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EDITORIAL

Chemistry: A Discipline in Decline

Two years ago the biologists celebrated the 50th anniversary of the Watson–Crick paper, announcing the structure of DNA. The birth of molecular genetics might have been viewed as a triumph of physics and chemistry, but the revolution in molecular biology that followed, swept away the bridges to the origins of the double helix. This year the physicists celebrate the centenary of Einstein's remarkable publications in *Annalen der Physik* in 1905. Quantum mechanics and relativity may be subjects far removed from the concerns of common people; nevertheless Einstein, more than anyone else, remains science's enduring icon. John Barrow analyses Einstein's special appeal: 'Einstein restored faith in the unintelligibility of science. Everyone knew that Einstein had done something important in 1905 (and again in 1915) but almost nobody could tell you exactly what it was.' In assessing the impact of Einstein on our perception of science, he concludes: 'Most amazing of all is that – despite the hullabaloo and the inevitable cynicism about celebrity in our age, especially in response to media-created icons – Einstein's scientific legacy is greater than ever.... His early scientific work was an unqualified success and his personal demeanour and response to fame an object lesson to all. That is why 2005 is the World Year of Physics – Einstein's Year' (*Nature*, 2005, **433**, 218). There is a clearly stated hope that pursuing Einstein's legacy, both in relativity and his oft-expressed apprehensions about quantum mechanics may yet lead to a new revolution in physics. There is a great sense of promise and optimism in the future of theoretical physics in the collections of commentaries that mark the Einstein centenary (*Science*, 2005, **307**, 865–890; *Nature*, 2005, **433**, 213–259). With both biology and physics celebrating famous anniversaries and looking at the future, I am inevitably drawn to ask: 'What about chemistry?'

Chemistry has sometimes been called a 'central science'. It straddles the vast terrain between biology and physics and shares borders with geology, metallurgy and medicine, among others. Yet, chemistry has a poor public image. Chemistry is associated with poisons ('strychnine in the soup' is an old favourite) and pollutants. The beneficial uses of pharmaceuticals and plastics fade into insignificance in the public mind, in comparison with the constant barrage of discussion on chemical dangers. Chemistry lacks the romance of biology or physics; the former promises to unlock the secrets of life, while the latter probes both the farthest reaches of the universe and infinitesimally small constituents of matter. There is an undeniable glamour in chasing after a mysterious new 'particle' or in discussing a 'theory of everything'. The technological advances that have flowed from the discoveries of physics and biology have in large measure been accorded a degree of public recognition, that has eluded some of chemistry's most useful contributions. The declining perception of the usefulness of chemistry is best illustrated by the steady closure of chemistry departments in the United Kingdom (UK). A recent estimate suggests that 'less than half of all UK universities offer undergraduate degrees in chemistry' (Clery, D., *Science*, 2005, **307**, 668). Public discussion of the declining fortunes of chemistry has been catalysed by the decision of the University of Exeter to close its chemistry department. The costs of teaching undergraduate chemistry and physics have escalated, with laboratory courses becoming a major drain on resources. Even as students are drawn away to more attractive courses, chemistry and physics departments must wrestle with declining student strengths and falling budgets. The marketplace of university education is becoming more competitive and the UK example may merely be a forerunner of what is to happen worldwide. The UK funding mechanisms, which tie university grants to research output, appear to be hitting hard at teaching departments, leading the report in *Science* to link 'Darwinian funding' to the 'demise of physics and chemistry'.

In India too, the signs of a decline in chemistry and physics have been evident for some time. Biology departments, both botany and zoology, have reinvented themselves as biotechnology departments. Students flock to biotechnology courses in colleges, which charge high fees, in the hope that these degrees will open the door to employment in the biotechnology sector, which is growing at a moderate pace. Physics and chemistry appear to offer little for the future. Unfortunately, many B Sc and even M Sc biotechnology courses have a minimal laboratory component, producing thousands of poorly trained students. The situation with respect to experimental training is also very poor in both undergraduate and postgraduate courses in chemistry and physics.

The decline of chemistry (and physics) departments in Indian universities has been easily noticeable. Several areas of traditional strengths, notably natural products chemistry and inorganic chemistry have withered away. Organic chemistry still appears to be moderately popular, with both students and teachers. As long as faculty retirement rates outstrip recruitment, there is little doubt that the decline will continue. The laboratory, which was once so central to B Sc and M Sc courses, is slowly disappearing; 'computer experiments' may soon be the only exposure that students may have in many areas of chemistry and physics. At present, one of India's strengths is its trained pool of organic and medicinal chemists, who have been critical to the success of the chemical and pharmaceutical industries. Synthetic chemistry is an area where specialized experimental skills may be far more important than theoretical understanding; performance at the bench more prized than articulation. This is also an area which is central to drug discovery and development. As major multinational pharmaceutical companies move towards cutting the costs and hastening the process of drug discovery, outsourcing the chemistry of pharmaceuticals may become commonplace. In the West, chemists will be hard to find; biologists are far more available. India may then be one of the most promising sites for outsourcing (Marris, E., *Nature*, 2005, **433**, 902). Organic and medicinal chemists will undoubtedly be in demand. It would then be important for academic chemistry departments to project these growing avenues for employment and enhance the intake of students.

Even as the fortunes of branches of science wax and wane, it is inevitable that interdisciplinary research is the mainstay of the future. The time has come to seriously consider restructuring the courses in science to permit greater flexibility for undergraduate and postgraduate students. The archaic system of 'main subjects' and 'ancillaries' or 'subsidiaries' may have outlived its use. Employable chemists, biologists and physicists of the future will need a greater appreciation and familiarity with sister disciplines. This is only possible when departmental boundaries are decisively breached. Unfortunately, the state of most of our academic institutions, precludes any serious, enlightened internal debate on academic matters. Reform must necessarily come from within.

In thinking about the state of chemistry, I could not but return to the theme of chemistry as an experimental science. For young students, in high school, there is a certain excitement when chemical experiments are performed. Fire, explosions, dramatic changes of colour, evolution of pungent fumes and the indescribably beautiful process of crystal formation can all fire a young imagination. I was fortunate to have played with a chemistry set as a child (they are exceedingly difficult to find nowadays). The joys of chemistry in a pre-adolescence age are wonderfully described in Oliver Sacks' *Uncle Tungsten. Memories of a Chemical Boyhood* (Vintage Books, New York, 2001). Sacks, a distinguished neurologist and highly acclaimed writer describes his infatuation with chemistry, in compelling style. His joys are simple: *'We made a "volcano" together with ammonium dichromate, setting fire to a pyramid of orange crystals, which then flamed furiously, becoming red-hot, throwing off showers of sparks in all directions, and swelling portentously, like a miniature volcano erupting. Finally, when it had died down, there was, in place of the neat pyramid of crystals, a huge fluffy pile of dark green chromic oxide'* (p. 78). Sacks notes that safety concerns have eliminated most reagents from chemistry sets and school laboratories in the West. He quotes Linus Pauling: *'Just think of the differences today. A young person gets interested in chemistry and is given a chemical set. But it does not contain potassium cyanide. It does not even contain copper sulfate or anything else interesting because all the interesting chemicals are considered dangerous substances. Therefore, these budding young chemists do not have a chance to do anything engrossing with their chemistry sets'*. Pauling and Sacks talk of an age that disappeared a long time ago in the West and barely touched India. In his superbly readable account, Sacks describes with a tinge of sadness the end of his affair with chemistry: *'But it was not sudden – I did not wake up one morning and find that chemistry was dead for me; it was gradual, it stole upon me bit by bit. It happened at first, I think without my even realizing it'*. Sacks' infatuation ends when he senses the inroads of theoretical understanding: *'This new quantum mechanics promised to explain all of chemistry. And although I felt an exuberance at this, I felt a certain threat, too'*. He quotes William Crookes: 'We shall be set free from the need for experiment, knowing, *a priori* what the result of each and every experiment must be'. Sacks is clearly bewildered: *'I was not sure I liked the sound of this. Did this mean that chemists of the future (if they existed) would never actually need to handle a chemical; might never see the colour of vanadium salts, never smell a hydrogen selenide, never admire the form of a crystal; might live in a colourless, scentless, mathematical world'* (pp. 312–313).

Even after two centuries of progress, chemistry is rooted in experiments. There is still considerable joy in creating new substances and in deciphering the sophistication of nature's chemistry. The discipline is also central to development, for new materials necessarily fuel new technologies. Chemistry's fortunes must surely take a turn for the better in the not too distant future.

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