c) There was an error in Figure 4. The numbers male (10) and female (20) should have been indicated.
d) The absence of symbols near the captions in Figure 6 is again an inadvertent error. The symbols defined in Figures 2–5, have been used throughout for males, females and controls, respectively.
e) The contradiction is that earlier workers reported immunosuppression during crowding whereas we show enhancement during crowding and this enhancement has been related to sex ratio. The earlier workers perhaps have not controlled the sex ratio. Psychoneuroimmunological basis for the sex ratio-related immunomodulation is a possibility. That is why we have mentioned 'The interpretation of the contradicting findings in the present study *perhaps* lies in terms of psychoneuroimmunology' (*perhaps* = possibly or maybe). Also, we have mentioned that enhancement of immune response is 'possibly' due to certain (sex) pheromones...' We have not mentioned anything categorically since the basis is not clear at the moment. The authors have also admitted that conclusive evidence for the role of pheromones can be given only after getting more information on fish pheromones.

We thank the reader for pointing the avoidable inadvertent errors in the presentation but we do not agree that the points raised are 'serious loopholes' in the study which require kindling of editorial vigilance of *Current Science*!

R. DINAKARAN MICHAEL
M. RAVIKUMAR

Department of Zoology,
The American College,
Madurai 625 002, India.

NEWS

Synchrotron radiation in science and technology*

The Abdus Salam International Centre for Theoretical Physics (ICTP), Trieste, is a rather unusual UN Institution on the Adriatic Coast of Italy just outside Trieste. ICTP offers every year, an unique opportunity to do research at regular intervals and, most of all, a place to think, talk and work. ICTP has a programme of organizing summer/winter/extended schools, colleges in frontier areas of science and technology in order to encourage scientists in taking up challenging R&D activities in front-line subjects and to act as a bridge between the scientists of developing and the developed countries.

The John Fuggle memorial Synchrotron Radiation (SR) school is a bi/tri-annual affair and named in memory of John Fuggle, who was instrumental in holding the first SR School to discuss about the possible exciting applications of SR and also giving training to young scientists all over the world so as to enable them to take up challenging tasks applying SR. Unfortunately Fuggle lived no longer to see his dream comes true and expired due to cancer at the age of 48 years before the first SR School started. In order to pay tribute to his memory, the Schools on SR were named after John Fuggle and are being held regularly bi/tri-annually.

The basic objective of the ICTP SR School demonstrates how the users/potential users of this source of radiation, i.e. SR are finding applications in an increasingly wide variety of fields of science and technology. The field of SR research and applications is making rapid strides and specialized applications in this area are expanding correspondingly. The objective of the ICTP school was to provide an up-to-date account of the recent impact and ongoing developments in the area of SR applications. I, personally, thank the organizers of the SR school for giving me an opportunity to participate and I also believe the various topics covered are the most comprehensive treatment of SR to date.

In all, six directors who are experts in their respective fields were there to guide and coordinate the activities of the School. Eighteen guest faculty plus six directors gave nearly 75 lectures as originally planned. There were informal seminars amongst the participants so as to interact and explore common areas of interest. In addition to the lectures/seminars, visits to Sincrotone Trieste were organized to record the spectrum as well as familiarizing oneself with the various beam lines. Substantial time was devoted to tutorials. Data analysis/reduction was imparted to the participants which was immensely beneficial for participants to follow up in their respective countries.

Synchrotron radiation

An immense range of new technologies associated with the selection of photon energy and polarization and with diffraction, scattering, spectroscopy time resolved studies and imaging has evolved from the use of SR. The interaction between different technologies has led to a very substantial 'tunneling' through the old 'potential' barriers between the disciplines of physics, chemistry and biology, resulting in a multidisciplinary and multiple techniques approach to the solution of scientific problems. Throughout the 1970s and 1980s, SR research probably gave a lead by this fresh approach to science which is now so essential to success in basic and applied research. There is hardly any area of science that has not benefited from SR.

X-rays penetrate all forms of matter – solid, liquid and gas – and are scattered

*Based on the ICTP SR School held from 3 November to 5 December 1997 at Trieste.

or absorbed to varying degrees. For almost a century they have provided one of the most versatile tools for the determination of atomic structures in solids and for imaging of living systems. The evolution of SR sources based on insertion devices has now yielded the most intense sources of X-rays ever devised. Perhaps the most notable improvements brought about by these advances have been in XRD methods, for example on very small crystals. Other techniques such as X-ray Absorption Spectroscopy (XAS) and Small Angle X-ray Scattering have become almost as routine as visible and ultraviolet spectroscopy.

The SR applications are by no means restricted to those mentioned above. One example, briefly, which follows from the advances discussed above is the use of microbeams for microlithography. It may well be that microbeams at synchrotron sources will be used to write the optical elements which are then used to exploit the beams. Microlithography of 3D objects is also imaginable and indeed has been used in the manufacture of micromachines in recent times.

The very high polarization of SR is an important feature that can be used to advantage in many measurements such as scattering and fluorescence experiments, including resonant nuclear Mössbauer scattering. The combination of all makes it an ideal source for an extremely broad, inter-disciplinary range of spectroscopic and structural studies.

Storage ring and its characteristics

The most capable source of SR is the storage ring. A closed continuous high vacuum chamber threads through various ring elements including a) bending magnet that bend the electrons in a circle and produces SR, b) special insertions such as Wiggler magnets to produce particularly intense or enhanced radiation, c) an rf cavity and associated power supply, which replenishes the energy by the electron beam into SR and d) vacuum pumps to evacuate the chamber. The above topics were discussed in depth along with theoretical calculations. The most important properties of SR from an experimental point of view are the total power radiated, the angular distribution, the spectral distribution, and the polarization, etc. Design parameters of the particular machine, i.e. prototype were discussed.

Instrumentation for SR research and beam lines

Instruments that have been developed to meet the specific requirements of particular research areas or techniques are discussed appropriately with special emphasis on ELETTRA SR facility. Incidentally, access to ELETTRA SR facility (Italy) along with Spring-8 (Japan) and VEPP (Russia) SR facilities are available to Indian scientists under bilateral cooperation with Italy, Japan and Russia through Ministry of Science and Technology, Government of India. Perhaps the most important instruments for research with SR are monochromators and detectors. These subjects were covered by A. Savoia, D. Cocco, W. Jark, A. Lausi and C. Lennardi. A. Benedetti discussed XRD beam line at ELETTRA and application of XRD technique to materials. Tutorials/discussion were organized and also hands-on training to familiarize participants with ray tracing analysis using SHADOW software which is important in a beam line to follow the path of electrons and position of monochromators and detectors, etc. XRD data reduction and extraction of results from a typical sample data by a software was also demonstrated.

X-ray photoemission and photoelectron diffraction

Various techniques like photoemission, XAS, etc. were discussed with a focal theme of the prominent advances that have been made since the advent of SR as an excitation source. The topics covered were photoemission, photoelectron diffraction (PhD) and X-ray Magnetic Circular Dichroism (XMCD). C. S. Fadley and A. Nilsson reviewed the photoemission technique in a comprehensive manner with emphasis that photoemission has been established as a very powerful tool for studies of the bulk and surface electronic structure of materials. So was PhD by C. S. Fadley. G. Fecher theoretically discussed the impact of XMCD in Materials Science and its utility. Introduction to PhD software and model calculations were done.

Small angle X-ray scattering and X-ray lithography

The techniques discussed are Small Angle X-ray Scattering (SAXS), X-ray Lithography, Inelastic X-ray Scattering as well as harnessing SR to various biological systems. Aldo Crievich and Peter Laggner lectured at length the use of SR for SAXS. Obviously, this is because the radiation emerging from multi GeV electrons is concentrated in a narrow cone of about 10–4 rad aperture about the instantaneous flight direction. Tutorials in SAXS were held after a visit to ELETTRA organized for obtaining the data on a protein. The differences between SAXS and Wide Angle X-ray Scattering (WAXS) are discernible through these tutorials. J. Doucet discussed in his presentation the possible avenues of various techniques to do biological macromolecules, using SR and the possible funding from the Industry. A brief introduction to inelastic X-ray scattering for deducing electronic structure was done by M. Krisch. C. Khan Malik in her talk and tutorials presented the practical means of replicating patterns in the fabrication of electronic and optical microdevices using X-ray lithography technique. X-ray lithography is an important alternative to optical lithography because it overcomes the fundamental limitations of diffraction and of shallow depth of field.

XANES, EXAFS, RESPES, high pressure, high temperature

The final week of the programme was devoted to XAS, Resonant Photoemission (RESPES) and XMCD. F. De Groot in his presentations introduced XAS, Soft XAS, RESPES and XMCD. A. Fontaine in his talks presented the EXAFS outputs in materials. H. Tolentino and A. S. Miguel in their lectures discussed about the basic concepts of the XAS beam line at European Synchrotron Radiation Facility (ESRF) and also EXAFS under high pressure and temperature. EXAFS data analysis and multiplet simulation were done along with the demonstration of FEFF code of J. J. Rehr.

In addition to the above lectures, special lectures by L. Fonda on holography, G. Margaritondo on ELETTRA SR Facility and Aldo Crievich on introduction to Brazilian SR Facility at Campinas were delivered. ICTP had extended generously to all participants the Computer and Library facilities for the entire duration of the School.

The breadth of application of intense SR, extending from the infrared through the visible and ultraviolet part of em spectrum and deep into X-ray and gamma ray regions brought into the same laboratory scientists from diverse specialties such as surface physics, biology and materials science, etc. The extraordinary properties of SR and its rapidly-increasing availability throughout the world have a profound impact on a broad range of scientific and technological branches. ICTP school has succeeded largely in accomplishing symbiotically for a larger cooperation in the SR research.

K. V. Ramana Rao, Department of Physics, University of Rajasthan, Jaipur 302 004, India

Compressed sulphur found to be a superconductor

A group of scientists from the Carnegie Institution and Russian Academy of Sciences report in *Nature* the surprising observation that sulphur becomes a superconductor at 93 GPa (9.3 million atmospheres). At this pressure, pure sulphur transforms to a superconductor with a T_c (critical temperature) of 10 K, or –263°C. As pressure increases, so does the superconducting temperature, at a rate of 0.06 K per GPa (up to 14 K). At a pressure of 160 GPa (the highest measured in the current experiments), T_c again increased to 17 K. In a related study, in *Phys. Rev. Lett.*, the same authors report the first measurements on a known superconductor, the metal niobium, above one million atmospheres (or one megabar) up to 132 GPa.

A material is said to be a superconductor when it loses resistance to electrical current flow. The phenomenon, one of the most non-intuitive in physics, has been recognized since 1911. Within the last decade, superconducting materials have been found at temperatures high enough to hold promise for energy-related applications, especially in the computer and electric energy fields. Most studies have focused on oxide-based ceramics.

The mechanisms of superconductivity in materials are of great theoretical interest but are, in many cases, in dispute. Studies of simple materials such as the pure elements that might superconduct, including an examination of the effects of pressure on T_c, are essential for understanding the underlying physics. Such studies, in turn, are crucial for designing new, technologically useful superconductors.

The authors of both papers are Viktor Struzhkin, Russell Hemley, Ho-kwang Mao, all of Carnegie's Geophysical Laboratory and NSF Center for High Pressure Research, and Yuri Timofeev, of the Institute of High-Pressure Physics, Russian Academy of Sciences. The group used the Geophysical Laboratory's megabar high-pressure diamond-anvil cell in conjunction with a magnetic susceptibility technique they have perfected over the past few years. The technique allowed them to determine the superconducting transition temperature without the need for placing electrical leads on the sample. Thus, they could perform their measurements on very small samples (down to 0.04 of a millimeter in diameter and a few thousandths of a millimeter in thickness). Tests of the method in the megabar pressure range (above 100 GPa) were done on niobium, which has a T_c of 9.5 K at atmospheric pressure but decreases to 4.5 K at 132 GPa (rather than increases).

Sulphur's transition from insulator to superconductor at 93 GPa was unexpected. Several years ago, scientists elsewhere had observed changes in optical properties of sulphur that suggested that the material transforms to a metal at about 90 GPa (at room temperature), with a corresponding change in crystal structure, and that it transformed to another structure at about 160 GPa. Recent theoretical calculations had predicted that sulphur would become a superconductor only at much higher pressures (above 550 GPa). The new results show that the material transforms directly from an insulator to a superconductor at the first transition (at 90 GPa). The results provide an important example of the large-scale changes in physical properties that can be induced by pressure.

The authors write in their *Nature* paper that their results are particularly notable because the metallic phases of sulphur have the highest T_cs of any elemental solid measured to date. Sulphur now joins the heavier members of its family in the periodic table of elements (the chalcogenide family, including selenium and tellurium), as a superconductor. This fact should provide critical tests for theories on superconductivity. In closing their paper, the authors write: 'Given the comparative simplicity of elemental sulphur for electronic structure calculations and knowledge of its high-pressure crystal structures, this element should provide important tests of possible new mechanisms.' The work is part of a much larger effort at the geophysical laboratory devoted to studying the behaviour of materials at ultrahigh pressures, including those that prevail deep within the planets.