Patrika

January 1994 No. 30 Newsletter of the Indian Academy of Sciences

59th Annual Meeting

At the invitation of the Indian Institute of Petroleum, the 59th Annual Meeting of the Academy was held at Dehra Dun from 6 to 9 November 1993. The meetings were held at the Indian Institute of Petroleum (IIP), the Wadia Institute of Himalayan Geology (WIHG), Dehra Dun and the University of Roorkee, Roorkee.

The Meeting began with inaugural session on the afternoon of Saturday 6 November at the Auditorium of the Indian Institute of Petroleum. In his welcome address, T S R Prasada Rao, Director of IIP, traced the history and importance of Dehra Dun with its many scientific institutions. The President of the Academy R Narasimha then introduced the Fellows and Associates present to the audience. He then delivered his presidential address on "The Dynamics of the Ramdas layer" A little more than sixty years ago, the late L A Ramdas discovered a curious atmospheric phenomenon which had not been explained satisfactorily till recently. The phenomenon is the observation of a temperature minimum some 20–50 cm above bare soil on calm, clear nights. The first reports of these observations were treated with much scepticism as the prevailing view was that the nocturnal temperature minimum always occurs at the ground. Tracing the history of the work on the lifted temperature minimum, Prof. Narasimha offered a new explanation. He emphasized that in this as well as many other phenomena it is important to account for surfaces that are not perfectly black radiatively, i.e. those whose emissivity is not unity.

The presidential address was followed by a special lecture by Santimay Chatterjee on "Meghnad Saha and Satyen Bose: Champions of a Common Cause". In his lecture he pointed out how Bose and Saha, so dissimilar in background and temperament, worked for a common cause towards the scientific development of the country and their concern for others, for the common people and for their country.

In the evening there was a variety entertainment of folk dances and music of the Garhwal Himalayan region by the artistes of All India Radio, Dehra Dun.

The first session on the morning of Sunday 7 November, under the chairmanship of Kalyan B Sinha, consisted of three lecture presentations by new Fellows/Associates of the Academy. Praveen Chaddah (Centre for Advanced Technology, Indore) in his talk on "Irreversible magnetization of superconductors", reviewed the macroscopic model developed three decades ago to correlate magnetic irreversibilities with the critical current density, the various developments of this model during the last five years and the experimental observations in high temperature superconductors that spurred these developments. The second talk was by Gautam Mandal (Tata Institute of Fundamental Research, Bombay) on "Phase transformations in cellular automata". Cellular automata show an amazing variety of dynamical behaviour, ranging from simple-period to chaotic to complex. Characterization of this complex behaviour is a major unsolved problem, interest in which lies in the fact that complex cellular automata rules show properties akin to those of many interesting systems in computer science, biology, chemistry and physics. C R Subrahmanya (National Centre for Radio Astrophysics, Pune) the last speaker in the first session, spoke on "Probing the universe with radio surveys". With the rapid technological developments in the fields of CCD's, fibreoptic instrumentation etc., and the revolution in computing and archival capabilities and a large synthesis radio telescope like the Giant Metre Wave Radio Telescope (GMRT), it should soon be possible to make very sensitive optical and radio surveys over large areas of the sky, leading to the revelation of inhomogeneities in the spatial

distribution of galaxies and a deeper understanding of the large-scale structure of the universe.

The second session on the 7th morning, chaired by V Krishnan, also consisted of three talks by new Fellows. D D Sarma (Indian Institute of Science, Bangalore) spoke on "Novel electronic structures in selected transition metal oxides". The electronic structure of several transition metal oxides cannot be described in terms of the ZSA diagram. Examples of such oxides are $NaCuO_2$, $LnLiO_3$ and $LaNi_{1-x}M_xO_x$. Sarma discussed the electronic structure and the metal-insulator transition in such oxides with reference to the phase diagram. The lecture by S K Bhatia (Indian Institute of Technology, Bombay) was entitled "Adsorption and transport in microporous solids". The last talk in the second session was by V R Choudhary (National Chemical Laboratory, Pune). He spoke on "Coupling of exothermic and endothermic reactions in methane/natural gas conversion". The energy crisis has emphasized the need to develop catalytic processes which require not only less external energy but can operate efficiently. He listed the coupling of several endothermic and exothermic reactions in the conversion of methane and natural gas into ethylene and their advantages.

The second session was followed by a special lecture by A P J Abdul Kalam, Scientific Adviser to the Defence Minister, Government of India on some of his experiences in technology development in India. A summary of his lecture appears in this issue.

In the afternoon the participants were taken on a sightseeing tour to Mussoorie.

There were two sessions on Monday 8 November, the forenoon session being held at IIP and the afternoon session at WIHG. It began with a special lecture by G Padmanaban (Indian Institute of Science, Bangalore) on "Molecular biology and public health". A summary of this lecture appears in this issue. There were four lecture presentations by new Fellows after the special lecture under the chairmanship of M K Chandrashekaran. The first was by Asha Mathur (King George Medical College, Lucknow) on the "Role of Japanese encephalitis virus (JEV)-induced chemotactic factor in the pathogenesis of disease". The second talk was by H S Savithri (Indian Institute of Science, Bangalore) on "Portrait of a small spherical plant tymovirus". The life cycle of most viruses involves the entry of the virus into a suitable host cell, disassembly of the protein coat resulting in the release of the nucleic acid, synthesis of viral-specific proteins using host cell machinery, replication of the viral genome, cell-to-cell movement and assembly of the progeny virions. Understanding these steps at molecular level is important not only for deciphering the mechanism of infection but also for evolving suitable strategies for the control of infection. She explained the use of a model called Physalic mottle tymovirus to study some of these steps. The next speaker was R K Banerjee (Indian Institute of Chemical Biology, Calcutta) who spoke on "Reactive oxygen metabolites in the generation of stress-induced gastric ulceration — Role of gastric peroxidase". The last talk in the session was by G P Pandey (National Chemical Laboratory, Pune) on "Harvesting light energy in chemical synthesis". He described the effort of his group to elucidate the ramification of the photoinduced electron transfer reaction from polyfunctional organic molecules. A photosensitized photosystem has been developed to bring about one-electron oxidation of arenes, amines and organoselenium compounds. The resultant radical cations have been used in various transformations of synthetic importance.

The afternoon session at the Wadia Institute of Himalayan Geology consisted of four lecture presentations by new Fellows. The first two lectures were under the chairmanship of N K Notani. The first speaker was N C Mandal (Bose Institute, Calcutta) on "Regulation of expression of galactose-catabolizing enzymes in *M. smegmatis*". A J Rao (Indian Institute of Science, Bangalore) next spoke on "Use of human placenta: A discarded tissue as a model to understand the process of differentiation". The placenta is an association of maternal and foetal tissues which develops during pregnancy in mammals. It serves a variety of functions such as transport of nutrients as an immunological barrier and as an endocrine gland by its ability to synthesize a variety of proteins, peptides and steroid hormones.

The last two lectures, under the chairmanship of K L Chopra, were by Placid Rodriguez (Indira Gandhi Centre for Atomic Research, Kalpakkam) and Ramesh Chander (University of Roorkee, Roorkee). The first talk by Rodriguez on "New toughness parameters from tension tests based on micromechanism of ductile fracture" was a journey through the various testing philosophies, mostly using research generated in his laboratories. The last talk by Ramesh Chander was on "Role of differential uplift of mountains in the occurrence of earthquakes in the Himalaya". He argued that earthquake studies in the Garhwal agree with geological evidence and suggested that the Higher Himalaya are rising relative to the Lesser Himalaya along the earthquake zone in

Garhwal. These earthquakes and the differential uplifts are due to the underthrusting of Himalayan rocks by the Indian shield rocks in response to the convergence of the Indian and Eurasian lithospheric plates.

There was an evening lecture at the Town Hall of Dehra Dun by K S Valdiya (Kumaun University, Nainital) on "Dynamic Himalaya: Continuing movements and uplift". With the help of numerous slides he spoke of the evolutionary history, the rich mineral deposits and the geodynamically sensitive areas of the Himalaya and the environmental and man-made degradation which it has suffered in recent times.

The last session of the Annual Meeting was held at Roorkee at the Civil Engineering Auditorium of the University of Roorkee in the forenoon of 9 November. It was a half-day symposium on "Natural Disaster Mitigation" under the chairmanship of Dr H C Visvesvaraya, Vice Chancellor of the University and consisted of lectures on the mitigation of natural disasters such as droughts, cyclones, storm surges and earthquakes. A report on the symposium appears in this issue.

The meeting ended with concluding remarks by the President at Roorkee University. The 59th Annual Meeting was attended by over 200 participants from outside Dehra Dun and included 117 Fellows and Associates. One of the best attended of Annual Meetings, it was enjoyed by all the participants, despite the hectic schedule on all the four days. The scientific programme was of a high standard. The organization and arrangements for the scientific meetings, the cultural event and the trip to Mussoorie were excellent. The logistics of transporting the participants from one place to another was very efficiently handled by the hosts. The Academy is grateful to the Director and staff of the Indian Institute of Petroleum, the Director and staff of the Wadia Institute of Himalayan Geology and the Vice Chancellor and his colleagues at the University of Roorkee for making the Meeting the splendid success it was. Our special thanks are due to Vinod Gaur and K G Ranga Raju for organizing the symposium on "Natural Disaster Mitigation".

A group photograph of the participants appears on pages 8 and 9 of this issue.

Honorary Fellows elected in 1993

S Nagakura, The Graduate University for Advanced Studies, Yokohama, Japan

Anatol Roshko, California Institute of Technology, Pasadena, USA

Jean Rouxel, Institut des Materiaux de Nantes, Nantes, France

Fellows elected in 1993

R E Amritkar, University of Poona, Pune, for his work in theoretical condensed matter physics

K R Anantharamaiah, Raman Research Institute, Bangalore, for his contributions in radio astronomy

N Balakrishnan, Indian Institute of Science, Bangalore, for his studies in aerospace engineering

A S Balasubramanian, Christian Medical College Hospital, Vellore, for his contributions to neurochemistry

S K Bhattacharya, Physical Research Laboratory, Ahmedabad, for his studies of paleoclimatology

D Chatterji, Centre for Cellular and Molecular Biology, Hyderabad, for his contributions to molecular biology

C Ganguly, Bhabha Atomic Research Centre, Bombay, for his contributions to nuclear fuel technology

P Ganguly, National Chemical Laboratory, Pune, for his studies of solid state and surface chemistry

B K Godwal, Bhabha Atomic Research Centre, Bombay, for his work in high pressure physics

A K Gupta, University of Allahabad, Allahabad, for his studies in mineralogy at high pressures

R V Hosur, Tata Institute of Fundamental Research, Bombay, for his work in structural biochemistry

R L Karandikar, Indian Statistical Institute, New Delhi, for his studies of probability theory

S C Lakhotia, Banaras Hindu University, Varanasi, for his contributions to genetics

J Maharana, Institute of Physics, Bhubaneswar, for his work in theoretical high energy physics

S K Malik, Tata Institute of Fundamental Research, Bombay, for his contributions to experimental condensed matter physics

K Muniyappa, Indian Institute of Science, Bangalore, for his studies of molecular genetics

K A Padmanabhan, Indian Institute of Technology, Madras, for his contributions to mechanical metallurgy

G P Pal, M P Shah Medical College, Jamnagar, for his studies of the biomechanism of the spine

M Periasamy, University of Hyderabad, Hyderabad, for his work in the area of organometallic chemistry

N Periasamy, Tata Institute of Fundamental Research, Bombay, for his contributions to chemical physics

T S R Prasada Rao, Indian Institute of Petroleum, Dehra Dun for his studies in and application of catalysis

M Ramakrishnan, Geological Survey of India, Hyderabad, for his studies in Precambrian geology

Randhir Singh, Haryana Agricultural University, Hissar, for his contributions to plant biochemistry

K L Sebastian, Cochin University of Science and Technology, Cochin, for his work in the area of theoretical chemistry

Tej Pal Singh, All India Institute of Medical Sciences, New Delhi, for his contributions to molecular biophysics

A Srikrishna, Indian Institute of Science, Bangalore, for his work in organic synthesis

V Srinivas, Tata Institute of Fundamental Research, Bombay, for his contributions to algebraic geometry

Technology Development in India

Summary of the Special Lecture entitled "Technology development in India — some experiences" by A P J Abdul Kalam, Scientific Adviser to Defence Minister, New Delhi at Dehra Dun on 7 November 1993.

Kalam, during the course of his lecture, listed the many successes in the area of technology development in India, his own personal experiences and how we have overcome many of the external and internal constraints on the nation through high scientific and technological effort and a consortium method to bring together multiple institutions.

He first mentioned the controversial cryogenic engine for launch vehicles. These vehicles may use solid propulsion (as in SLV-3 and ASLV) or liquid propulsion (as in PSLV). However, an efficient energy level is possible with a combination of liquid oxygen and liquid hydrogen as fuel. The question before ISRO was can we make the cryogenic engines for the GSLV programme which involves the development of materials that can stand cryogenic temperature, the design of a tubo-pump whose speed has to be several times that of classical tubo pumps, leak-proof sealing of pumps, a high capacity liquid hydrogen plant and facilities for storage and handling of this liquid. He felt that India has the necessary capability to produce cryogenic engines in about three years.

In aerospace, a new technology of supersonic combustion is emerging as a prospective propulsion system for long-range missiles and reusable launchers and it is necessary to take advance action to build such technologies within the country. Technology development has now blossomed into an integrated design capability for multi-mission military systems of missiles, armaments, naval equipment, radars and supercomputer capabilities using parallel processors. Another example is the development of steel armour for our Light Tank which has found wide application to meet the needs of paramilitary forces. Many R & D laboratories are now involved

in developing microelectronic devices and systems. For the anti-tank missiles, an integration of a thermal sight system, a semiconductor array detector and a Joule-Thomson cooler is being developed. A phased array radar has been developed for the missile system and phase shifters that electronically steer the radar beam through orchestrated computer control, are being made in the country. Many organizations are involved in the design and development of a highly manoeuvrable, multi-role light combat aircraft (LCA). He listed the many obstacles that had to be overcome before we were able to develop a re-entry technology for hypersonic re-entry vehicles. Another area in which success has been achieved is the designing of a high-speed coprocessor which can work with any microprocessor and is three times faster than those available abroad. A gallium arsenide foundry would be ready by 1994 to fabricate monolithic microwave ICs for microwave circuits for aircraft, satellite and missile applications. He pointed out that the technologists are developing programmes not only for weapons and special equipment for our defence needs. They are also for use in commercial and medical sectors. Examples are materials like pure silver and copper for the electronics industry, composite calipers to aid polio-handicapped people, *orthosis* products and heart pacemakers.

His main theme was the importance of teamwork and commitment to a national goal in achieving technological competence. He stressed the need to build a culture of celebrating our successes and not always bemoaning our failures. Only strong minds which can face failures will succeed. When "Prithvi" fails, there is a novel guidance algorithm developed indigenously; when "Akash" homes on, there is an embedded modern guidance algorithm. In hardware, Walchandnagar Industries have made the booster and Larsen & Toubro the sustainer casing; the propellants came from our Ordnance factories, and the radar from Bharat Electronics. When "Trishul" enters into user trials, one of the marvels will be having an integrated tracked vehicle, with the launcher, radar, missile, and embedded software coming from multiple industries and R & D laboratories.

He concluded his lecture with the message "only sweat can generate fire and that fire cannot be extinguished. Fire in scientists will lead to technological strength for the nation. Yes we can do it".

Molecular Biology

Summary of a special lecture entitled "Molecular biology and public health" by G Padmanaban of the Indian Institute of Science, Bangalore, delivered during the 59th Annual Meeting at Dehra Dun on 8 November 1993.

Molecular biology has paid very rich dividends in terms of both advances in fundamental life sciences and human welfare. Molecular biology research today is highly interdisciplinary. Biologists with a variety of interests use the approach and tools of molecular biology to answer fundamental questions. Some of the most visible aspects of the impact of molecular biology are in medicine and public health, agriculture, and the biotechnology industry.

Molecular biology is concerned with three basic issues: how information is encoded in the structure of DNA, how the information is retrieved, and how the information is transmitted through generations. Advance in these three areas has led to some truly astonishing successes in biomedical science. Two outstanding advances in biological science in this century are the unravelling of the molecular basis of immune response and the understanding of cancer. These advances are a good illustration of the power of molecular biology.

The impact of molecular biology on medicine and public health can be assessed by considering genetic disorders and infectious diseases. The last decade has seen many successes in the identification and characterization of the genes involved in several inherited disorders. Notable examples are Duchenne muscular dystrophy, cystic fibrosis and Huntington's disease. Several recent spectacular successes are due to the approach known as reverse genetics, in which the gene and its product are identified and isolated after a series of steps starting from a knowledge of the approximate chromosomal location of the gene. This knowledge is usually available from pedigree studies and now more commonly as a result of the rapid progress in building maps of the human chromosomes. In the battle against infectious disease, molecular biology has provided us with better and quicker diagnostic methods, and novel and more effective vaccines.

Recombinant DNA technology has led to the manufacture of a recombinant hepatitis vaccine. Molecular biology is also shedding new light on many other infectious diseases such as leprosy, tuberculosis and cholera, and parasitic diseases such as kala azar and sleeping sickness, all of which are a great burden on the poorer countries.

The biotechnology industry has gone through a revolution after the advent of gene manipulation techniques and rapid development in other fields spurred by the promise of molecular biology — computer applications in modern biology, biochemical and immunological methods, microbiology and cell culture, and instrumentation and manufacturing equipment. The industry, worldwide, is worth hundreds of billions of dollars, and has been concerned with development of diagnostics, protein pharmaceuticals and vaccines, rational drug design and gene therapy. Some of these that have been in the news are recombinant insulin, interferon and growth hormone and ELISA kits for the diagnosis of various diseases, including AIDS. Gene therapy is one of the most recent examples of the impact of molecular biology on medicine. A few human trials have already been conducted in the United States, and more have been permitted. Gene therapy is a promising development in the battle against inherited diseases.

The last decade has seen a significant improvement in the quality of research in modern biology in the country. About 50–60 research groups have capabilities to carry out frontier research in the area. Antibody and DNA-based diagnostics for hepatitis strains, malaria, filaria, tuberculosis, cysticircosis, typhoid etc have been developed and agreements have been signed with industries for the production of atleast some of the kits. Two candidate human fertility control vaccines and leprosy vaccines are in advanced stages of trial. A couple of recombinant DNA products namely epidermal growth factor and streptokinase have been cloned and expressed at a level where commercial exploitation can be considered. The infrastructure has been built up to a modest level. An academia-industry-government agency partnership is needed to forge ahead from a modest base assiduously built in the last decade.

Disaster Mitigation

The Indian Academy of Sciences concluded its 59th annual meeting, held in Dehra Dun, with a symposium on mitigation of hazards associated with natural disasters. The symposium took place at the University of Roorkee, an appropriate venue considering the pioneering work in earthquake engineering carried out at Roorkee. The symposium was also appropriate because the recent earthquake in Maharashtra has again focused attention on the lack of preparedness against natural disasters.

Preparedness was indeed the recurring theme in the seven talks that comprised the symposium, including an introduction by V K Gaur of the CSIR Centre for Mathematical Modelling and Computer Simulation in Bangalore and a presentation by H C Visvesvaraya, Vice Chancellor of the University of Roorkee.

Visvesvaraya presented what he called an 'engineer's view' of the situation in earthquake engineering. An important point he made was that planning for earthquake engineering and construction of earthquake-resistant structures should become 'anticipatory' and not be merely 'reactive', and should cover as much of the seismic hazard-prone population as possible rather than be limited to places that have suffered major quakes.

The recent Maharashtra earthquake brought into focus the need to reassess the present version of the seismic zone map of India, especially with reference to peninsular India. This was also clear from the fascinating Evening Lecture on 8 November at Dehra Dun by K S Valdiya of Kumaun University, Nainital. While the Indian subcontinent pushes against the Eurasian plate and causes the Himalayan region to accumulate seismic stress, there are regions in the peninsula that also accumulate such stresses on account of the movement of the Indian plate.

In his lecture, K N Khattri of the Wadia Institute of Himalayan Geology said that identifying active faults and seismic source zones was one of the first tasks in establishing a state of preparedness against earthquake hazards. He also described the use of recurrence relations that gave the probability of earthquakes above a certain magnitude. The geology of a region is also important, he added. He also showed examples of

the use of synthetic seismograms generated by computational methods and comparisons of these with the actual recorded seismograms for the 1991 Uttarkashi earthquake and the 1985 Mexico City earthquake. He also mentioned the need to do strong motion calculations for regions like Tehri.

A confounding factor in all earthquake-related studies is the element of uncertainty. R N Iyengar of the Indian Institute of Science, Bangalore highlighted this point and discussed some aspects of uncertainty in ground motion behaviour, soil properties and building response. He showed the usefulness of computing a response spectrum and stated that analyses of this kind and comparison with actual behaviour had been done for the 1967 Koyna quake and the recent one in Maharashtra. He drove home the point that earthquake engineering should prepare for future, *unknown* earthquakes rather than ameliorate the damage caused by previous ones.

Tropical cyclones, storm surges and droughts were the other natural disasters discussed in the symposium. P V Joseph showed how an empirically derived method of prediction of the growth of a cyclone had proved fairly successful. India's east coast cyclone radar network, meteorological balloon facilities and satellites have provided sufficient input for fairly successful cyclone warning. Indeed, the Andhra cyclone of May 1990 was anticipated, and precautions, including the evacuation of 650,000 people, were taken. This prevented a catastrophe. He however, emphasized the need for improvement in India's warning systems, chiefly the setting up of radars with Doppler facility, use of a reconnaissance aircraft based at Madras, accurate wind instruments for wind speeds up to 300 km per hour, and statistical-dynamical methods of cyclone track prediction.

An important point made by P K Das, a former chief of the India Meteorological Department, was that there was a decreasing trend in the number of fatalities due to storm surges caused by cyclones. This was attributable to our warning systems. However, improvements are required in the mathematical models of wave height at peak surge. The Department of Ocean Development, now subsumed under the Department of Science and Technology, has supported a project on modelling of storm surges at the Indian Institute of Technology, New Delhi. He also showed examples of fair agreement between the computed peak surge and the observed surge.

Drought due to failure of the monsoon was the subject of the presentation by D A Mooley formerly of the Indian Institute of Tropical Meteorology, Pune. He discussed the predictive value of taking into account the well-known El Nino phenomenon and warming over the South Pacific in monsoon forecasting.

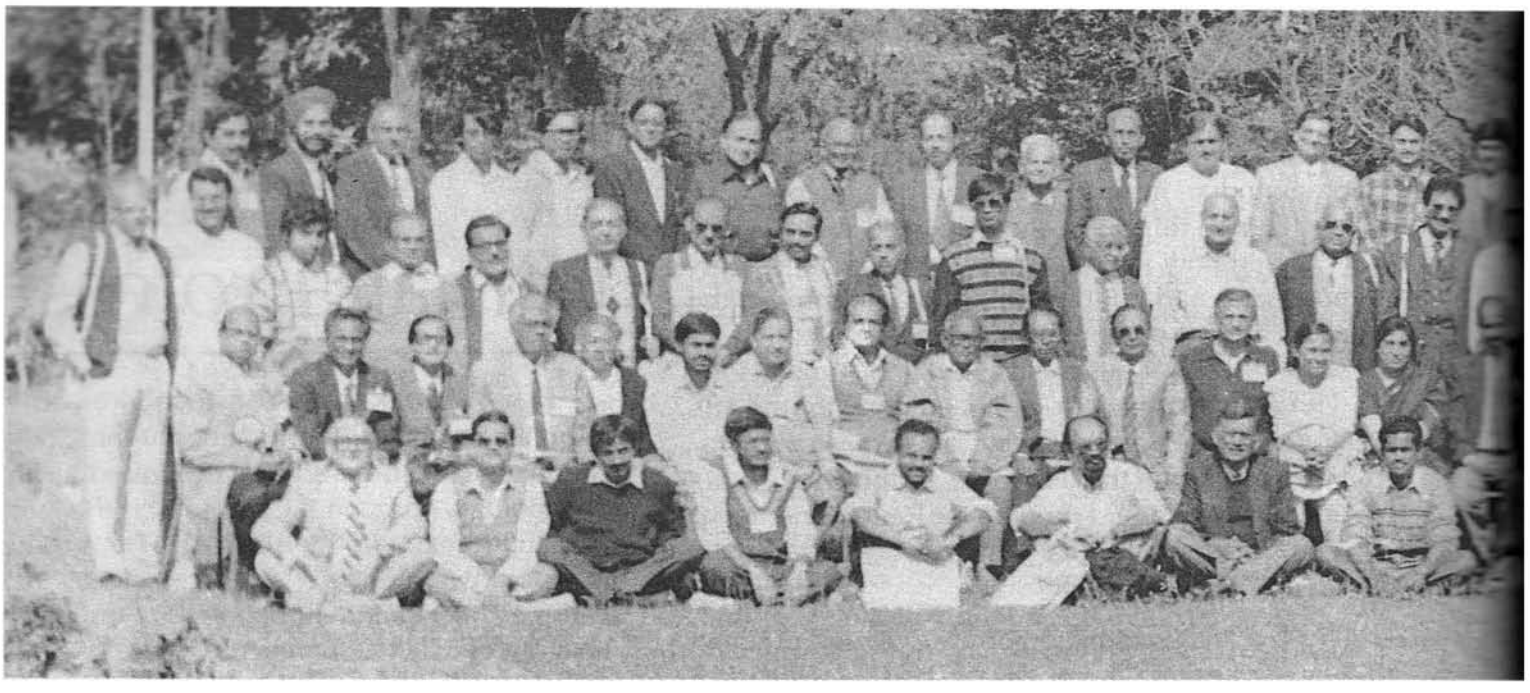
Raman Professor

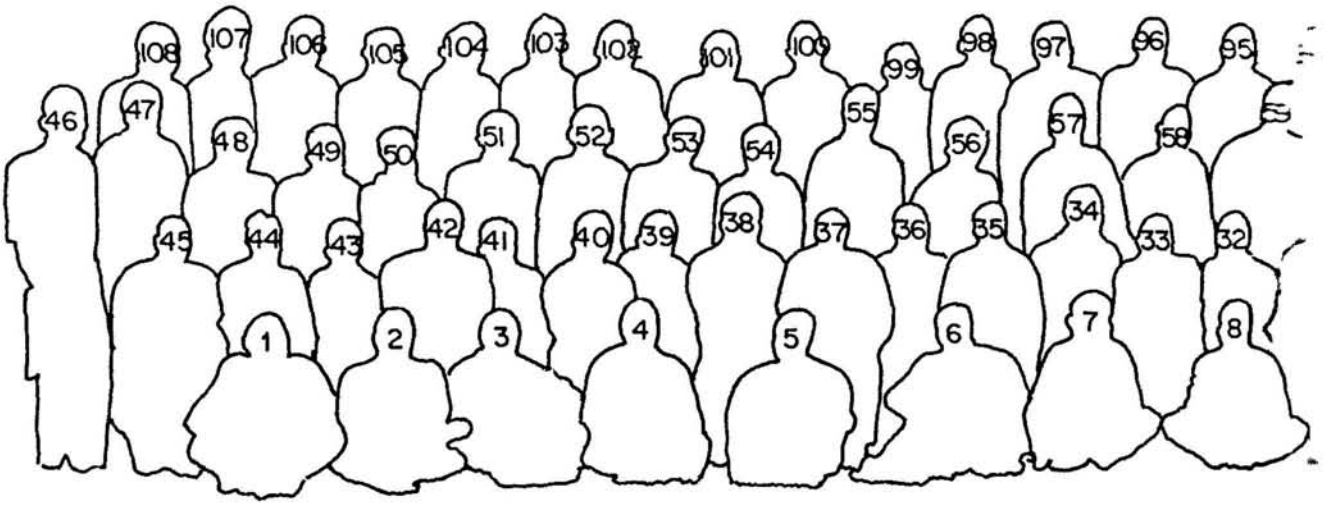
Prof. Anatol Roshko, the Theodore von Kármán Professor of Aeronautics at the Graduate Aeronautical Laboratories of California Institute of Technology, Pasadena, California, is the latest Raman Professor of the Academy. He is in India for about two months from December 1993 to February 1994 and will be based at the Indian Institute of Science, Bangalore.

Prof. Roshko is one of the leading experimental fluid dynamicists in the world today. During a career spanning 40 years, he has made pioneering contributions to the understanding of turbulent shear flows. His investigations of the wake behind a circular cylinder and of the effect on it of a splitter plate have become classics. In the 1970s he produced spectacular evidence of coherent structure (the "Brown–Roshko" vortices) in turbulent mixing layers, a contribution that has had a profound impact on our concepts of the nature of turbulent motion, and on our ability to control and manage turbulent shear flows. He has also made outstanding contributions to our understanding of the structure of separated flows. His scientific work is characterized by simple but deep experimental investigations of the most significant problems in fluid dynamics.

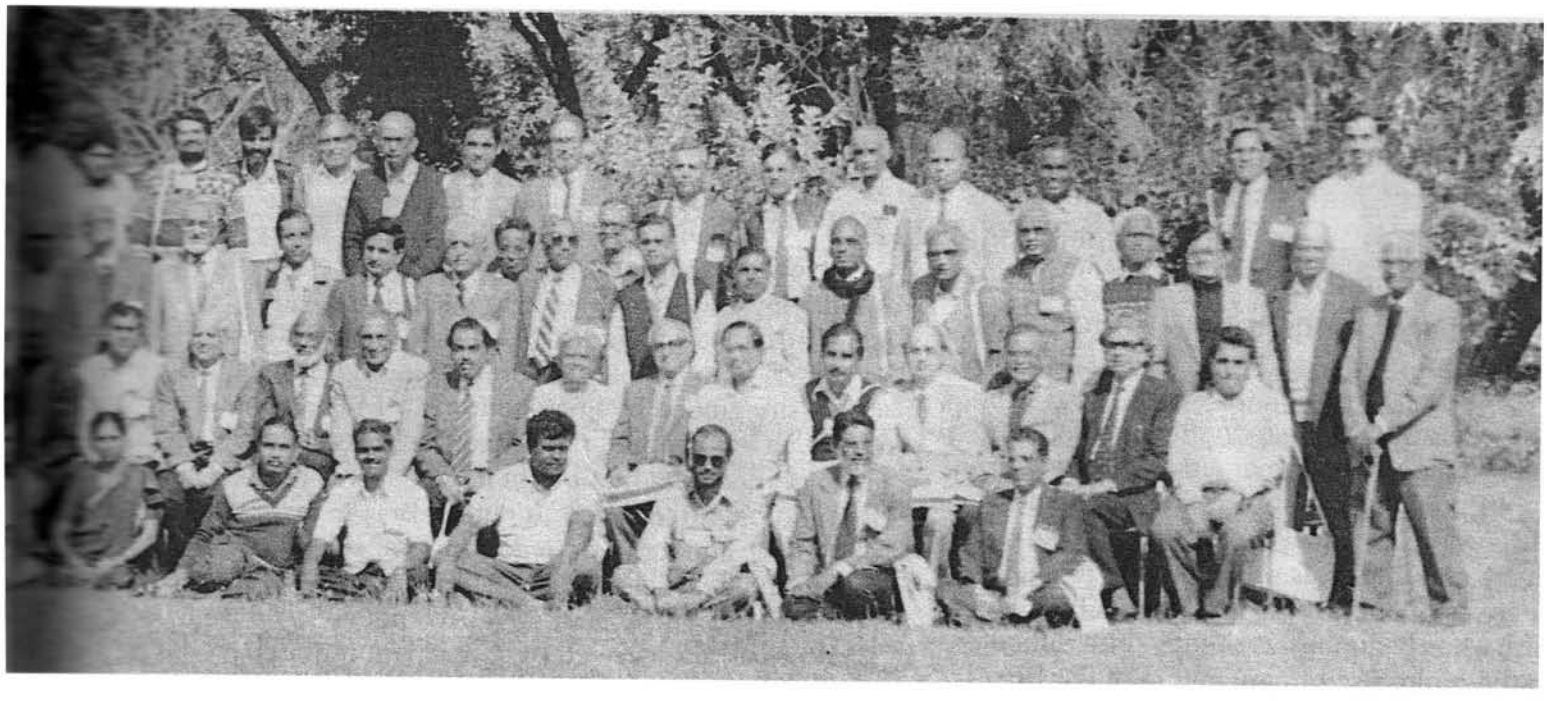
Prof. Roshko is a member of the US National Academy of Engineering and a Fellow of the American Academy of Arts and Science. He has close connections with Indian scientists and has been a frequent visitor to India. He was recently elected an Honorary Fellow of the Academy.

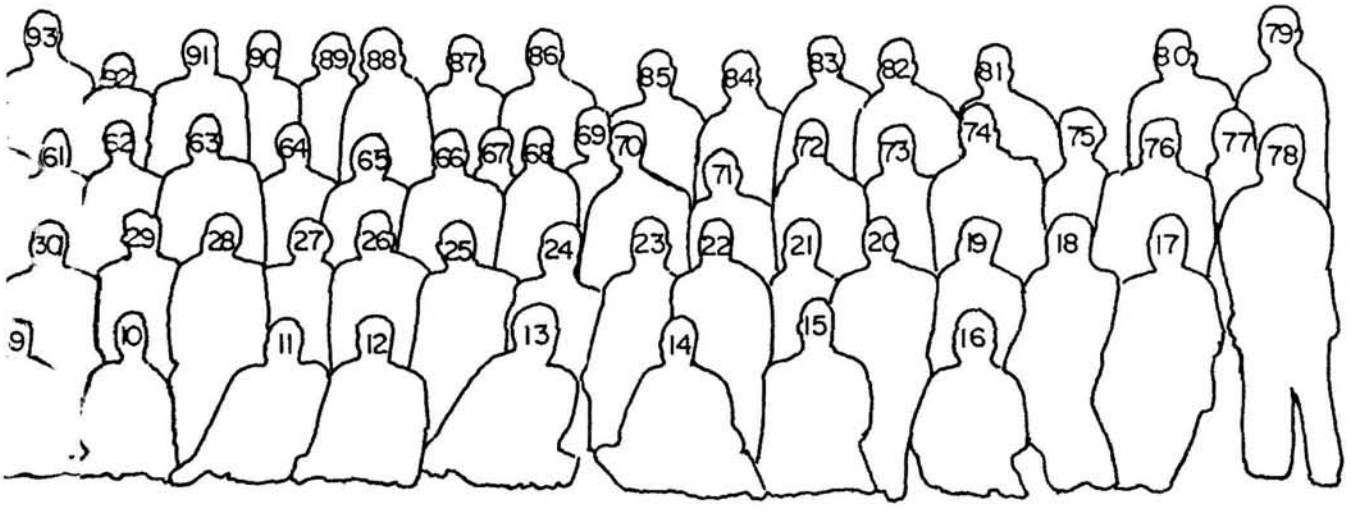
Participants at the 59th Annual Meeting at Dehra Dun





1. K K Mahajan
2. N C Mandal
3. P K Chattaraj
4. S K Ghosh
5. S Ramakrishnan
6. S Bhaduri
7. Ramesh Chander
8. A Jayakumar
9. R Shyamala
10. K Shanthy
11. G Madhavan
12. C Vedamurthy
13. P Jayaraj
14. S R Shetye
15. R J Azmi
16. J B Joshi
17. P Rodriguez
18. V K Gaur
19. P K Das
20. S Biswas
21. R K Banerjee
22. K B Sinha
23. J C Bhattacharyya
24. A K Raychaudhuri
25. M K Chandrashekaran
26. V Krishnan
27. G Padmanaban
28. S S Jha
29. N Viswanadham
30. S Varadarajan
31. R Narasimha
32. Asha Mathur
33. H S Savithri
34. Probir Roy
35. T K Roy
36. S K Ghosh, Cal.
37. K Naha
38. V N R Pillai
39. L K Pandit
40. Gautam Mandal
41. K S Valdiya
42. A Mookherjee
43. S N Sarkar
44. A B Roy
45. K S Jauhri
46. G R Desiraju
48. Rajshri Sarkar
50. R Jayaraman
51. D N Bose
52. A P Sarma
53. A K Raychaudhuri, Blr
54. K R Rao





55. D D Sarma
56. P V Kulkarni
57. M K Mehta
58. S Sriramachari
59. G P Pandey
60. N Panchapakesan
61. R N Iyengar
62. P K Sen Sarma
63. F Ahmad
64. B M Deb
65. S Chandrasekaran
66. D D Awasthi
67. S K Bose
68. H O Agrawal
69. Deepak Kumar
70. N Sathyamurthy
71. A J Rao
72. S K Srinivasan
73. N K Notani
74. J P Mittal
75. U W Kenkare
76. V R Choudhary
77. B Venkataraman
78. S Rangaswami
79. R R Viswanathan
80. R S Sharma
81. R Srinivasan
82. T Pradhan
83. T Ramakrishnan
84. G S Agarwal
85. Y Singh
86. V C Thakur
87. P Chaddah
88. E S Raja Gopal
89. K N Khattri
90. N A Prakash
91. N Charakumar
92. A J Parameswaran
93. Rajiv K Mishra
94. A S Raghubanshi
95. A M Kayastha
96. S K Bhatia
97. S K Mishra
98. P V Joseph
99. D A Mooley
100. U C Mohanty
101. A S N Murthy
102. S M Chitre
103. S Mitra
104. C R Subrahmanya
105. T Ramasami
107. Surjit Singh
108. P P Das

Organic Synthesis and Catalysis

A Discussion Meeting on "Organic Synthesis and Catalysis via Metalloorganics" was held at the National Chemical Laboratory, Pune, on 23 and 24 September 1993, under the auspices of the Academy.

The chemistry of organometallic compounds or *metalloorganics* has emerged as a field with enormous potential for application in organic synthesis and catalysis. Even bio-organic chemistry and materials science stand to gain from its advances. In India, research in metalloorganic chemistry has begun only recently. The difficulty lies in the multi-disciplinary nature of this area and the lacuna of an adequate curriculum in postgraduate courses. The experimentation usually demands stringent inert atmosphere techniques and modern spectroscopic analyses, which are often beyond the reach of average University faculty.

The meeting the first of its kind in India, had as its main objective the provision of a forum for the exchange of ideas amongst organometallic chemists, to create an awareness of international research in various directions, and, to assess and promote the research currently being conducted in India. The presentations revealed that a large number of groups are actively engaged in research in this area. While the interests were widely varied, ranging from clusters to cobaloximes, the seriousness of their pursuit was evident. It was also heartening to note that the average age of participants was around thirty.

The meeting consisted of three types of presentations: a) special lectures which dealt with overviews of research areas, b) invited lectures describing significant contributions from Indian laboratories, and c) posters, by enthusiastic research students and associates depicting new, exciting results and continuing interests.

Unprecedented stereo- and regiocontrol in complex metal-mediated transformations immensely enriched the arsenal of organic synthetic chemists. The special lecture of Dr S Chandrasekaran (IISc) illustrated this with impressive examples of new and useful reactions and their application in the synthesis of complex targets, natural and non-natural. Dr T K Sarkar (IIT Kharagpur) described a judicious use of silicon in his synthesis of (±)-cucurbic acid and (±)-methyl epijasmonate. Dr A Sarkar (NCL) presented an account of remote stereocontrol on arenechromium templates where the metal fragment acts as a stereodirecting group. The new half-sandwich arene-ruthenium complex characterized by Dr Z Shirin and Dr R N Mukherjee (IIT Kanpur) promises rich chemistry waiting to be synthetically exploited.

New reagents are sometimes developed by modifying existing reagents to attain improved selectivity and efficiency. Such modifications must originate from an intuitive understanding of chemistry guided by imagination. Dr M Periasamy (Univ. of Hyderabad) described the systematic development of a number of new reagents derived from boron, aminoboranes and $NaBH_4/I_2$ in particular, and those derived from transition metals to effect selective transformations. Dr S K Nayak (BARC) discussed novel synthetic transformations induced by low-valent titanium complexes while Dr A G Samuelson (IISc) presented the activation of allylic substrates promoted by copper (I). In their poster, D Jayaprakash and Samuelson displayed an interesting zinc-mediated allyl transfer in aqueous medium. The unexpected ring opening of THF in organometallic reaction medium, observed by S Bhar and B C Ranu (IACS), questioned the suitability of this solvent in many such reactions.

Several posters were presented on the involvement of organometallic reagents in group transfer reactions. B G Hazra (NCL) described selective *trans* dichlorination and dibromination mediated by manganese. E Nandanam and B B Lohray (NCL) proposed a new transition state model for the enantioselective dihydroxylation of unfunctionalized alkenes catalysed by OsO_4. D Chatterjee (CSMCRI) presented a study on the epoxidation of olefins by Ru (V) oxo complexes.

Organometallic complexes are also synonymous with catalysis. Some of the major uses of cobalt as an oxygenation catalyst was discussed by J Iqbal (IIT Kanpur). His associate Beena Bhatia presented illustrations of a host of other organic transformations effected by cobalt catalysis. The construction of asymmetric quarternary carbon centres through a catalytic pathway was discussed in detail by A K Sarkar (Presidency College, Calcutta). S Sengupta (Jadavpur Univ.) disclosed the preliminary results of palladium catalysed reactions being developed to construct biaryl-derived targets. The use of phase-transfer catalysis in organometallic chemistry was illustrated by S Vancheesan (IIT Madras).

Metal clusters bridge the span between homogeneous and heterogeneous catalysis. S Bhaduri (Alchemie) forwarded arguments as well as evidence to refute the notion that catalysis through cluster compounds usually involve breaking down of the cluster to provide active mononuclear species. He also pointed out that clusters can be tailored to provide highly selective catalytic species. Activation of phenylacetylene in butterfly clusters of iron and facile C-C bond cleavage were highlighted by P Mathur (IIT Bombay). An interesting poster on cluster chemistry by S K Bhar and R L Dey (Jadavpur Univ.) featured synthesis and characterization of new R-P bridged clusters of iron and cobalt.

One of the most important aspects of organometallic chemistry is the study of their structures. The chance observation of an unusual product by S K Chandra and A Chakravorti (IACS) raised an intricate mechanistic question concerning cobalt/organic ligand interaction. S K Chowdhury and A Sarkar (NCL) presented evidence in support of an unusual affinity of a phenyl ring for a proximal methyl group, relevant to the existence of a CH/π stabilizing interaction. S Bhattacharya and V D Gupta (BHU) displayed structural studies on cyclopentadienyl-zirconium (IV) complexes, while M V Gururaj and B S Chandrasekhar (Gulbarga Univ.) disclosed structal characterization of mixed polypyrazolyl borate complexes of Zr, V, Mo, Ni and Cu. Structural studies were also carried out by A S Kumbhar and S B Padhye (Poona Univ.) on *cis*-dicarbonyltetraiodoiridium (III), an intermediate in the catalytic cycle of oxycarbonylation promoted by iodide. S S Tavale and V G Puranik (NCL) presented the X-ray structure determination of a giant tetrameric manganese complex with greater than ninety atoms. C Gopinathan (NCL) and his group displayed a poster depicting insertion reactions in selected organoruthenium complexes.

To address contemporary research efforts in synthetic polymeric materials and advances in polymerization catalysts, S Sivaram (NCL) provided an excellent overview of the field. He illustrated with specific examples, the unprecedented control of reactivity, regiospecificity, stereoselectivity and enantioface selectivity possible during polymer synthesis using organotransition metal catalysts. Involvement of metal-carbene intermediates in polyacetylene synthesis was explored by B Gita and G Sundararajan (IIT Madras). H B Singh (IIT Bombay) presented his work on the synthesis of some novel organotelluriums of potential synthetic interest and material application.

E D Jemmis (Univ. of Hyderabad) elucidated the theoretical framework for organometallic chemistry and illustrated how the isolobal concept simplified descriptions of FMO's of ML_n fragments. The application of theory to understand structure and reactivity of the carbyne ligand was based on his own work.

The latest development in the area of metalloorganics is their application in biological systems. S B Padhye (Poona Univ.) presented an account of current research efforts in metalloimmunoassay where organometallic complexes are used as labels for studying enzyme-substrate, hormone-receptor and antigen-antibody reactions. His work on bioorganometallics involved the design, synthesis and structural characterization of a tetrameric manganese cluster for the photoreactivation of manganese depleted spinach PS II particles. Two consecutive presentations of the same session concerned synthetic exploits of cobaloxime chemistry discussed by B D Gupta (IIT Kanpur) and S Roy (IICT). A related facet of this chemistry was presented by K Qanungo and B D Gupta in a poster.

In the concluding session of panel discussion, it was unanimously agreed that a serious beginning in organometallic research has been made despite all the limitations of an Indian laboratory. It was suggested that training programmes like summer/winter schools and workshops should be organized as a national initiative to sustain the growth of this discipline. To foster closer interaction with practising chemists of this area, such small and intensive meetings could be organized periodically in various parts of the country.

Special Issues of Journals

1. *Pramana –J. Phys.*, Supplement to Vol. 41, December 1993, pages 1–544, Proceedings of the "Tenth DAE High Energy Physics Symposium" held at Bombay, December 1992.

The issue contains 37 papers presented at the DAE symposium on high energy physics held in Bombay in December 1992. The first paper is the keynote address by Jogesh C Pati on "Current trends and future perspectives on high energy physics". The seven topics covered are standard model, heavy flavour physics, beyond the standard model, heavy ion collisions, non-accelerator particle physics, particle astrophysics and formal theory.

The last paper in the Proceedings is a summary of the symposium by H S Mani. A list of the 163 participants is included at the end.

2. *Sādhanā*–Academy Proceedings in Engineering Sciences, August 1993, Vol. 18 (71 and 72), Parts 3 and 4, pages 365–728, "Surveys in Fluid Mechanics–III".

This issue is the third in the series of Surveys in Fluid Mechanics that have been published by this journal (the first appeared in 1981, and the second in 1987, collected in a volume titled Recent Developments in Fluid Mechanics and Space Technology). As on the previous occasions, the Surveys are extended versions of invited lectures given at the Asian Congress of Fluid Mechanics; the present issue contains those presented at the 5th Congress in the series, held in Taejon, Korea during 10–14 August 1992.

The first paper is the Tani Memorial Lecture, given at Taejon by Fujihiko Sakao (Higashihiroshima). He investigates (at the request of a medical doctor) the familiar method of examining a patient with a stethoscope. From analysing the sound field outside a soft tube in which the vocal cords and "obstacles" are simulated, the author concludes that there are new diagnostic possibilities, and perhaps even potential for improvements in the common stethoscope.

P K Sen (Delhi) reviews recent developments in the stability of spatially growing boundary layers, which is still the subject of some controversy. The new treatment he proposes here produces better agreement with experimental data.

A series of papers on computational fluid dynamics follows. S M Deshpande (Bangalore) pursues the intriguing possibilities of setting up numerical schemes for solving the (continuum) Navier-Stokes equations that exploit a connection with the Boltzmann equation of the kinetic theory of gases. A variety of applications of such "kinetic schemes are described, including an Euler code for hypersonic flows. Daiguji (Tohoku) and Shin (Daejeon, Korea) describe other numerical schemes that use curvilinear grids, especially for handling turbomachinery flows. Both compressible and incompressible flows are included, and a $K\varepsilon$ turbulence model with low Reynolds number corrections can be incorporated.

Hussain, Virk and Melander (Houston, Texas) describe two new studies in vortex dynamics inspired by the need to understand coherent structures in turbulent flows. These developments enable distinct advances in the "structural" approach to turbulence, which as the authors point out has brought fluid mechanics back into what had become a branch of statistical physics. Direct numerical simulations, along with the powerful tool of helical wave decomposition, provide new and fundamental insights into the physical processes that are at the heart of the problem of turbulent flows.

Kiya (Hokkaido) also uses the vortex methods to study several interesting flows, including jets from elliptic nozzles, unsteady flow past a disk at angles of attack, and a collection of vortex rings whose interaction leads approximately to the Kolmogorov spectrum. Kiya uses vortex blobs to compute these flows: as he points out, vortex methods have several advantages: they do not need complex grid systems, computation is confined to only vortical regions in the fluid, and high Reynolds number flows are not unmanageable (as they are in say finite difference approaches to direct numerical solutions of turbulent flows).

V C Patel (Iowa) presents a comprehensive review of three-dimensional flow separation, which is actually much more common in real life than the more intensely studied two-dimensional problem. Both kinematic and dynamic complications of three-dimensional flows are formidable, so the phenomenon is still beyond the reach of definitive theoretical or numerical analyses, as well as of comprehensive measurement. Drawing on both experimental and computational results, Patel summarizes work on a prolate spheroid and a wing intersecting a plane, both over a wide range of incidences, and points

out that laminar flow separation offers a much richer topological variation than turbulent flow does.

The Ghias, with Yang and Osswald (Cincinnati), are also concerned with separated flows — in particular unsteady ones of the kind that are important for "super-manoeuvrable" aircraft operating in post-stall flight regimes, as well as for compressor, helicopter and windmill blades. They tackle these problems of dynamic stall by solving the unsteady Navier–Stokes equations and show not only favourable comparisons with experiment, but also possibilities for active control of the flow.

T J Chung (Alabama at Huntsville) continues with CFD, this time adopting finite element methods for handling flows that occur in supersonic combustion, involving in particular shock/turbulence interactions and chemical reactions.

Clive Fletcher (New South Wales) reports on the simulation of a complex industrial flow, namely that in a coal classifier. This involves the use of an algebraic stress model for turbulent flow in a two-phase (gas-particle in this case) medium. Fletcher, who views the study as an exercise in computational engineering, shows how design changes may be suggested by such simulations.

Another class of problems in engineering fluid mechanics is bluff-body flows: buildings, bridge piers, offshore platforms etc. Guocan Ling (Beijing) looks at some idealized problems in this class, such as oscillating plates and cylinders, with particular attention given to the effect of unsteadiness and the vortical structure of the wake.

Takayama (Tohoku) and Ben-Dor (Beer Sheva) provide some experimental relief by reviewing the transition from Mach to regular reflection in supersonic flow over wedges. A wealth of flow visualizations using holographic interferometry techniques in a shock tube illustrates the numerous types of reflection possible.

P N Shankar (Bangalore) sees evaporation and condensation as problems in fluid mechanics. Strange phenomena, such as temperature jumps and anomalous gradients, have been predicted by kinetic-theory treatments of the problem in the pure vapour phase. Shankar reviews recent work on the problem, with some surprising results but with much that still remains to be understood.

The present collection ends (as it began) with bio-fluid dynamics: this time on fish propulsion. Analysis of performance from this viewpoint, by Tong, Zhuang and Cheng (Anhui, China), leads to a tentative understanding of the morphological adaptation of fish propulsion modes in biological evolution.

The Taejon Congress deliberately emphasized computational fluid dynamics, so it is no surprise that more than half of the present collection is concerned with that subject. Even otherwise, comparison with the first volume in this series shows beyond doubt the vastly greater role that computation now plays in fluid mechanics. The editor hopes that this volume, like previous ones, will provide readers with a stimulating collection of surveys of recent developments that show the rich variety of fluid-dynamical problems that are still demanding investigation and solution, and incidentally also present a cross-section of the best Asian work in fluid mechanics.

3. *Sādhanā*–Academy Proceedings in Engineering Sciences, September 1993. Vol. 18 (73), Part 5, Pages 729–890. "Non-linear Dynamic Systems"

This special issue is devoted to discussing different aspects of nonlinear dynamics in power systems. Historically power systems have evolved over the years from a single power station supplying an isolated load to a highly interconnected complex nonlinear dynamic system. Consequently new phenomena arise and they need to be studied by power system analysts. In this issue the Editor seeks to provide some insights into a few of these areas of interest. Broadly the issue is divided into three parts — analysis, computation and control of nonlinear dynamics associated with large scale power systems.

In the first article, Hill, Hiskens and Mareels discuss the stability properties of the differential-algebraic equation (DAE) model of the power system. The DAE model is the result of neglecting the fast 60 Hz transients which occur in the transmission lines and stator windings of synchronous machines. This type of model is at the heart of most simulation studies in power systems, namely stability, computation and control. In the next paper, Cheung and Chow discuss simulation of only the slow dynamics in the DAE model using singular perturbations and integral manifolds. Slow dynamics characterize the angle stability phenomena in power systems. In the third paper, Tan, Varghese, Varaiya and Wu discuss a phenomena physically present in power systems but rarely analysed in a mathematical framework, namely bifurcation and chaos. The mathematical tools of bifurcation and chaos are becoming increasingly important in the stability analysis of stressed power systems. The fourth paper by Padiyar and Sastry discusses a

Lyapunov-based energy function method for DAE systems inclusive of HVDC lines. The energy-function method is going to play an important role in a quick filtering of contingencies for on-line dynamic security assessment. The fifth paper by Vittal, Khammash and Pawloski applies some of the recent results in robust control theory to the stability problem in power systems. Specifically the stability question is examined with respect to uncertainties in modelling of different subsystems in a large-scale power system. The sixth paper by Bose presents a review of parallel processing techniques in dynamic simulation of power systems. Different parallel algorithms and their implementation on large-scale power systems are discussed. The next paper by Ajjarapo discusses the application of bifurcation and continuation analysis techniques for the voltage collapse problem. The emphasis is on static bifurcation and algorithms to find the saddle node bifurcation point. The remaining three papers address issues arising out of low frequency oscillations in power systems.The paper by Sen Gupta and Sen presents a physically based explanation of the low frequency phenomenon occurring in power systems and reviews some of the adaptive power system stabilizer (PSS) schemes. A particular adaptive PSS scheme based on a frequency identification technique and gain scheduling is discussed. The next paper by Sharma and Prabhu discusses the coordination of PSS and static var compensators (SVC) for reliable operation when the PSS is inoperative. A sector criterion is used to define robust regions in the *P–Q* plane. Finally the paper by Ranjan, Pai and Sauer presents an analytical formulation of the small signal model for multi-machine power systems with static nonlinear loads. Using this model, voltage stability is discussed under varying loads and the phenomena of Hopf bifurcation is illustrated.

The set of papers in this issue covers the emerging interest in nonlinear dynamics as applied to power systems. Hopefully this will contribute towards greater interest in this area on the part of academia and industry. Power system analysis is rapidly becoming a scientific field of study in its own right.

4. *Proceedings–Chemical Sciences,* Vol. 105, No. 6, December 1993, pages 311– . "Solar Energy and Applied Photochemistry"

This volume contains papers based on lectures given at the Second International Conference on Solar Energy Storage and Applied Photochemistry held in Cairo, January 6–11, 1993. The conference was hosted by Ain Shams University (ASU) under the auspices of President Mubarak.

The sun was recognized as a vital source of life in Egypt several millenia ago and has played a central role in Egyptian culture. Contemporary European culture is widely regarded as having its origins in the Middle East and so international scientific exchanges between this region and the rest of the world are a natural development. It was, therefore, fitting that the International Conference on Solar Energy and Applied Photochemistry was held, for the second time, in Egypt and particularly in the "city of the sun" Heliopolis, one of the suburbs of Cairo.

The development and application of chemical reactions occur across and between scientific disciplines and photoinduced chemical processes are no exception. Thus conferences concerned with photochemistry attract a range of contributions from several scientific disciplines. The common goal is to understand and use photochemically induced molecular changes. The breadth of the scientific interests represented in this conference was considerable, reflecting the fact that solar energy storage and its conversion has many facets including photovoltaic processes, semiconductor-driven chemical devices, waste water treatment, fuel generation and the synthesis of compounds using near ultraviolet or visible radiation.

The conference attracted over two hundred photoscientists in different disciplines from twenty-four countries dedicated to the task of utilizing solar energy in one way or another. It enabled many young scientists to make contact with international experts and thereby to help in establishing new national photochemical activities.

5. *Journal of Biosciences* , Vol.18, No. 4, December 1993, pages 423–564. 'Diversity and flexibility of biotic communities in fluctuating environments'

As a collection of living species, every biotic community responds to environmental change in characteristic ways. Now, at the end of the millenium, the themes of habitat alteration, environmental degradation, and global responses to past and future disturbances, fuel a burgeoning science. Growth in this multidisciplinary and richly relevant sphere of inquiry was reflected by papers presented at the International Geosphere-Biosphere Project (IGBP) Symposium held in Kyoto, Japan during December, 1991— many of which are incorporated in this special issue of the Journal of Biosciences.

Ecosystem studies usually focus on geological,

chemical and physical processes affecting biotic communities. Such communities are seen as composed of certain subunits-species, guilds, or even more simply, aquatic or terrestrial plants, animals or biota. However, just as the basic laws of chemistry and physics drive the ecosystem, animal behaviour and plant flexibility provide the glue that holds it together. Attempts at understanding ecosystem processes, must closely consider such details and acknowledge that plant and animal responses to change are vital to the structure and functioning of any ecosystem. When considering biodiversity, more emphasis is befitting for the study of what a species of plant or animal does, rather than merely how many species are found living together. Behaviour and flexibility determine the character of biodiversity, and taxon counts are simply not enough, by themselves, to either describe or characterize a fauna or flora. More functional and holistic approaches are needed to study ecosystems — affording insight and predictability as natural communities pass through the trials of time and human-induced or natural disturbances.

Long-term observations that include an assessment of response to major changes constitute a large portion of the contributions given in this volume. Although these studies span arctic realms to "aseasonal" tropical rainforests, along with marine, freshwater and terrestrial habitats, in all fairness, it must be said that the emphasis is tropical and Asian. The subject matter is both plant and animal, and the subjects themselves are seen either as individuals, entire populations, trophic levels, communities or ecosystems. Building from a basis of regional and quasi-periodic cues such as the El Niño-Southern Oscillation (ENSO) event, which affects nearly half the globe, to disturbances on a small scale, then turning to geologic events that have, over eons, created islands and split apart ecosystems, each chapter examines and explains features and adaptations corresponding to "catastrophic" and "background" disturbances or, in a less spectacular vein, seasonality.

These collected studies are comparative and reveal some of the profound consequences stemming from fluctuations in the environment — an environment that occasionally produces hurricanes, forest fires, landslides, floods, massive erosion, toxification, droughts, and many chemical and physical imbalances that, by their nature, must be corrected. That the so-called corrections result in outstanding adaptations, exposed to our scientific scrutiny only every so often should be one of the principles taken from this unique assemblage of papers and ideas.

Obituary

John Gatenby Bolton "Astronomer Extraordinary" was born in Sheffield on 5 June 1922. After going through his local grammar school, he won a scholarship to Trinity College, Cambridge. He graduated in Physics with honours in 1942 and joined the Royal Navy as a Radar Officer, but was soon recruited into radar research at the then Secret Telecommunications Research Establishment. On leaving TRE in 1944, he served with the East Indies and Pacific Fleets till 1946.

At the end of the war, he opted to settle down in Sydney, Australia, where he joined as Assistant and later Principal Research Scientist at the Commonwealth Scientific and Industrial Research Organization (CSIRO), whose Radiophysics Laboratory was directed by E C Bowen. Radio emissions from the Sun had been discovered during the war and there was much activity investigating these.

Using equipment built for a solar eclipse expedition to Brazil, which was called off, Bolton began a period of epoch-making observations. Before World War II all information about the Cosmos had been obtained through the visible part of the electromagnetic spectrum. During the half century since then the observable universe has been shown to be populated with galaxies radiating powerfully at radio wavelengths. It all began in 1948 when Bolton with two colleagues observed that three distant objects known from optical observations were extremely powerful emitters of radiowaves, one in our own galaxy and the other two in external galaxies. He also worked for a short while on warm-temperature freezing nuclei and instrumentation for large-scale cloud seeding.

Bolton joined the California Institute of Technology in 1955 as Senior Research Fellow and later as Professor of Radio Astronomy and in the six years before he returned to Australia created the Owens Valley Radio Observatory, with its twin 90 foot, railmounted telescopes. It was quickly recognized as a world centre and provided a much-needed boost to radioastronomy in the USA.

Bolton returned to Australia as Chief Research Scientist at CSIRO in 1961 to supervise the construction of the 210- foot telescope at Parkes, NSW. He took charge as Director of the Australian National Radio Astronomy Observatory (ANRAO) in 1962 to begin a third and equally spectacular phase in his career. Major contributions were

made in almost every branch of radioastronomy. His lifelong interest in the discovery, classification and identification of radio sources found his greatest reward in these years. The Parkes Catalogue lists more than 8000 sources, including several hundred quasars.

More than anyone else, he brought radio and optical astronomy together. He was among the earliest to recognize the unity of astronomy across all wavelengths. In 1972, Bolton retired as Director, ANRAO but continued in Parkes as Astronomer-at-Large till 1981, when illhealth forced him to retire to Queensland. Many honours came his way. He was elected as Honorary Fellow of the Academy in 1973.

He was awarded in 1951 the Edgeworth David Medal of the Royal Society of NSW, in 1967 the Encyclopaedia Britannica Gold Medal and Prize for Science in Australia, in 1977 the Gold Medal of the Royal Astronomical Society and in 1988 the Bruce Medal of the Astronomical Society of the Pacific.

He was elected a Fellow of the Australian Academy of Sciences in 1969 and a Foreign Honorary Member of the American Academy of Arts and Sciences in 1972, a Fellow of the Royal Society in 1973 and Associate of the National Academy of Sciences of the USA in 1980. He served as Vice President of the International Astronomical Union from 1973 to 1979.

He passed away on 6 July 1993.

Editor: Anna Mani
Published by G Srinivasan, Editor of Publications
for the Indian Academy of Sciences, Bangalore 560 080
and typeset by him at R D Typesetters, Bangalore