of each other. It is more difficult to imagine the same sort of thing succeeding in London, particularly as the specialized institutes are widely scattered. It might be a better idea in some cases to create joint posts for senior staff, who would act in a consultative capacity. There seems no reason why more postgraduates in engineering should not tackle biological subjects for their theses. Technical colleges might also be encouraged to participate increasingly in this work.

Industry's Role

One area of collaboration has yet to be mentioned—the part played by industry. Often the purpose of medical research is to provide equipment, such as the heart-lung machine and the artificial kidney, to improve existing treatments or make new treatment possible. Once a piece of equipment has been developed and is to be widely used, industry must take over its production. If the research worker has an idea which has obvious practicable application it is not usually difficult to get expert help. But he needs to get it at an early stage in the work, since a research worker is not a design and production engineer. If, however, the immediate application of the idea is not so obvious or may require costly development, industrial help may be much more difficult to get. Whether industry is willing or not, the National Research Development Corporation can often come to the rescue. Some will say that firms make excessive profits in this field, and help only if a good profit is to be seen. But it is right and proper that profit should be made if companies are to continue to give help with the development of ideas. Few research workers seem to appreciate the cost of the development of equipment.

Certain research work cannot be carried out at all unless industry is first prepared to make and develop the tools. Take

research on hyperbaric air and oxygen therapy, for example. A company must either be given a research and development contract to produce the pieces of equipment needed, or it must decide that here is a field which will expand and therefore justify the risk of its own capital. There is obviously a place for both lines of action.

Conclusion

In all branches of industry amalgamation is in fashion to provide the capital and technical resources needed for the more complicated projects. This is happening in the field of medical and biological engineering. A recent example is the formation of the Medical Division of Vickers Limited, which has been merged with Oxygenaire. But that is not the only type of closer working we need. Medical research contributes to the national product, and it cannot continue to play the part it should in the nation's affairs without adequately trained manpower and increasing funds. It is industrial effort which produces the funds in the first place. Industrial success is the result of an adequate educational system. In these days it is essential that a closer liaison should develop between those in academic research and industry in the disciplines of biology and medicine and physics and engineering. It seems that this can take place only if students of both disciplines do not specialize too early but receive a wide education in general science first. In this country early specialization could be a grave danger to the scientific and industrial collaboration we need.

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Surveillance and Early Diagnosis in General Practice

A colloquium on surveillance and early diagnosis in general practice was held at Oxford on 7 July. It was arranged by the Office of Health Economics and the chairman was Professor J. N. MORRIS (London). For the purpose of the meeting the term "surveillance" had been defined as "procedures aimed at the protection of individuals against chronic non-communicable diseases," and the day's programme dealt with two aspects of the subject. The first was the organization of widespread and possibly automated screening programmes; the second was the extension of clinical medicine, primarily in general practice, to increase the likelihood of particular diseases being detected, whether the patient had consulted the doctor for that disease or not.

Requirements for Screening Programme

The colloquium opened with an account by Dr. J. M. G. WILSON (London) of the general principles of surveillance. Having described some of the historical background he listed ten requirements which he considered important to the success of a public health screening programme. The disease must present an important problem; it must have an accepted treatment; facilities for diagnosis and treatment must be available; there must be a recognizable latent or early symptom stage; suitable tests or examinations must be possible; the tests must be acceptable to the population; the natural history of the disease must be understood; there must be an agreed policy on treatment; screening must be a

continuing process; and finally the cost of the programme must be reasonable compared with other medical care expenditures.

Dr. Wilson also made the distinction between epidemiological surveys, intended to provide information about the incidence and natural history of the disease, and "case-finding," where the primary object was to find patients with illness and to bring them to treatment. Turning to surveillance in general practice, he thought the main differences from public health screening resulted from the opportunity for direct and continuing contact between the general practitioner and the patient. Borderline cases could be noted on the patient's record card and kept under review. Good patient records in general practice should make selective screening of