CURRENT SCIENCE

Volume 99 Number 9 10 November 2010

EDITORIAL

Science and Medicine: Building an Interface

'Translational research' is a popular term, used with a stamp of authority by those who formulate research policy. In simple terms, the phrase appears to describe the process needed to transform the research output of academic research laboratories into useful products, procedures and services. In the sphere of research 'translation' can be both difficult and uncertain, often facilitated by individuals with uncommon attributes. While translation is a word that can, in principle, be applied in any branch of science, it is most often used in the context of modern biological research. No field of science has grown as rapidly, spreading its tentacles in all directions, as biology. Indeed the common public perception of biology, fostered during years of school, as a boring, descriptive subject may change rapidly as there is greater dissemination of the remarkable progress made over the past fifty years. The advances in biology directly impact two major areas of broad public concern, medicine and agriculture. Over the past twenty years or so, the loose use of the term 'biotechnology' has obscured the view of the broad discipline of biology in India. The growth of departments of biotechnology in colleges and universities, alongside departments of botany, zoology, life sciences and microbiology must surely puzzle outsiders, who attempt to grasp the meaning of biology. 'Translation' when applied to biological research undoubtedly refers to exploitation of results in medicine and agriculture. Biomedical research in the West has been a booming enterprise for over three decades. The budgets of the National Institutes of Health (NIH) in the United States have grown dramatically in this period and scientists in other disciplines, chemistry, physics and engineering among them, have drifted in substantial numbers to work on interdisciplinary problems, that successfully attract NIH support. The growth of the biomedical enterprise in the West has also been fuelled by the progressive increase in funding for these areas by private foundations, the Howard Hughes Medical Institute and the Wellcome Trust amongst them. Western institutions, most notably in the United States, have built a strong tradition of clinically oriented research, often spearheaded by physician-scientists, who sometimes sport both MD and PhD degrees. The biomedical enterprise in the United States has undoubtedly benefitted by the association and, often, colocation of medical schools and clinical research facilities within the environment of major research universities. Medical school entrants have already received a broad undergraduate education, setting them apart from medical graduates in India, whose exposure to other disciplines is limited to the years in high school. The US National Institutes of Health, which viewed from afar, has a mind-boggling $31 billion budget boosted, curiously enough in the recession, by an additional injection of $10.4 billion provided under legislation entitled the 'American Recovery and Reinvestment Act' (Wadman, M., *Nature*, 2010, **466**, 808). NIH has played a central role in the expansion and successes of biomedical research over the last few decades. In sharp contrast to the West, the gulf between science and medicine has been almost unbridgeable in India; 'two cultures', a phrase made famous by C. P. Snow, which appear to have evolved over the years with little in common.

In thinking about medical education, I was drawn to a marvellous account of the life of William Harvey (1578–1637), who discovered the circulation of blood. The author, Andrew Cunnigham, writes: 'This was, and still is, simply the most important discovery about the anatomy and physiology of the human and animal body that has ever been made' (*Cambridge Scientific Minds* (eds Harman, P. and Mitton, S.), Cambridge University Press, 2002, pp. 21–35). In this essay, written for a volume celebrating Cambridge University's long and distinguished history, Cunnigham asks whether Harvey's early education at Cambridge over a period of six years (1593–1599) contributed in any manner to his development 'as the great anatomical researcher he turned out to be'. He refers to a speech after Harvey's death, which pays a great tribute to Caius College where Harvey 'drank in philosophy and medicine from the purest and richest spring of all, if there be such another dedicated to Apollo in the British Isles'. From Cambridge, Harvey journeyed to Padua, 'the greatest nursery of medicine in its day', where he was influenced by the anatomical research and teaching of Fabricius. What are the factors that shaped Harvey; Cambridge or Padua? Cunnigham answers: 'For these, [Harvey's ground breaking researches] Padua was exclusively responsible. However, by the chances of his education – first The King's School and then Caius College – Harvey was steered towards the priceless innovative teaching of Fabricius in Padua'. Over the centuries inspirational teachers have sown the seeds of discovery in the minds of gifted students. In medicine and in science, teaching and research merge seamlessly in environments that promote 'translation' and 'innovation'. This is a conclusion that is not often appreciated and, indeed, sometimes vigorously contested in the many discussions of the future of education and research in science and medicine in India today.

The contributions of basic scientific research to the advance of medicine throughout the 20th century are evident. Unfortunately, there seems to be little appreciation of the need to integrate science and medicine in India. The turf battles between the Ministries of Health and Human Resource Development will ensure that the emphasis on regulation and control dominate discussions of medical education and research. In thinking of examples of advances and discoveries in unrelated fields that have impacted medicine, I realized that the earliest Nobel prizes in physics recognized serendipitous discoveries that have revolutionized medical practice. In 1895, Wilhelm Röntgen observed that the 'impact of cathode rays on the glass vacuum tube was generating a new kind of invisible ray'; rays which made a distant fluorescent screen glow. Röntgen rays had 'extraordinary penetrative power'; a property that led to the birth of imaging in medicine. Röntgen famously despatched 'X-ray photographs of his wife's hand which produced an almost ghoulish image that clearly showed her bones and wedding ring' to several prominent physicists in Europe. This action soon resulted in a situation where 'all hell broke loose.' (The Nobel Prize in Physics 1901; Nobelprize.org). Henri Becquerel followed up on this discovery: 'At the beginning of 1896, on the day that news reached Paris of the experiments of Röntgen… . I thought of carrying out research to see whether all phosphorescent material emitted similar rays. The results of the experiments did not justify this idea but in this research I encountered an unexpected phenomenon… . Of all the phosphorescent materials, uranium salts seemed particularly suitable for this investigation… . I found that the uranium salts had emitted rays which produced the silhouettes of the crystalline sheets through the black paper and various screens of metal or thin glass laid on the plates.' (A. H. Becquerel Nobel Lecture 1903). This, of course, was the discovery of radioactivity. The Nobel prizes in Physics in 1901 and 1903, two of the earliest awards, recognized discoveries that have had an immeasurable impact on medicine and many other areas of science. Researches in physics and chemistry that have transformed medical practice can also be illustrated by more recent examples. Three dimensional imaging in medicine became a reality with the invention of computed tomography (CT), which permitted image reconstruction, resulting in the award of the 1979 Nobel Prize in Medicine to G. H. Hounsfield, an electrical engineer, and A. H. Cormack, a physicist. In his Nobel lecture Hounsfield had begun to realize that NMR imaging, then in its infancy, would indeed prove to be even more versatile in its application to medical problems. A dramatic illustration of the enormous dividends that may accrue to medicine from research in apparently esoteric fields is provided by the development of magnetic resonance imaging (MRI). Paul Lauterbur's Nobel lecture in 2003 is entitled: 'All Science is Interdisciplinary – from Magnetic Moments to Molecules to Men'. There cannot be a more succinct summary of the progression of scientific advance across disciplines. Indeed in the area of magnetic resonance the earliest Nobel Prizes were in physics, followed decades later by two in chemistry, progressing almost inevitably to the 2003 award in medicine. At the very beginning of his work in the early 1970s, Lauterbur clearly recognized the potential of NMR imaging in studying the human body. However, his first experiments resulted in an image of two 1 mm glass melting point capillaries filled with ordinary water (H_2O, which provided the signal from hydrogen nuclei), placed inside a 5 mm glass tube filled with heavy water (D_2O). This technique of imaging first named as 'zeugmatography' (a word with classical Greek origins), was to grow very rapidly into MRI, an enormously sophisticated, but nevertheless indispensable, diagnostic tool in hospitals. The seeds of basic science can indeed yield succulent fruit in the field of medicine. The history of MRI (and indeed many areas of successful science) is best summarized in an old American saying: 'From little acorns, tall oaks grow'.

Are there any lessons to be learnt from experiences elsewhere for the biomedical research enterprise in India? The rise of the corporate hospitals and private clinical facilities (euphemistically called 'nursing homes') has substantially eroded the influence of 'teaching hospitals', which indeed are best suited to create an ambience of research. The limitations in the number of medical students pursuing MD degrees, automatically restrict the flow of clinically trained researchers into fields which lie at the borders of science and medicine. The 'stand alone' nature of the best of our clinical research centres provides little scope for interactions among scientists, engineers and clinicians. The efforts at translation, well intended and undoubtedly required, need more than financial resources and new institutions. They need concerted attempts to transform undergraduate medical education and to create opportunities for students and young clinicians to be exposed to the broad sweep of science that has transformed medicine over the past century. The physician-scientist is an extremely rare species in India. The task ahead in medical research and education in India will be to create a new generation of clinical researchers, who will taste the excitement of science. One can only hope that they will effect a transformation that will place biomedical research in India, centrally, at the confluence of science, engineering and medicine.

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