appropriate antigen presentation using different formulations should be attempted (Alan Saul, QIMR, Brisbane, Australia). The first single gene DNA vaccine (CSP of *P. falciparum*) was recently used in phase 1 trials in humans to assess safety and immunogenicity. This may pave the way for multi-gene DNA vaccines against malaria and other infectious diseases (Samaj Kumar, NMRI, Rockville, USA). Malaria vaccine development thus has a long way to go but has remained in the forefront in using the latest advances in vaccine development.

Animal models for malaria

Suitable animal models are crucial for malaria research and for vaccine development in particular. Studies in murine models have shown that both CD4+ T-cells and B cells are necessary for protective immunity. $\gamma\delta$T-cells that have a limited TCR repertoire play a minor role in early control of parasitemia (J. Langhorne, Imperial College, London, UK). Different mice haplotypes exhibit different levels of cerebral malaria when infected with the same clone, *P. berghei* ANKA. Cerebral complications are associated with an increase in a specific VB family of T-cells (D. Mazier, INSERM, Paris, France). Studies in the murine model have shown how the genetic background can influence immune responses to vaccine candidates such as MSP-1. Constructs based on the C-terminal fragment of MSP-1 have also been tested in Aotus monkeys. In two different species of Aotus monkeys only one showed protection although the antibody titres were similar in both species and neither blocked erythrocytes' invasion. These data highlighted the need to understand the mechanism of protective immunity as well as the need to have well-defined correlates of protective immune responses (S. Kumar, NMRI, Rockville, USA).

Administration of C-terminal fragment of MSP-1 administered in three doses four weeks apart elicited high titre antibodies and protected toque monkeys against *P. cynomolgi* bloodstage challenge (K. Mendis, University of Colombo, Sri Lanka) which appears to be a good model for human malaria.

There was vigorous scientific activity during the conference. All scientific sessions were well attended. A major feature and outcome of the conference was coming together of malaria scientists from every part of the world in one place which led to discussions and possibilities of several collaborations. One criticism, often heard during the conference, was that there were too many good parallel sessions and participants would have liked to attend them all.

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Academy's Annual Meeting

What does one expect of a meeting of an Academy of scientists? For one thing, unlike in meetings of professional societies, one would expect to hear talks on a wide range of subjects. And, in keeping with the status and reputation of an Academy, which is essentially an honour society where the Fellows are elected almost invariably for their achievements in research and in some cases because of their exceptional promise, one would expect to hear about some of the high quality research being carried out in the country. The last time I covered an annual meeting of the Indian Academy of Sciences was a special occasion – the Diamond Jubilee meeting held at Bangalore where the past presidents of the Academy and a number of special invitees, a few of them from the United States, spoke (*Curr. Sci.*, 1995, **68**, 23–24). Then I enjoyed, as did the others in the packed J. N. Tata auditorium, listening to General Sunderji, Calyampudi Radhakrishna Rao, and Abdul Kalam, among others. This year's meeting was a regular one with no Jubilee to celebrate and no generals and star speakers from abroad. Nevertheless, my trip to Hyderabad for the 63rd Annual Meeting of the Indian Academy of Sciences, 1–3 November 1997, was rewarding.

P. Rama Rao, President of the Academy, deserves to be congratulated for assembling some very good workers to speak about their current endeavours. Obviously, he has worked hard to showcase some of the best work that is going on in the country, and he has covered a fairly wide range – from gravitational clustering to ocean currents. Apart from 22 talks under lecture presentations and two symposia – one on Progress in Science and the other on Engineering Molecules, Microstructures and Materials – and Rama Rao's Presidential Address (on viscous creeps in metals), there were two well-attended public lectures by C. N. R. Rao and V. Radhakrishnan and a special lecture on some recent developments in leprosy research by Indira Nath of the All India Institute of Medical Sciences.

It has always been a tradition that the President of the Academy opens the meeting with an address completely devoid of the usual platitudes, reflecting current research. The area of viscous creep in metals has tremendous significance for high temperature materials, and at the same time needs deep insight into basic microscopic processes which contribute to the observed behaviour. It was a revelation to learn that there is so much good ongoing work both on the phenomena and mechanisms in the country.

Engineering

While, as expected, most of the talks were by Fellows or Young Associates of the Academy, there were at least two talks by non-Fellows, both on indigenous achievements in high tech areas. I am referring to Neelakantan's presentation of VLSI design work and the efforts at hardware–software codesign at ANURAG and Ashok Jhunjhunwala's presentation of corDECT technology for low-cost high-quality voice and data communication in both urban and rural areas developed at his laboratory at the Indian Institute of Technology in Chennai. H. S. Mukunda's work on developing technologies for generating energy from bioresidue is another example of quality academic research of immediate relevance. Incidentally, per capita consumption of energy in India is among the lowest in the world, and the country needs to tap all kinds of energy sources. Both Mukunda and Jhunjhunwala believe that while quality of work is important, it is even more important to work on problems of immediate relevance. Mukunda wondered if the Fellowship of the Academy, put together with considerable difficulty, was being used properly and if the government was consulting them on issues facing the country.

There were four more presentations by engineers – V. H. Arakeri on the experimental observation of a sonoluminescent system with exclusive narrow band emission, Ashish Lele on the role of hydrophilic and hydrophobic interactions on the phase behaviour of aqueous polymer solutions and the design and use of hydrogels having controlled transition temperatures, A. K. Mallik on modelling of nonlinear vibration isolators such as those made of polymeric materials, and Dipankar Banerjee on the heat tolerance and plasticity of intermetallic compounds with particular reference to the Ti_2AlNb phase.

Physical sciences

As usual, physical sciences had a fair share in this year's meeting. Although T. Padmanabhan of IUCAA was not the only one to lose the conference bag, he lost his bag and the transparencies for his talk (on gravitational clustering and transfer of power in a system made of collisionless particles evolving in an expanding universe) a few minutes before his turn to speak! But Paddy rewrote all the transparencies – some of them indeed rather complicated with several equations – quickly and made what turned out to be one of the best presentations of the meeting. Professionalism at its best. Other speakers in the physical sciences were Sriram Shastry on spin waves and the connection between speculative and exact physics, Pramesh Rao on scattering of radio waves in the interstellar medium, Ajay Sood on squeezing of phonons, Satish Shetye on the dynamics of seasonally-reversing ocean currents around the Indian subcontinent, and Somnath Dasgupta on the tectonometamorphic history of the Eastern Ghats granulite belt. Condensed matter physics and astronomy were given importance in this year's meeting. A whole session was devoted to particle physics at the Annual Meeting held at Madras (*Curr. Sci.*, 1996, **71**, 109–127).

Biology

Over the past two or three decades, biology, like it did in the West following the seminal 1953 *Nature* paper of Crick and Watson, has become an important part of science in India. This year's Annual Meeting of the Academy showcased some excellent work carried out in different parts of the country. There were three papers on different aspects of protein folding by Jayant Udgaonkar, Rahul Banerjee and P. Guptasarma. While Udgaonkar spoke on the first experimental evidence for the view that folding intermediates and transition states are ensembles of different forms and not unique structures, Banerjee presented work on surface complementarity of buried residues of a wide variety of protein folds, estimated using a mathematical function. Guptasarma addressed the issue of stabilization of the four crystallographically identified domains of the two polypeptides constituting the enzyme glutathione reductase and provided evidence for autonomous folding and unfolding of the domains although they depend on each other for their structure and stability in the native state.

There were two other papers in biology, one on unravelling the complexities in the regulation of eukaryotic gene expression at the chromatin level by M. R. S. Rao, and the other on detection by FISH analysis of hyaluronic acid-binding protein localized on human chromosome 17p12-p13 by Kasturi Datta. It is possible that the sequence of HA-binding protein can be used to analyse the human genome database.

Chemistry and materials science

This year's symposium, convened by K. V. Raghavan, dealt with the theme 'molecules, microstructures and materials' and it featured two organic chemists, a polymer chemist, a molecular biologist and a metallurgist. J. Chandrasekhar spoke on how modern theoretical and computational methods could be used to generate fundamentally new structural motifs and illustrated the endless possibilities with some well-chosen examples such as molecules with twisted amide bonds and a planar singlet cyclo-octatetraene derivative. Darshan Ranganathan explained with some superb transparencies how self-assembling molecular modules can be used to prepare highly regular structures, including potential antibiotics and industrial catalysts. She presented some very interesting recent work, some of it published in the *Journal of the American Chemical Society*, on assembling amino acids and peptides through hydrogen bonding and metal–ion participation. At the next higher level of complexity, we had S. Sivaram speak on engineering macromolecules via chemical synthesis. One major problem polymer chemists face is that invariably the end product of a reaction is a mixture of many molecular species. The goal, of course, is to increase the yield of the desired species to close to 100%. Easier said than done! Sivaram reviewed recent work towards understanding primary bond-making and bond-breaking process in the assembly of macromolecular structures and the ability to control these reactions with precision. In a presentation considerably different from the others in this symposium, R. Nagaraj spoke on a subject of clinical importance – countering microbial infection based on a molecular level understanding of microbial pathogenesis.

Another paper on chemistry, by D. Basaviah, dealt with stereoselective organic synthesis, especially in the areas of Baylis–Hillman reaction and biotransformations.

The public lectures

The two public lectures provided a study in contrast, reflecting the personalities and the very different styles of the speakers. Radhakrishnan's talk on locomotion, the art of overcoming friction, was in the grand tradition of the famous Friday lectures of the Royal Institution. He looked at one topic, viz. motion in land, water and air and how human ingenuity has developed devices and mechanisms to overcome friction. There were anecdotes and occasional tinges of humour. The physics of drag and lift on bodies moving in a fluid is far from trivial and often counterintuitive. Biological evolution has produced marvels of optimised performance, by insects, birds, and fish, exploiting these principles. Engineers are now doing the same in many areas, and noteworthy contributions have come from gifted and dedicated amateurs in areas like hang-gliding and wind surfing which are usually classified as recreational. Overall, it was a controlled performance of a quiet achiever. It was truly a popular talk, with the minimum of technicalities but not compromising with the scientific content. But why did Radhakrishnan read out of a text, wondered my neighbour in the audience.

C. N. R. Rao's talk on the agony and ecstasy of doing borderless chemistry was wide ranging, characterized by uncontrolled (and infectious) enthusiasm, and attempted at once to give the audience an insight into the ways a scientist and his mind work, somewhat in the mould of James Watson's eminently readable, if somewhat controversial, *The Double Helix*. He touched on some of the most interesting recent developments in chemistry, materials science, solid state science – superconductivity, new forms of carbon, ceramic nanotubes, colossal magnetoresistance, etc. – and drew upon his own work, some of which is yet to be published and not even two weeks old. He even presented some raw data collected a few days ago in his laboratory. Rao paid handsome tributes to the founder of the Academy and said that the greatest honour that he had in his life was the fact that he was nominated to the Fellowship of the Academy by none other than the late C. V. Raman, and attempted to emulate Raman in giving a public discourse to a large but mixed audience. If anyone in India can talk about the agony and ecstasy of doing science, sure-Rao must be one of them. He has had a long and eventful career in science and science administration, held and continues to hold many high offices – both Indian and international – and has been in and out of the establishment. In short, he has seen the ups and downs (mostly the former), not only in science *per se* but also in the politics of science.

Rao began the technical part of his talk stating that most major advances in science have come from holistic approaches and not from narrow discipline-based efforts. He bemoaned the transformation of what used to be natural philosophy during the times of Michael Faraday and Lord Rayleigh breaking down into physics, chemistry, etc. and further into inorganic chemistry, organic chemistry, and so on and on. He then went on to narrate, from his work in recent years, how exciting it was to do science unmindful of the boundaries associated with narrower and narrower specialties and how frustrating and agonizing when someone else pips one to the post, often because one has to depend on experimental facilities located overseas. For example, Rao told about some exciting work on nanotubes and metallic nanorods that demanded sophisticated analytical tools such as high resolution electron microscopy, electron energy loss spectroscopy and a powerful synchrotron (for looking at the structure) available nowhere in India. Under these circumstances, how could we hope to compete with the rest of the world, he asked. When I heard him say that, I remembered Valiathan, who had drawn attention, in his Sir A. L. Mudaliar Endowment Lecture delivered at the University of Madras some ten years ago, to the futility of continued dependence on tools developed elsewhere ('Surgery in India'). More recently, Valiathan had talked about Indian researchers using the tools and methods developed elsewhere without bothering to learn how to make the tools and methods (*Curr. Sci.*, 1997, **72**, 911). It occurred to me that Rao was in the right position to apply corrective measures. Indeed it would be interesting to look into the social dynamics of Indian science and examine the factors that, despite fifty years of Independence, permit such dependence on tools and techniques developed elsewhere without our contributing to the global pool, and restrict much of our scientific efforts to remain 'derivative'. Of course, there was the inevitable mention of the Nobel Prize. In his view Kroto and Smalley, who won the Nobel Prize, for their work on fullerenes, 'which would have taken about an hour's experimental work', did not deserve as much credit as Kratschmer who was the first to make large-scale synthesis of new forms of carbon possible. Rao was unhappy that, despite much cajoling from him, Indian organic chemists are reluctant to work on fullerene reactions. Rao predicted that carbon chemistry has a great future.

Hearing Rao, one came to know that he has been an early bird at every major development in structural and solid state chemistry, be it high temperature superconductivity or fullerenes or nanoscience and in recent times colossal magnetoresistance. Seeing him in action, the listeners, especially the young, would have been impressed. His enormous energy, enthusiasm, ambition to achieve, and a sense of not getting one's due were all evident. To illustrate the last point, Rao told about his pioneering work on zirconia nanotubes, which was covered by journals like *New Scientist*, but not by any Indian journal. Rao wished he was a theoretician! Life would have been much easier and one could have avoided much heart ache, he said. I think it is the case of the other side being greener. I guess theoreticians in India are often isolated and feel the loneliness of a long-distance runner.

In his Presidential address, Rama Rao drew attention to the need to excel in a few chosen areas rather than spread our resources and efforts on too many areas. A very sensible thing to do in a resource-poor country, I thought. In her special lecture, Indira Nath gave a detailed account of her work on leprosy establishing the change that occurs in Th phenotype during the course of human diseases and suggested the possibility of newer therapeutic tools and vaccine development.

While at Hyderabad, I spoke to many Fellows and others. There was one common view. Not all the talks were comprehensible to non-specialists. The speakers could have as well presented the talks to their own professional colleagues. In an extreme case, an impatient experimental physicist Fellow of the Academy wondered what was going on in biology. He felt the answers to questions were rather vague and rarely clear cut. Agreed that biology deals with systems which are several orders of magnitude more complex than physical systems and that the language of biology is yet to achieve the same level of precision as that of physics. Even so, if we need to achieve 'borderless science', Indian scientists, especially Fellows of the Academy, should pay special attention to developing skills of communicating with non-specialists.

Beyond the talks

The Academy meet went beyond professional talks by experts. About 25 college level science teachers from different parts of the country were invited to join the Fellows and Young Associates of the Academy for the entire duration of the meeting. Roddam Narasimha and Raghavendra Gadagkar were in charge of the teachers' programme and they spent a considerable amount of time with them discussing how best the college teachers could take advantage of the expertise that the Academy could provide. It is all too easy for academics to remain aloof in their proverbial ivory tower. That wouldn't do much good, especially at a time when the government of the day is looking at higher education as a 'non-merit good' and is suggesting that laboratories should earn their keep, and when it is becoming increasingly difficult even for institutions of the stature of the Institute of Mathematical Sciences, Chennai, to get good students. The college teachers were encouraged to move freely with the Fellows, invite them to their institutions for short duration, and seek opportunities to work in the laboratories of the Fellows. On the whole, this is an excellent initiative. It is largely informal and does not involve a huge budget. However, the success of the programme depends on several factors, such as the motivation of the college teachers, the extent of cooperation they get from the experts, and the ability of the Academy as a whole and in particular the Fellows active in the programme to sustain the level of motivation and interest of the teacher participants over a long period of time. Of course, such programmes can, if not carefully handled, degenerate into picnics for teacher participants. In one of the two meetings the teachers had with Narasimha and Gadagkar, Madhav Gadgil came along to tell how students from several colleges in Tamil Nadu and Karnataka are taking part in a major project called 'Lifescape' focusing on biodiversity. This project is reminiscent of the Cauvery Project conceived by C. R. Krishna Murti more than a decade ago. Such participatory exercises can go a long way in motivating teachers and students alike.

The meeting hosted by Hyderabad-based institutions led by the Indian Institute of Chemical Technology was attended by more than 200 Fellows and Young Associates. I thought the Fellowship was younger and more cosmopolitan than it used to be. The local press covered the event very well.

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RESEARCH NEWS

1997 Nobel Prize for Physics: Laser cooling and trapping of atoms

The Nobel Prize in Physics for 1997 has been awarded jointly to Steven Chu of Stanford (USA), Claude Cohen-Tannoudji of the College de France (France) and W. D. Phillips of National Institute of Standards and Technology, Gaithersburg (USA) for their prolific work on laser cooling and trapping of atoms. Principles of laser cooling of atoms were propounded earlier than the work for which the award has been made. But it was the extensive experimental work of Chu and Philips which not only made laser cooling in three dimensions a practical reality for the first time, but also produced the astounding result that the temperatures achieved were systematically lower by an order of magnitude than the theoretical estimates. An explanation for such lower temperatures was provided by the theoretical work of the French and Stanford groups. Techniques of laser cooling and trapping have led to many applications of ultra-cold atoms which will be mentioned at the end of this article.

Doppler cooling

Consider a two-level atom with a ground state $|g\rangle$ and an excited state $|e\rangle$ separated by an energy $\hbar\omega_0$. The rate of absorption of photons by such an atom as a function of photon frequency is given by a bell-shaped curve called the Lorentzian shown in Figure 1 *a*. Absorption of a photon raises the atom from the ground state to the excited state. The atom has a mean life time τ in the excited state before reverting to its ground state by the spontaneous emission of a photon in a random direction. The half-width of the absorption curve, denoted by Γ, is of the order of a few MHz in frequency and is proportional to the reciprocal of the decay time τ.

If such an atom is placed between two counter-propagating laser beams tuned to a frequency ω_L slightly below resonance (i.e. $\omega_0 > \omega_L$, the detuning $\delta = \omega_L - \omega_0$ being negative; such a detuning is called *detuning to the red*), the following situation develops (Figure 1 *b*). If the atom is moving towards the right with a velocity v, the frequency of the photon travelling in the $-x$ direction gets Doppler shifted to a higher value $\omega^+ = \omega + \Delta\omega$, where

$$\Delta\omega = (v/c)\,\omega_L, \qquad (1)$$

in which c is the velocity of light. The shifted frequency comes closer to the absorption frequency ω_0 and the absorption rate increases. On the other hand, the laser beam travelling in the $+x$ direction gets Doppler shifted to $\omega^- = \omega_0 - \Delta\omega$ and the absorption rate is reduced. The differential absorption rate is proportional to the atom velocity, for small values of the velocity. Since each photon carries a momentum $\hbar k$ ($k = 2\pi/\lambda$, where λ is the wavelength of the laser beam) in the direction in which it is travelling, the absorption of a photon causes the atom to acquire this momentum in the direction in which the photon is travelling. So the differential absorption rate causes a net force F on the atom which is proportional to its velocity but is *opposite* in direction to this velocity (Figure 1 *c*). This force is