Patrika

July 1989 No.19 Newsletter of the Indian Academy of Sciences

55th Annual Meeting

At the invitation of the Madhya Pradesh Council for Science and Technology, the University of Bhopal and the Regional Research Laboratory, Bhopal, the 55th Annual Meeting of the Academy will be held at Bhopal from 10–13 November 1989.

The scientific programme will include two symposia, two evening lectures and lectures by Fellows and Associates.

The symposia will be on "Developmental Genetics" and on the "Pros and Cons of the Narmada Valley Project". The evening lectures will be on "Unique masterpieces of Central Indian Art" by Shri K K Chakravarty and on "Molecular mechanisms of transmembrane signalling" by Prof. J Ramachandran.

The following is a provisional list of lectures by Fellows and Associates.

Catalysis and organometallic chemistry — S Bhaduri

Instabilities at reacting interfaces in ceramic systems — K T Jacob

Intelligent engineering systems — V V S Sarma

Some novel one- and two-dimensional methods in high resolution NMR spectroscopy — S Subramanian

The physics of fluctuating membranes — S Ramaswamy

X-ray spectroscopic studies of complex oxides — G Sankar

Siting, energetics and mobility of absorbates in zeolites — S Yashonath

Certain numerical characters of singularities of an algebraic variety — Balwant Singh

An unconventional mode of repair of DNA damage — R Jayaraman

Physico-chemical mechanisms controlling engineering behaviour of clays — A Sridharan

Pressure-temperature-time trajectory of the granulites from Ganguvarpatti, South India, and its implications on crustal evolution — Anand Mohan

Algebraic *K*-theory of singular varieties — V Srinivas

Novel aspects of quantum theory of magnetism — G Baskaran

Visits to Sanchi, Bhimbetka and Bhojpur will be organized on 12 and 13 November.

All Fellows and Associates attending the Annual Meeting will be paid first class railway fare from their place of residence to Bhopal and back, in case they are unable to obtain travel support from other sources. Arrangements for the stay of Fellows and Associates will be taken care of by the organisers.

During the period of the Annual Meeting, the Editorial Boards and Sectional Committees will also meet at Bhopal.

Special Publications

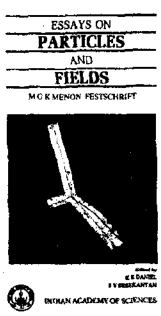
In addition to the fortytwo special publications described in earlier issues, the following volume was published in 1989.

Essays on Particles and Fields: M G K Menon Festschrift, edited by R R Daniel and B V Sreekantan, 307 pages, published in 1989, distributed by the Oxford University Press.

This Festschrift is a tribute to Prof M G K Menon, on his sixtieth birthday, by some of his many friends, admirers and scientific colleagues. Physicist, administrator and policy maker, he has influenced the growth of Indian science in more ways than one, leaving on the minds of those who came in contact with him in each of his capacities, abiding impressions of a wise, warm and generous personality.

It honours a man, who for over thirty years, has held an extraordinarily wide range of scientific, administrative, educational and policy-making responsibilities at perhaps the highest level that any scientist has done anywhere in the world, keeping alive at the same time his research interests, abreast of the latest developments in all of them.

The volume consists of contributions from his former colleagues at the University of Bristol and the Tata Institute of Fundamental Research and from international collaborators and colleagues in national and international scientific bodies. They cover the various fields in which he has been actively interested in the last 35 years and range from underground particle physics and neutrino physics to astronomy and oceanography. The volume ends with tributes from Dr and Mrs Beppo Occhialini, Prof R E Marshak, Prof Abdus Salam and Prof Charles H Townes.



A copy of the Festschrift was formally presented to Prof Menon by Prof C N R Rao, President of the Academy, at a function held at the Raman Research Institute on 24 July 1989.

Special Issues of Journals

Nuclear Structure, Pramana: Journal of Physics, Vol. 32, No.4, April 1989.

This special theme issue of Pramana — Journal of Physics is a written and edited version of the Proceedings of the Symposium on nuclear and subnuclear physics held at the Physical Research Laboratory in June 1988, on the occasion of the superannuation of Prof S P Pandya. The theme has been developed in topics arranged in 27 articles as nuclear many-body problems, self-consistent field theory for nuclei, nuclear reaction theory, statistical nuclear physics, quantum chromodynamics, hadron physics and plasma problems. The special issue which surveys the current status of nuclear physics will be of standing value as a reference volume on the exciting subject of nuclear structure and associated problems.

Associates – 1989

G Athithan, ANURAG, Hyderabad — Computer software

B Basu, Tata Research Development and Design Centre, Pune — Thermal science and engineering

S K Chakrabarti, Tata Institute of Fundamental Research, Bombay — Theoretical astrophysics

A Deshpande, Raman Research Institute, Bangalore — Observational radioastronomy

G Ganguly, Indian Association for the Cultivation of Science, Calcutta — Opto-electronic materials

U Maitra, Indian Institute of Science, Bangalore — Organic reactions

A Mehra, University of Bombay, Bombay — Chemical reaction engineering

S Mohanty, Indian School of Mines, Dhanbad — Structural geology

Rukhsana Chowdhury, Indian Institute of Chemical Biology, Calcutta — Molecular biology

N Nitsure, Tata Institute of Fundamental Research, Bombay — Algebraic geometry

The World of Elementary Particles – past and future

Lecture given by Prof. N Mukunda at the function held on 24 July 1989, at the Raman Research Institute to honour Prof. M G K Menon on his sixtieth birthday.

The occasion for this lecture was the release of the volume entitled 'Essays on particles and fields', edited by R R Daniel and B V Sreekantan as a *Festschrift* in honour of M G K Menon, one of the distinguished Fellows of the Academy. The speaker began by recalling the support that he had received from Prof. Menon. He then went on to his main theme, a wide angle view of particle physics. Perhaps the subject began with the early philosophers who turned to atoms as a means of avoiding the infinities of the continuum. The electron was the first elementary particle to be recognised as such in the late nineteenth century mainly through the efforts of J J Thomson. One could say that the photon was introduced by Einstein in 1905 in connection with the photoelectric effect. But it is remarkable how much resistance there was to the concept, at least till the twenties, when the Compton effect revealed the energy and momentum of the photon. Meanwhile, the proton, regarded as the simplest atomic nucleus, made its entry through the work of Rutherford, who was also tempted to speculate on the existence of one more neutral particle which he termed a neutron. The discovery of this particle had to wait for Chadwick in 1932.

Dirac in 1931 had already proposed a new particle on purely theoretical grounds, which he called the antielectron. It is interesting that he took this step only after every other option had failed! This is in contrast with the attitude of many theorists today who have no hesitation in postulating hundreds of unobserved particles if it is expedient to do so.

The subject of nuclear physics began with Heisenberg's recognition of the strong nuclear force and isospin in 1932. But a vital step forward came from Yukawa in Japan when he proposed a new particle — the meson — as the carrier of this force with a mass a few hundred times that of the electron. This was not an isolated discovery but part of a Japanese tradition which was later continued by others.

The study of cosmic rays with the cloud chamber led to the discovery of Dirac's positron and the muon — the latter mistakenly taken to be Yukawa's particle. It was the systematic use of photographic emulsions as detectors by Powell and coworkers at Bristol that led to many new discoveries, the first being the pi-meson of Yukawa. Prof. Menon was fruitfully associated with this group in a period when the so-called strange particles were studied. A great mystery in that period was called the τ-θ puzzle. This referred to two particles with almost identical properties, one decaying into two pi-mesons and the other into three. Dalitz showed that the products had opposite parity in the two cases and the puzzle was finally resolved when Lee and Yang proposed that parity was not conserved — that exact mirror symmetry did not exist in nature — and τ and θ were the same particle.

Coming to theory, Dirac's work forced people to consider processes in which particle-antiparticle pairs could be created and thus the subject became, unavoidably, a difficult many body problem. The quantum theory of fields was created to describe these processes and had great successes but led to great difficulties when applied to the strong interaction. In the sixties, physicists revived an old idea of Heisenberg—the S matrix — which describes all processes in terms of scattering amplitudes without direct reference to space-time. However, in the seventies, field theory made a comeback with many new ideas and with the success of the unified electroweak theory of Glashow, Weinberg and Salam.

The improvement of accelerator techniques meant that the focus moved away from cosmic rays. Literally hundreds of shortlived strongly interacting particles were found. It needed many new ideas to bring order to this zoo — strangeness, the eightfold way, and quarks. Interestingly, the name of Gell-Mann is associated with these developments, along with those of others who independently arrived at similar ideas — Nishijama, Neeman and Zweig. The count of leptons (each with an associated neutrino) remained at two — the electron and muon — until their heavier cousin (called the tau) was found in 1975. Since the number of quarks was now manageable, grand unified theories were proposed permitting transformations between quarks and leptons. This implies that the proton is unstable, though with a lifetime exceeding the age of the universe by more than twenty orders of magnitude.

One of the triumphs of the modern era of accelerators is that the long sought after carriers of the weak force — the W and Z particles — were seen. Things have changed considerably since the era when the track of a new particle was actually seen in a cloud chamber or emulsion. Today's "seeing" involves giant accelerators and detectors, teams of hundreds of workers, and elaborate computer analysis and simulation of an enormous number of events, each with a large number of particles. It is not clear to what extent a sense of participation and achievement can be derived by a majority of the workers on such huge projects.

Returning to theory, a relic of the S-matrix era has returned with a vengeance. Nambu had pointed out that one of the popular models could be reinterpreted in terms of an extended object in space-time — a string. String theory has now attracted a large number of theorists as a possible "theory of everything" with very elegant and novel mathematics. Unfortunately this theory has grown increasingly and dangerously remote from confirmation by present-day or even future experiments.

The lecture concluded with this rather sombre outlook for the future of particle physics. But there is no doubt that the large audience which had gathered for the occasion were treated to a remarkable survey of this most basic area of physics. It would be hard to think of a topic or treatment more suited to such a gathering, honouring as it did Prof. M G K Menon, himself a particle physicist.

Whispering Galleries*

The Science of Architectural Acoustics, i.e the study of the behaviour of sounds inside enclosed spaces or public buildings is receiving a great deal of attention at the present time. This is not surprising in view of the obvious practical importance of such knowledge in designing halls for public speaking or for theatrical or musical performances and in correcting by suitable means the defects of existing halls. The diminution of noise in places such as hospitals, libraries etc. where quiet is essential is also a branch of enquiry falling within the scope of the subject. I do not propose, however, in this paper to deal with either of the questions referred to above, interesting as they are, but will confine myself to a discussion of certain remarkable effects noticed occasionally in large public buildings. The term "Whispering Gallery" is however general and may be applied to any structure, whether natural or artificial, which exhibits the special properties of enabling faint sounds to be heard across extraordinary distances.

The Cathedral at Girgenti

One of the best known of Whispering Galleries is in the Cathedral at Girgenti in Sicily. The building itself lies outside the ordinary routes of tourist travel and owes its fame to the circumstance that a certain legend concerning it was given wide publicity in an Encyclopaedia article by Herschel and passed current into the text-books of Physics. The story goes that in this Cathedral the slightest whisper is borne with perfect distinctness from the Great Western floor to the cornice behind the high altar, and that by a most unlucky coincidence, the precise place from which the sounds were best conveyed was chosen for the place of the confessional. Secrets never intended for the public ear thus became known to the dismay of the confessor and the scandal of the people by the resort of the curious to the opposite point which seems to have been discovered by accident. Prof. W C Sabine of Harvard University who visited the Cathedral a few years ago verified the statement that there were two places in the building, a hundred feet apart between which it was possible

*Substance of an address given by Prof. C V Raman at the Benares Hindu University; published in the Central Hindu College Magazine, Vol. XXIII, February 1923, pp 34-38.

to communicate by whispers in the manner stated, the effect being due to the fact that the curved ceiling of the Cathedral acted as a focusing mirror and concentrated the sound waves travelling from the place of origin to the place of observation. Prof. Sabine, however, was inclined to think that the story was apocryphal, owing to the extreme inaccessibility of the point at which the whispers were said to have been overheard. The legend however is so pretty that it seems a pity to have to disbelieve it.

Some Whispering Galleries at Calcutta

Indian readers will naturally be more interested to read of the Whispering Galleries in our own country. I shall begin first by referring to a Whispering Gallery the existence of which was discovered by myself. Visitors to Calcutta will have noticed the dome of the Calcutta General Post Office which is the most imposing structure amongst the many stately piles that surround Dalhousie Square. Below the dome is a row of windows which light the hall below and immediately below this again, at the level of the clock-face, is a circular gallery running round the building and having a perfectly smooth circular wall some fifteen-feet high. The gallery is above the public rotunda and may be entered by a small door opening out on the terrace of the main building. Unfortunately throughout the greater part of the day, the place is very noisy, but the visitor who gets into the gallery early in the morning or late in the evening when the hum of traffic has died away will find it easy to converse with an assistant across the dome, fifty-seven feet off, in the gentlest of whispers. The effect is to be ascribed to the smooth wall of gallery around which the sound waves creep circumferentially and reach their objective with very little loss of energy on the way.

The Victoria Memorial

This structure recently completed at Calcutta is the finest public building in the "City of Palaces". It occupies a privileged position in the Maidan between the City and Fort William and its white marble dome with the winged statue of Victory Crowning all may be seen from afar. The visitor to Calcutta should not fail to see this great pile. Entering by the great gates facing the Maidan towards the Ochterlony monument, he will pass through the portico and vestibule into the circular hall which stretches up from floor to dome of the Memorial. At the centre of the hall stands the statue of the Young Queen Victoria. Looking up, the visitor will notice first, a gallery some forty feet from the floor, then higher, the twelve semi-circular paintings on the walls, above these the eight great windows lighting the hall and then finally about a hundred feet from the floor a circular gallery with marble railing running round just underneath the inner or false dome which forms the roof of the hall. The wall of this gallery has a distinct slope inwards and is in fact practically part of the inner dome; it is interrupted by eight openings of which seven are great circular windows covered by glass which light the dome and can be seen from outside. The eighth opening is the entrance into the gallery.

The real or outer dome of the Memorial and the false or inner dome enclose a ring-shaped space into which it is possible to enter by a wooden stair-case provided for the purpose. At the bottom, there is just room comfortably to pass round between the two domes, and above, the space rapidly widens out. At the time the Memorial was under construction the architects noticed the remarkable acoustic properties of the space between the two domes and this was referred to in the Press.

Recently I visited the Memorial to investigate this for myself and soon discovered that there were, in reality, two whispering galleries in the building; one was the space between the two domes, and the other was the circular gallery below the inner dome. The acoustic properties of the latter, had, curiously enough, remained unnoticed. A brief description of the effects noticed in the two galleries would not be out of place. In the space between the two domes, the most remarkable feature is the extraordinary way in which even slight sounds are taken up and repeated many times. The sound of a footfall or of a handclap is heard over and over again, some fifteen or twenty times, the successive returns of the sound showing a gradual softening away in the sharpness in the sound.

The slightest whisper goes round and is perfectly audible everywhere, and the effect is distinctly uncanny, particularly as the observer and his assistant are screened from each other by the mass of the inner dome. In the gallery below the inner dome, the multiple echo is much less perceptible, but the sounds of whispering can be heard easily anywhere. The diameter of the gallery is about the same as that of the Calcutta General Post Office, but the effect noticed is distinctly more striking. This may be ascribed to the inward slope of the walls which would undoubtedly favour the concentration of sound along a narrow belt skirting the gallery.

The explanation of the remarkable multiple echo heard in these and other galleries of similar type is very simple and instructive. As I have already mentioned, the peculiar acoustical property of the gallery arises from the fact that the sound waves are practically compelled to travel in a curved path striking the circular wall of the gallery, and they can go round and round the gallery, many times before they disappear. Each time the wave passes the observer, it is heard once, and if the wave completes, say fifteen circuits round the gallery, it is heard repeated fifteen times. This simple explanation can be shown to be correct by timing the interval between successive returns of the sound. This has been done by me and the time-interval found to be equal to the circumference of the gallery divided by the velocity of sound, exactly as expected.

The Gol Gumbaz at Bijapur

The most remarkable whispering gallery in India is undoubtedly that in the great tomb of Sultan Muhammad at Bijapur. I cannot do better than quote a few extracts from the eloquent description given by Mr Cousins of the great monument in his volume on Bijapur architecture published by the Archaeological Department.

"Transcending all other buildings at Bijapur in simple mass and dominating the landscape for miles around, the great Gol Gumbaz or tomb of Sultan Muhammad, stands alone. For size, few other buildings in India can be compared with it. Its noble proportions and magnificent dome are only seen to the fullest advantage from a distance. When close up to it, the dome seems to sink into the building, and to require an immediate terrace or storey to raise it into full view. A few extra feet here would certainly have improved the general design, even when viewed from further off. The impressive grandeur of the building and its imponderable mass simply overwhelm the spectator with awe. It stands in the extreme east end of the city, its massive basement resting upon the solid rock. The vast mausoleum stands out with most striking effect when viewed, as Muhammad himself must often have seen it, from the upper hall of the Athar Mahall, when, backed by great storm clouds, the low western sun suddenly bursts through a rent and illumines the great building. It then flashes out into brilliant contrast against the rolling masses of angry black clouds the yellow tints of its walls are bathed in a golden glow, and the great dome shines like burnished brass. Under all this glory peacefully repose the remains of Sultan Muhammad.

The dome and its size

A glance at the plan of the Gol Gumbaz shows what a simple building it is for all its size—just a great square hall, enclosed by four lofty walls, buttressed up by octogonal towers at the corners, and the whole surmounted by a hemispherical dome. The great size of the dome, and the neat and perfect manner in which by means of cross arching and pendentives, the square walls have been worked up to meet it, are the most notable features of the building. The extreme outside measurement of the mausoleum including the towers is 205 feet square. The extreme height to the apex of the dome from the base of the building is 198 ft. 6 inches; the exterior diameter of the dome is 144 ft. while the interior diameter, measured 124 feet 5 inches; and the great hall, below, with no intermediate supports of any kind, inside its walls, is 135 feet 5 inches square. The interior height, from the level of the floor, around the tomb platform to the top of the dome is 178 ft. Within the base of the dome is a broad gallery, 11 feet wide, which hangs out into the interior of the building, 109 feet 6 inches above the floor. Narrow stair-cases wind up through the corners of the building where the towers join it, and passages lead out from them on to each of the pigeon-holed storeys of the towers.

The great hall below, which is covered by the dome, covers an area 18,337.67 square feet, from which if we take 228.32 square feet for the projecting angles of the piers carrying the cross arches, which stand out from the walls into the floor, two on each face, we get a total covered area uninterrupted by supports of any kind, of 18,109.35 square feet. This is the largest space covered by a single dome in the world, the next largest being that of the Pantheon at Rome, of 15,833 square feet. If we add the pendentives to the actual dome, to which they naturally belong as part of the superstructure, this then becomes the greatest domical roof in the world.

But, was not this great dome, after all, but an after-thought... Before the walls of the Gol Gumbaz had risen many feet, it would seem that the plans were altered. The daring spirit of the architect, urged on perhaps by Sultan Muhammad himself, incited him to attempt the more stupendous task of hanging a mighty dome right across the whole expanse of the outer walls; and it seems almost incredible that the man who conceived, and carried to such a successful issue this magnificent project should have passed into oblivion; his very name is unknown.

Its Whispering Gallery

Another remarkable feature in the building is its whispering gallery, which runs round, inside the dome, at its base. Access is gained to it from the terraced roof around the base of the dome, by eight small door ways through it. As may be seen from the section and the model it hangs out into the building being supported upon the crowns of the cross arches below; and it is about eleven feet wide; inside the low parapet wall which protects it. On entering the building a person is struck by the loud echoes which fill the place in answer to his footfall; but these sounds are intensified on entering the gallery. The footfall of a single individual is enough to wake the sounds as of a company of persons, and, in response to ordinary conversation, strange weird sounds and mocking whispers emanate from the wall around. Loud laughter is answered by a score of fiens safely ensconced behind the plaster. The slightest whisper is heard from side, and a conversation may be easily carried on across the diameter of the dome, in the lowest undertone, by simply talking to the wall, out of which the answering voice appears to come. A single loud clap is distinctly echoed ten times."

The Granary at Patna

I cannot conclude an account of the Indian Whispering Galleries without referring to this most curious structure which stands to-day as the monument of a mistake. The Granary was built in the days of the East Indian Company under the orders of Warren Hastings and was intended to be used as a storehouse for grain in times of famine. It is a massive structure of brick-work, its walls being twelve feet thick, and is of the shape of a colossal bee-hive some ninety feet high with a circular base. Two stair-cases on the exterior of the building lead to its top (which is now closed) from which a fine view may be obtained of the Ganges and the surrounding country. The interior of the building is merely the circular floor and the domical wall which roofs it over, and is rather gloomy being lighted only by four doors at ground level. The building was never used as a granary and is now merely a store house for furniture. It is well worth a visit on account of its very remarkable acoustics. In September last, I was at Patna for a few hours and inspected the Granary. The most striking feature is the multiple echo heard inside the building in answer to the slightest sound. When the observer stands exactly at the centre of the building, however, this disappears and we have simply a single and surprisingly loud echo in which the original sound is reproduced with great fidelity.

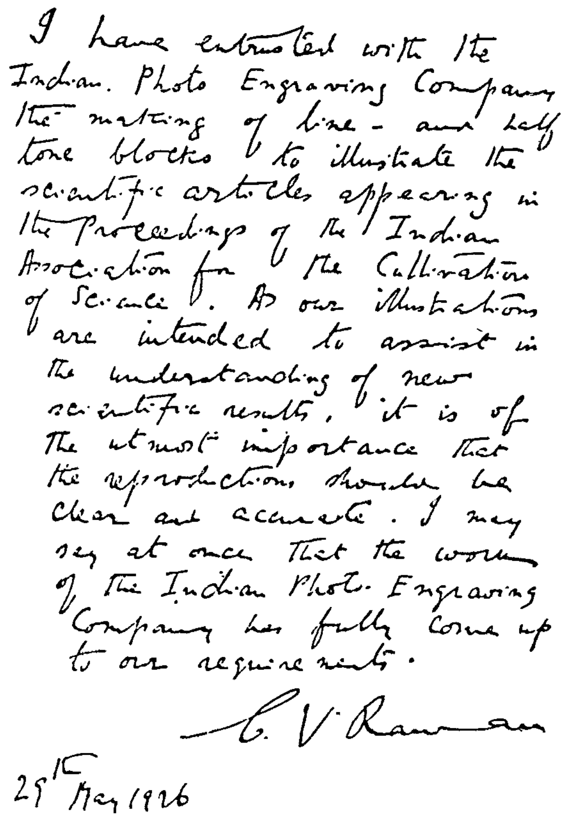
Other Whispering Galleries

Acoustical curiosities of other kinds are no doubt to be found in many other public buildings in India and it would take too long to enter into them here. Nor is it possible within the limits of this article to describe the many interesting cases that have come to notice in Europe and America. A mention should, however, be made of the Whispering Gallery at St. Paul's Cathedral in London which the writer studied in detail while in England last year. Those who are interested will find an account of the results of his investigation in the Proceedings of the Royal Society of London for January last. This gallery is of the same general type as at the Calcutta General Post Office described above, only much larger and with certain distinctive features which give it a most striking character.

An Opinion

Reproduced in original as we felt it would be of interest to our readers.

– Editor


I have entrusted with the Indian Photo Engraving Company the making of line- and half-tone blocks to illustrate the scientific articles appearing in the Proceedings of the Indian Association for the Cultivation of Science. As our illustrations are intended to assist in the understanding of new scientific results, it is of the utmost importance that the reproductions should be clear and accurate. I may say at once that the work of the Indian Photo Engraving Company has fully come up to our requirements.

— C. V. Raman

25th May 1926

Obituaries

Suri Bhagavantam, a Foundation Fellow of the Academy and a former student and close associate of Prof. Raman for over forty years, passed away at Madras on 6 February 1989.

He was born on 14 October 1909 in Gudiwada, in the Krishna district of Andhra Pradesh. He had his early education in the City College School of Hyderabad, securing the coveted Gokhale scholarship. He graduated with the first rank in 1928 from Nizam College, affiliated then to the Madras University.

His scientific career may be said to have started in 1928, when as a 19-year old graduate he joined Prof. Raman's research group at the Indian Association for the Cultivation of Science in Calcutta. He commenced his research with investigations on the optical and magnetic anisotropy in aromatic and aliphatic series of compounds. Soon after the discovery of the Raman Effect in 1928, he took up for study the Raman spectra of gases, concentrating on the interaction between rotation and vibration, the effect of pressure and the polarisation and intensity distribution in the wings accompanying the Rayleigh scattering as well as the vibrational scattering. It was Raman and Bhagavantam who considered in detail the 'reversal' of circular polarization in Raman scattering for an experimental demonstration of the spin of photons.

In 1932, when he was only 23 years old, he was recommended by Prof. Raman for a faculty appointment in the Andhra University, Waltair and he was appointed thereto. The young professor fully justified the appointment. A flourishing school of Optics and Group Theory and its applications to physics, grew under his leadership. Later as Principal of the University Colleges at Waltair, he was able to attract capable scientists to other departments. The Andhra University became an outstanding Centre of Studies in Physics, Chemistry, Marine Biology and Geodesy and Geophysics. During this period, besides continuing his investigations on Raman Effect, he established an active school of experimental research in ultrasonics and developed new techniques for the measurement of elastic constants. He also turned his attention to the application of group theory to a study of the normal modes of oscillations in crystals, with special reference to Raman scattering. His two books published during this period, namely 'Scattering of Light and Raman Effect' and 'Theory of Groups and its Applications to Physical Problems' are still among the best books that any research worker can find on these topics.

The rare combination of scientific eminence and experience in administration, naturally resulted in his being chosen in 1948 as the first scientific liaison officer of independent India in UK. Fortunately for science, he was released from that position to join as Director of the Physical Research Laboratories of the Osmania University.

With his horizon widened by his recent stay in Europe, he set about establishing an extremely active school of physics at Osmania University, where until then there had been no tradition of research. In 1952 he became Vice Chancellor of Osmania University.

By the time he left Osmania in 1957, the Physics Department had come to be recognized as one of the best in India and work was being done in spectroscopy, ultrasonics, cosmic rays, X-rays, photoelasticity, geophysics and radio astronomy. He later extended his studies to magnetic symmetry and physical properties of crystals and published his third book 'Crystal Symmetry and Physical Properties'. He also contributed to the development of teaching at undergraduate and post graduate levels to a very high standard. With his example to emulate, the other departments of the University also developed research activities on an unprecedented scale. He also took steps to rejuvenate astronomical studies and research in Hyderabad, one of the concrete results being the creation of the Rangapur Astronomical Observatory with its 48 inch optical telescope and its modern accessories, donated by the National Science Foundation of the USA.

He enjoyed research with a dedicated zeal and his interests ranged from diffraction of light by high frequency ultrasonic waves to the elastic behaviour of matter under very high pressure, and from transport properties in magnetic crystals to relaxation phenomena in piezoelectrics.

From 1957 to 1962 he was the Director of the Indian Institute of Science, Bangalore, where he added to his interests communication technology, aeronautical sciences and radio astronomy.

With his deep understanding of the basic sciences and properties of materials, his interest in practical applications of science and technology to problems of human welfare and his imaginative approach to human relations, it was not surprising that in 1962, he was called upon to take up the post of Scientific Adviser to the Minister of Defence, Government of India.

During his seven years as Scientific Adviser to the Defence Minister, he did much to promote selfreliance in defence systems. He started several new defence science laboratories including three major ones in Hyderabad, dealing respectively with materials, electronics and missiles. He was also connected with Bharat Electronics Limited and Hindustan Electronics Limited serving these organizations in various capacities.

He was awarded honorary degrees by many universities and the Shanti Swarup Bhatnagar Medal of the Indian National Science Academy in 1970. He was Chairman of the committee appointed by the Government for the reorganization of scientific research in India and as a member of the Electroncis Commission and of the Aeronautics Commission, was closely associated with the planning of electronics and aeronautics development in India.

He was Vice President of the International Union of Pure and Applied Physics, President of the Indian Geophysical Union and of the Physics Section of the Indian Science Congress.

He was Vice President of both the Indian Academy of Sciences and the Indian National Science Academy. He was President of the UN Committee on Science and Technology in Developing Countries (COSTED) from 1972–1980.

A dedicated scientist, a fine teacher and an able administrator, by his example and his many-sided activities he made a profound impression on the academic and scientific life of the country. For his family and for countless numbers of his friends, colleagues and students, his death is an irredeemable loss.

Emilio Gino Segre the winner with Owen Chamberlain, of the 1959 Nobel Prize for Physics for the creation of antiprotons, was born in Tivoli, Rome on 1 February 1905. The son of an industrialist, he went to school in Tivoli and Rome, and began his university studies in 1922 with the idea of becoming an engineer. In part due to Enrico Fermi's influence, he changed his field of study to physics, which had fascinated him since childhood. He took his doctor's degree in 1928 under Fermi.

Segre's versatility in his scientific work was a trait he developed as a student and as a member of Fermi's famous 'Roman School' of Physics in the late 1920's. Although best remembered for his nuclear research, Segre's early work was in atomic physics. His earliest experiments were in the field of atomic spectroscopy, in which he studied forbidden lines, their Zeeman effect and highly excited atoms, whose orbits were a thousand times larger than those of normal atoms. Following a period of military service, he did postgraduate work with Otto Stern at Hamburg and with Pieter Zeeman in Amsterdam, before returning to the University of Rome as an Assistant Professor in 1932.

Segre and his colleagues took part in the experiments on neutrons directed by Fermi in 1934, during which all available elements, including uranium, were bombarded with neutrons, forming transuranic elements. In 1935 the neutron work was crowned by the discovery of slow neutrons. Slow neutrons, with velocities comparable to thermal agitation, acquire peculiar properties, that later proved to be very important for the development of nuclear power.

Segre left Rome in 1936 to accept the position of Director of the Physics Laboratory at the University of Palermo. Although his laboratory was not well-equipped, by using simple techniques, he discovered the first artificial element technetium, in collaboration with C Perrier, a professor of minerolgy.

While visiting California in 1938, Segre was dismissed from his position at the University of Palermo by the Fascist Government of Italy. He remained at Berkeley, California, first as a research associate in the Radiation Laboratory and later as a lecturer in the Physics Department. He continued his work in nuclear chemistry, discovering with Corson and McKenzie, the element astatine, the heaviest of the halogens and with Kennedy, Seaborg and Wahl, plutonium-239 and its fission properties.

From 1943 to 1946, he was a group leader at the Los Alamos Laboratory, where the studies on spontaneous fission by his group had important consequences for the development of the atomic bomb. In 1946 he returned to the University of California at Berkeley to work as a Professor of Physics till he retired in 1972. His investigations in nuclear physics cover many areas such as isomerism, spontaneous fission and high energy physics.

In 1955, using the Bevatron particle accelerator, Segre and Chamberlain succeeded in producing and identifying antiprotons and thus set the stage for the discovery of many additional antiparticles. His book 'Nuclei and Particles' was published in 1964.

Segre was naturalized as an American citizen in 1944. He was elected an Honorary Fellow of the Academy in 1971 He was member of the US National Academy of Sciences and many other learned societies. He also received a number of honorary degrees and medals.

He was appointed Professor of Nuclear Physics at the University of Rome in 1974, subsequently becoming emeritus. He passed away near his home in Lafayette, California on 22 April 1989.

Erratum

S. Ramaseshan writes......

In the printed version of the talk I delivered in Calcutta entitled "The Portrait of a Scientist — C.V. Raman" which appeared in **Patrika** (January 1989) there is an error. The sentence reads:

> "When the mathematicians of the world presented a copy of Ramanujan's bust to the Indian Academy of Sciences at Bangalore, the astrophysicist S. Chandrasekhar .... wrote:"
>
> The sentence should be replaced by:
>
> "The mathematicians of the world desired to present Mrs Ramanujan with a bronze bust of Ramanujan. The U.S. mathematician Richard Askey persuaded the sculptor Paul Granlund to undertake the making of this bust. Prof. Chandrasekhar and his wife Lalitha graciously offered to present one of the copies to the Indian Academy of Sciences. At that time the Chicago Astrophysicist wrote: ...."

As reported in **Patrika** (April 1985) the formal presentation and the unveiling of the bust was done by Mrs Lalitha Chandrasekhar on 6 February 1985, during the Golden Jubilee celebration of the Indian Academy of Sciences, when she related the story of how the bust came into being and how the sculptor transformed the photograph of Ramanujan (discovered by her husband in India in 1936) into a three-dimensional work of art.

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