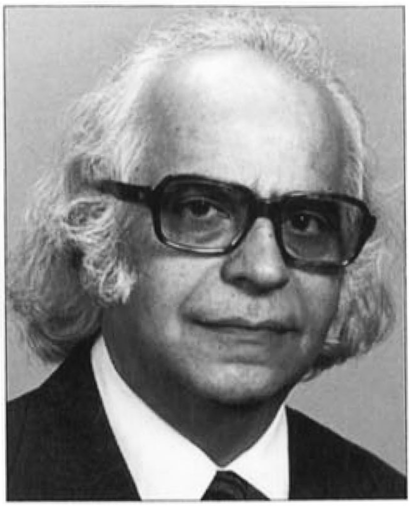
Yash Pal

Ramanath Cowsik

A fine sense of aesthetics in the arts and sciences, a deep commitment to social egalitarianism and justice, an all-inclusive attitude towards the rich and the poor, the mighty and the meek, and above all, a completely sincere and genuine personality are some of the qualities that propelled Yash Pal towards his great accomplishments and makes him a living legend of 'Indian science'. For me, 'Yash represents Quetta with its earthquake, pre-partition Punjab with its graciousness, liberalism, secularism, vibrancy and aristocracy; steeled in the trauma of partition, but retaining all these qualities', the doyen of Indian science, M. G. K. Menon said nearly ten years ago, as he wished Yash Pal all the very best on his eightieth birthday. What are the conditions of his birth and upbringing, what are the events in his life, and who are the personalities that influenced and moulded Yash Pal? What are his signal accomplishments in science, in the national development and in international spheres of activity, in education, not only at the universities in India, but also of the population as a whole? The purpose of this article is to provide answers to these questions; discursive as they might be within the compass of these pages, it is hoped that they may sum up to provide the reader an image of the many-faceted wonderful personality of Yash Pal.

From the cradle to the crucible

Yash was born in Jhang, a small town on the eastern bank of River Chenab in Punjab on 26 November 1926, to a family with highly ethical and cultural values. We may recall that just two years before his birth, the Nobel Laureate Abdus Salam was born in the same town and Wolfgang Pauli had introduced the concept of spin quantum number of elementary particles. During his early childhood and primary education, he lived a quiet and pleasant life with his parents in the desert town of Quetta, Balochistan, where his father was working for the Government of India, under the British rule. The peaceful life in Quetta was disrupted in 1935 by the 7.7 magnitude earthquake, in which an estimated 60,000 people died and much of the town was reduced to rubble. Fortunately, Yash and his brother were dug out of the collapsed house along with their sister and were sent to the village of Kot-Isa-Shah, to live with their maternal grandfather. The Indian Army was called in to clear the rubble and rebuild the rudiments of the town. After about a year in the village, the children rejoined their parents in Quetta and resumed their education. After a couple of years, their father was transferred to Jabalpur in the Central Provinces of India (Madhya Pradesh) and Yash and his family moved from the



desert climes of Balochistan to the lush green surroundings of Jabalpur on the banks of River Narmada. With such interruptions in the middle of his school years, his education continued. After about a year, fearing another transfer of his father to an unknown destination that would interrupt his education, Yash was moved to Lyallpur in Faisalabad to live with his aunt. But his stay in Jabalpur was not all in vain – Yash was introduced to self-study and more importantly came under the influence of a great teacher, Pawar, who adopted the Socratic method of teaching and a conversational style for his lessons, instead of the usual prepared lectures.

It was during his Lyallpur days that the deepest and the lasting influences on Yash's personality occurred. The Second World War was already raging in Europe and in the West and across Burma and Rangoon in the East. Within India, the civil disobedience movement had gained in strength under the leadership of Gandhi and the 'Quit India' movement was in full swing. Yash, as most persons of his generation, came strongly under the influence of Gandhi's ideas of freedom and egalitarianism, ahimsa, sincerity of purpose and effort that gave an inner dignity to the people transcending their station in life. He read Jawaharlal Nehru's *Towards Freedom*, an autobiography written in the Almora prison. No one who has read this book could escape admiring the courage, indomitable spirit, a delicacy and fineness in feelings and the sheer intellectuality that characterized Nehru's personality.

Yash matriculated in 1942 and went on to study B Sc in physics at the Punjab University. Here, too, destiny played a role in effecting an alchemy on his personality – a long period of sickness accorded his time to read and reread books by Thoreau and Tolstoy amongst others. He had moved to Lahore for continuing his studies in physics towards a M Sc degree at the Punjab University. By that time his father had been transferred to New Delhi. Yash went there for summer vacation. It was the year 1947, the summer was hot and Nehru gave the speech to the constituent assembly: 'At the stroke of the midnight hour, when the world sleeps, India will awake to life and freedom.' India had been partitioned into two countries: Pakistan and India. The riots had broken out and hundreds of thousands of refugees of the minority population started coming across the border into India. For Yash, there was no going back to Lahore to continue studies towards a Master's degree in physics. The government in Delhi was making frantic efforts to provide shelter to the refugees and feed them. In fact, the people of India had been mobilized, aid packages with whatever they could spare – food, old, discarded clothes and anything – were sent to the centres close to the border where refugees were given shelter. Yash volunteered and came into contact with personalities like Gandhi and Nehru, doing his best to serve. After all, Gandhi had pleaded, 'I ask of no man more than what he can give'.

In order to continue his studies, with great enterprise and with the help of several enlightened persons, notably

D. S. Kothari, a physics professor and several of his classmates from Lahore, Yash organized classes in physics, which were held in some army barracks, left vacant after the Second World War. At that time important discoveries were being made in England and America, in the field of 'particle physics' using photographic emulsions as detectors and Yash decided to learn this technique and carry out some research for writing his dissertation for obtaining his M Sc degree. But, where was he to find a lab, and wherefrom can he obtain the chemicals for making the photographic emulsions? Here the goddess of opportunity smiled upon him. He saw an advertisement for the position of a research assistant at the Tata Institute of Fundamental Research (TIFR), Bombay (now Mumbai) founded in 1945 by Homi Jehangir Bhabha. Even though the required qualification for the position was an M Sc degree, Yash secured the position and the support for completing his M Sc dissertation at TIFR – and thus began his illustrious career in science.

Cosmic rays and particle physics

Yash Pal's work on nuclear emulsions, as photographic emulsions are called when they are functioning as detectors of energetic charge particles, proceeded smoothly. Yash and a fellow student, Devendra Lal became close friends and collaborators. Lal was a bundle of energy and good humour. Their combined energies earlier devoted to pranks and escalated practical jokes, were now channelled to produce innovative solutions to practical needs of the experiments. The inseparable pair, Lal and Pal, had a wonderful stroke of luck – in 1950, Bernard Peters from the Rochester University came to visit a scientific conference organized by Homi Bhabha at TIFR, which had moved from 'Kenilworth' to the spectacular 'Old Yacht Club', next to the Gateway of India, at the mouth of the Bombay harbour. Earlier, in the fall of 1947, Marshak of Rochester University had visited Bristol, and impressed by the power of nuclear emulsion technique, had initiated a programme to study cosmic rays using nuclear emulsions, along with Helmut Brandt and Peters. Peters was to lead an American team to carry out a balloon flight in India to expose a stack of nuclear emulsions at high altitude in the atmosphere where the cosmic rays could penetrate without much attenuation.

Peters was a brilliant scientist and had received his Ph D degree working under the guidance of J. R. Oppenheimer. Lal, Pal and Peters became an inseparable trio. Peters was not very happy in America when McCarthyism was raging strong. Accordingly, he accepted the invitation of Bhabha to join TIFR and moved to Bombay.

Important scientific results pertaining to cosmic rays, high-energy interactions and new elementary particles started coming out in quick succession from the efforts at TIFR, with the trio as the main proponents working occasionally with M. S. Swami, T. Rama, R. R. Daniel, A. Krishnan, S. Mitra and others. Amongst these, the following papers are perhaps the most important both for their scientific value and for their influence on charting the course for the further contributions that were to follow from Yash Pal's efforts: (1) Production and interactions of mesons as very high energies (Lal, D., *et al.*, *Phys. Rev.*, 1952, **87**, 545), (2) Properties of heavy unstable particles (Lal, D., Yash Pal and Peters, B., *Phys. Rev.*, 1953, **92**, 438) and (3) Observations on τ-mesons and on K-mesons giving rise to capture stars (Lal, D., Yash Pal and Peters, B., *Proc. Indian Acad. Sci.*, 1953, **38**, 277). This was the beginning of Yash Pal's contributions to these fields; one was particle production at high energies and the second related to experiments that led to the discovery of 'strangeness quantum number'. A brief description of the $\tau - \theta$ puzzle and associated production of hyperons and K-mesons may be found in an article that described the scientific contributions of M. G. K. Menon[1].

Important developments took place in Yash Pal's life in 1954. He married Nirmal whom he had been courting for over a decade. Nirmal is a great personality, intelligent, sensitive, buoyant, cheerful, wise and practical. Bhabha, who had been very much occupied in the atomic energy programme, and in fact, in drawing up the architectural plans for building up the scientific and technological infrastructure of India, felt that it would be beneficial to send Yash to work under the guidance of Bruno Rossi at MIT, USA, who was engaged actively both in the field of cosmic rays and in deciphering the nature of K-mesons.

The associated production of K-mesons and hyperons like Λ^0, Σ^{+-0}, etc. were well understood mainly due to the work of Gell-Mann and Nishijima. A new quantum number strangeness, S, had been postulated, with the assignment $S = +1$ for K-mesons, $S = -1$ for the hyperons and $S = 0$ for the protons, neutrons, π-mesons and other particles which had been identified earlier. It was assumed that strangeness was conserved in the nuclear interactions that produced the K-mesons and hyperons. This explained why they had to be created in association with each other: the sum of their strangeness was zero, as was the strangeness of the normal particles which produced them. On the other hand, the hyperons decayed into protons or neutrons and pions, and K-mesons decayed into π-mesons, i.e. into particles having zero strangeness. The decay lifetime was long $\sim 10^{-10}$–10^{-8} sec. Thus it was clear that the 'weak' forces that were responsible for the decay did not conserve the strangeness quantum number.

This assignment of strangeness quantum numbers led to an interesting new phenomenon in the context of the neutral kaons, K_0 and $\bar{K}_0$, which Yash investigated along with members of Rossi's group at MIT. These are antiparticles of each other, connected by the C parity operator which changes particles to antiparticles. Since S quantum number of $K_0 = +1$ and of $\bar{K}_0 = -1$, the two particles have independent identities, as far as strong interactions are concerned, which conserve strangeness. Any transformation of K_0 to $\bar{K}_0$ involves a change in $\Delta S = -2$.

$$\mathrm{CP}|K_0\rangle \to |\bar{K}_0\rangle,$$

$$\mathrm{CP}|\bar{K}_0\rangle \to |K_0\rangle.$$

However, both K_0 and $\bar{K}_0$ can decay into two pions, π^+ and π^-, and mixing of the two can take place via the virtual process

$$K_0^0 \leftrightarrows \pi^+ + \pi^- \leftrightarrows \bar{K}_0^0.$$

We know from independent studies, that weak interactions conserve CP to better than 1%. Accordingly, we can form CP eigenstates by mixing them

$$|K_1\rangle = \frac{1}{\sqrt{2}}(|K^0\rangle + |\bar{K}^0\rangle);\ \mathrm{CP} = +1,$$

$$|K_2\rangle = \frac{1}{\sqrt{2}}(|K^0\rangle - |\bar{K}^0\rangle);\ \mathrm{CP} = -1,$$

so that $\mathrm{CP}|K_1\rangle = |K_1\rangle$ and $\mathrm{CP}|K_2\rangle = -|K_2\rangle$.

Now, for the conservation of CP, it can be shown that the allowed decay modes for these particles are

$$|K_1^0\rangle \to \pi^+ + \pi^- \text{ or } \pi^0 + \pi^0; \quad \tau = 5\times10^{-8} \text{ sec},$$

$$|K_2^0\rangle \to \pi^+ + \pi^- + \pi^0 \text{ or } \pi^0 + \pi^0 + \pi^0; \quad \tau = 9\times10^{-11} \text{ sec}.$$

The longer lifetime of K_2^0 is mainly because of the smaller phase space available for its decay into three pions. Note that K_1^0 and K_2^0 are not antiparticles of each other and as such will have different masses and, of course, different decay modes. Because of their different lifetimes, they are also referred to as *K*-short and *K*-long.

One of the key experiments in which Yash participated was to measure the difference between the masses of K_1^0 and K_2^0. To see how this experiment was carried out, we may note that a beam of K_0 particles, created in high-energy collisions, while propagating will behave like an admixture of K_1^0 and K_2^0 particles, each of which has a well-defined mass. Starting with an ensemble of K_0 mesons, a straightforward application of quantum mechanics predicts an intensity, $I(\bar{K}_0, t)$ for the $\bar{K}^0$ particles with time

$$I(\bar{K}_0,t) = \frac{I_0}{4}\left[e^{-\frac{t}{\tau_1}} + e^{-\frac{t}{\tau_2}} - 2e^{-\frac{\tau_1+\tau_2}{2\tau_1\tau_2}t} \times \cos\left\{\left(\frac{\Delta m}{\hbar}\right)t\right\}\right].$$

The above equation shows that the intensity of $\bar{K}_0$ particles in a beam is zero at time $t = 0$, but it will increase to a maximum at later times and will have an oscillation superimposed on an exponentially decaying intensity. By measuring $\bar{K}_0$ as a function of distance, through its ability to generate hyperons like Λ^0 in its interactions, Δm can be estimated. The best value of Δm measured today is given by

$$\Delta m = 3.5 \times 10^{-6} \text{ eV},$$

or $\Delta m/m_{K_0} \approx 7 \times 10^{-15}$ (remarkable measurement indeed).

Yash successfully defended his thesis and obtained his Ph D from MIT in 1958. And when he returned to India. Peters had already made arrangements to move to Denmark, to lead the space science activities there. Notwithstanding this, their collaborative efforts continued.

From particle physics to astroparticle physics and astrophysics

Yash continued with his interest in particle physics at TIFR working with Siddheshwar Lal analysing cosmic ray interactions recorded in cloud chambers. Soon many students flocked to him – Asim Roy, T. N. Rengarajan, Ramanath Cowsik, Shyam Narayan Tandon, Ram Prakash Verma and many others. His style of guiding students was unique. He provided a benevolent umbrella under which the students could grow intellectually, and develop their individuality and creativity. Once the student had made some progress, he will have a long and thorough discussion of the developments bringing his intellectual and aesthetic sensibilities to bear on the problem. The room would be filled with smoke from his pipe and Trichinopoly cheroots, which he would light up when the pipe became too hot. There would be long pauses in the conversation, sometimes lasting as long as half an hour, during which he would be thinking deeply about the points under discussion. And when he emerged from his contemplation, he would state clearly the next course of action.

Yash continued the study of high-energy interaction with stacks of nuclear emulsions exposed to beams of protons of 24 GeV and pions of 17 GeV at the particle accelerators in Geneva, Switzerland, at the 'Conseil European pour la Recherche Nucle'aire (CERN)'. Armed with the insight gained from these studies, he took up a visiting professorship at the Niels Bohr Institute in Copenhagen to work with Peters on modelling high-energy interactions and applying the model to understand the propagation of cosmic rays through the Earth's atmosphere.

The 'fireball–isobar' model developed by Pal and Peters rests on two experimentally observed features of particle production in high-energy interactions. The pions produced in the interactions seemed to prefer to move close to the direction of the high-energy projectile, so that the transverse component of their momenta was small, on the average ~250 MeV, irrespective of their own momenta or the energy of the primary particle; the number of particles also increased with their energy of the primary particle. Secondly, there were very energetic pions produced in the collisions, which appeared to have a memory of the charge of the incoming projectile. For example, an incoming proton produced preferably positive pions of high energy and neutrons produced more of negative pions, both of course with low transverse momenta. In the model developed by Pal and Peters, the colliding particles (in the centre of momentum frame; CMS for short) invest about 30–40% of their energy in creating a fireball of pions and particle–antiparticle pairs. The number of these particles increases with the energy of the incoming particles in the CMS, so that the temperature of the fireball does not increase beyond several hundred MeV. Thus, the pions radiated by the fireball emerge from the collision with low transverse momenta.

The colliding particles themselves emerge from the collisions in excited states, called isobars, which deexcite with the emission of pions. These pions have small transverse momenta but carry, on the average, about 10% of the energy of the projectile and also have charges, which on the average reflect those of the parent particles. As the spectrum of primary cosmic rays is steep, $f(E) \sim E^{-2.7}$, the leading particles emerging from the decay of the isobars dominate the spectra of the secondary pions which will also have the same spectrum, $E^{-2.7}$, at production. This model of Pal and Peters was successful in explaining the observed spectra and charge ratio of muons in the atmosphere, which arise from the decay of the pions. This was the first application of 'scaling' of cross-sections in high-energy collisions, even though the current ideas of scaling have become more sophisticated, after the advent of quark and parton models. All the same, the model of Pal and Peters provides an excellent framework for calculation of the secondary spectra cosmic rays.

About halfway through his two-year sabbatical at Copenhagen, Yash accompanied by Peters visited TIFR for a short period during which Yash initiated his students in the rudiments of the isobar model and set them the task of calculating the fluxes of neutrinos and antineutrinos of various kinds arising from the decay of pions, kaons and muons created by cosmic rays in the Earth's atmosphere. Armed with foot-long multi-log slide rules, his students took up the challenging task. At that time, not even all the decay modes and branching ratios of kaons were known. But TIFR was a wonderfully vibrant institution and one could estimate these by consulting persons like K. V. L. Sarma, G. Rajasekharan, V. Gupta and several others, who were fully engaged in the study of elementary particles. Fortunately, for the students, Pal and Peters came back to TIFR in the summer of 1963 to continue their work and get it ready for presentation at the International Cosmic Ray Conference, which was to be held at Jaipur, in December. The students could consult with them and complete the calculations, along with brief notes as to how one may detect the neutrinos underground or with large balloons filled with pure water and submerged in a lake or ocean. Along with major contributions by Peters and Pal to the conference, a short note on the neutrinos was also submitted by Pal and his students. Not surprisingly, the work of Pal, including the possibility of detecting cosmic-ray neutrinos, evoked significant interest in the community of cosmic-ray scientists. Subsequently, Pal wrote two major papers, one with Peters on the fireball–isobar model for particle production as applied to cosmic rays and the other with his students on atmospheric neutrinos and the methods of their detection.

Thereafter, Yash Pal's interests turned towards the transport of cosmic rays in the Milky Way Galaxy and related astrophysical and cosmological problems. In 1964, he and his students considered the question – is it possible that the Universe is filled with a sea of neutrinos and if so, what is the bound on the Fermi-energy of such a sea? When a highly energetic cosmic ray, almost at the end of the observed cosmic-ray spectrum moves through such a sea, in the reference frame of the cosmic ray the neutrinos will appear to be very energetic and will interact with the cosmic-ray particle generating electrons, muons and other particles. Of course, the energy needed for the production really comes from the cosmic rays. Such processes would induce a cut-off in the spectrum of cosmic rays at very high energies and having observed the cosmic-rays up to $\sim 10^{19}$–10^{20} eV, one can set a bound of ~2 eV on the Fermi energy of such a neutrino sea. Later, when the cosmic microwave background was discovered in 1965, showing that the Universe was filled with radiation at ~2.7 K, it was precisely this kind of consideration that led Greisen, Zatsepin and Kuzmin to predict the end of the cosmic-ray spectrum at $\sim 10^{20}$ eV.

Turning our attention towards Yash Pal's studies relating to the transport of cosmic rays in the Galaxy, we note that the motivations were provided by the somewhat paradoxical nature of the spectra of secondary nuclei like Li, Be, B in comparison with those of the primary nuclei such as C, O, Si and Fe. Suppose we place a slab of matter of sufficient thickness to produce the secondaries through spallation reactions, two difficulties are encountered in fitting the spectra: First, energy losses suffered by the nuclei in ionizing the atoms in the slab lead to a cut-off at low energies that was more severe for heavier nuclei. Secondly, the observed spectrum of the secondaries and the primaries could not be matched for any thickness of the slab. The key idea to resolve this difficulty was that there was a steady state established for the density of cosmic rays within the Galactic volume that represents a balance between the injection of the cosmic rays into the volume by sources like the supernova remnants and their subsequent leakage from the Galaxy into the intergalactic volume. In other words, there was a distribution of sources within the interstellar space and the cosmic rays diffused throughout the volume generating secondary nuclei through collisions with the interstellar gas, and escaped with an effective time constant, out into the intergalactic space. This idea was effective in removing the apparent discrepancy between the spectra of various primary and secondary nuclei in the cosmic rays. The idea was also applied successfully to understand the spectrum of cosmic-ray electrons which suffer energy losses due to Compton scattering on the photons constituting the cosmic microwave background.

With a clear understanding of the propagation of cosmic rays through the atmosphere, Yash Pal collaborated with Gaurang Yodh in getting the first evidence for a slight increase in the p–p inelastic cross-sections with energy, a feature that was later confirmed by experiments at the accelerators.

In the 1960's Yash Pal and his group developed a magnetic spectrometer for cosmic ray studies. In many ways it was a remarkable instrument. Using nuclear emulsions coated on the glass plates, it was capable delineating the trajectory of cosmic rays with an accuracy of ~1 μm over ~50 cm before and after the particles were deflected in a 3 K Gauss field of a permanent magnet. The tracks were also photographed using a pair of wide-gap spark chambers, which sandwiched a centimeter thick lead plate that would convert gamma rays into electron positron pairs. This instrument had a maximum detectable rigidity of ~40 GV/c and was thus capable of measuring the spectra of cosmic rays up to this rigidity. It could also be used to search for anti-nuclei in primary cosmic rays. The lead-spark-chamber sandwich could record gamma rays from cosmic sources – a pioneering instrument indeed. This instrument was flown over Hyderabad in a balloon at ~115,000 ft above sea level for a few hours. The data that were collected yielded the spectrum of the nuclei and an upper bound on anti-nuclei in cosmic rays. Further balloon flights could not be carried out due to lack of funds.

In response to the nation's call

After the sudden demise of Vikram Sarabhai, Satish Dhawan assumed the position of Chairman, Space Commission in 1972. He was firmly of the opinion that the space programme in India must be driven by application that would benefit every citizen of India. Sarabhai had already initiated the Satellite Instructional Television Experiment (SITE) that would transmit instructional television programmes to villages in India for a period of about one year, utilizing the powerful transponders on the American geosynchronous ATS-6 satellite located over Kenya. The Satellite Applications Centre (SAC) had been just set up in Ahmedabad and SITE was one of its key objectives. Dhawan persuaded Yash Pal to take the position of Director at SAC, Ahmedabad and oversee the SITE programme. Yash plunged into the task. It was here that the alchemy effected on him by the independence movement, and the deep values and societal concerns ingrained into him by Gandhi and Nehru found full expression. On 1 August 1975, almost 28 years after he stood next to Nehru as a volunteer bodyguard amongst the refugees in Delhi and almost 28 years after India had attained independence, the earth stations set up with indigenous effort in Ahmedabad and Delhi transmitted television programmes on education for children, agriculture, animal husbandry, hygiene, health and family planning that were beamed back to Earth by the ATS-6 satellite and received by 2400 direct-reception TV sets in 2400 villages located in Andhra Pradesh, Bihar, Gujarat, Karnataka, Madhya Pradesh, Orissa and Rajasthan, where people spoke different languages. More than 1500 persons – engineers, physical and social scientists, film makers, media persons, educationists and villagers who spoke only the local dialect and who lent their image and voices to the programmes that were broadcast – all had participated in the grand effort orchestrated by Yash Pal. This was one of the greatest mass communication experiments ever undertaken.

How was this accomplished? The saga of SITE and other important developments like remote sensing taken up by SAC have written up elsewhere, and a few quotes from Yash Pal will suffice here: 'I think we tried to do everything ourselves and succeeded in most cases – there were marvellous people at SAC – young people who grew in an amazing way.' When the SAC engineers with some advice and technical support from Govind Swarup and V. Radhakrishnan had succeeded in building the high-quality low-noise amplifiers needed for the programme, Yash remarked 'This I consider a very important moment in building confidence – had SAC engineers been denied the chance, it would have been difficult to develop the atmosphere of creativity that came to pervade SAC…a civilization that protects its young from the hassles of doing things themselves deprives them of great joy and ultimately leads its society into a state of permanent dependence.' 'All were emotionally involved in the project. It wasn't that it suddenly came. It was wonderful to discover that when the objective has value and you seek help, worthwhile people consider it a favour that you asked them.' In retrospect, Yash commented, 'For the 1500 people directly engaged in the experiment, SITE was a deep human experience. It generated new capabilities, demystified space technology, and helped nucleate a large island of confidence. But of far greater significance was the generation of new kinship between technologies and the grass roots problems of the country, a common concern for the ultimate social and human goals'. In 1976, Yash Pal was awarded the 'Padma Bhushan' by the Government of India, in recognition of his contributions to science and space technology. A few years later, in 1980 he was awarded the Marconi Fellowship in recognition of his 'wise and humane leadership in applying modern communications technology to meet the needs of isolated rural villagers in India'. This international award had been established to recognize an outstanding individual for lasting contributions to human progress through innovations in telecommunications technology or sciences.

On the world stage

The high regard in which he was held by the world community of space scientists, administrators and entrepreneurs propelled Yash Pal onto the world stage. The Secretary General of the United Nations, Javier Pérez de Cuéllar, invited him to be the Secretary General of the Second UN Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE-II), which was to be held in Vienna, Austria in 1982. Leaving the mantle of leadership of SAC Ahmedabad on the able and experienced shoulders of E. V. Chitnis, Yash moved to the United Nations Headquarters in New York, in order to lay the groundwork and to create an atmosphere of cooperation amongst the nations in utilization of 'space' and organize the conference that would later endorse the broad guidelines for space exploration and use. Again the guiding principle was Gandhian egalitarianism. The benefits accrued through space exploration and activities in space should be for the benefit of the whole of mankind. There should be a broad-based cooperation amongst the nations. Apart from purely conceptual aspects, mechanisms for engendering the cooperation and the rules and guidelines for conducting activities in space had to be developed to avoid conflicts of interest or monopoly. For example, the work being carried out under the auspices of Union Radio-Scientifique Internationale (URSI), in the allocation of frequencies and bandwidths for radiocommunications and radio-astronomy, etc. had to be extended to satellite-based communications as well. The conference was a great success. As we have seen on numerous occasions when Yash is in the chair, so it was during UNISPACE-II, the nations set aside their narrower goals, and agreed to cooperate for the betterment of mankind.

Back to planning India's development

After meticulously consolidating the gains that UNISPACE-II accorded towards cooperation amongst the nations in the utilization of space, Yash returned to India in 1983 to serve as the Chief Consultant to the Planning Commission.

A singular achievement during the period was the establishment of high quality communication system in the power sector of the country. We are living in an era of communications and the connectivity enabled by easy and speedy communication between stations and individuals far removed from one another has revolutionized not only the power sector but all aspects of our life today.

The then Prime Minister of India, Indira Gandhi, appointed him as the Secretary, Department of Science and Technology (DST), New Delhi with a concurrent responsibility as the Advisor to the Planning Commission. Not long thereafter, a great tragedy struck the country – Indira Gandhi was assassinated. We may well imagine the shock waves this event sent through every aspect of the life of our nation and its governance. Rajiv Gandhi took over as the Prime Minister and was soon able to infuse a sense of confidence and stability back into the people. Rajiv believed that we needed to rejuvenate the education system in the country, especially at the level of the universities. He persuaded Yash Pal to give up his position as the Secretary, DST and take over the University Grants Commission, as its Chairman.

There were three key ideas that Yash persued in his efforts to improve the quality of education in India. After independence, the research activities had moved steadily away from the universities into a small number of research institutes, which certainly were carrying out important research and contributing to the nation's growth and capabilities, but did not have the mandate to influence the education at the university level. At the same time, the research being carried out at the universities had become less dynamic due to lack of facilities and support. To remedy this, Indira Gandhi had already approved in 1984, the setting-up of state-of-the-art major facilities which the universities could claim to be their own, a place where the faculty and students could go to carry out their experiments. Yash oversaw the establishment of two of the very first such facilities: the first to be approved and completed in 1990 was the Inter-University Accelerator Centre (IUAC), also called Nuclear Science Centre, located in the southern part of New Delhi, close to the Jawaharlal Nehru University campus with Ayagiri P. Patro as the founding director. It houses one of the largest tandem accelerators, 15UD-Pelletron and other accelerators like superconducting linear accelerator and related facilities. Several research groups from hundreds of academic institutions within India and occasionally institutions from other countries make use of this facility. The second is the Inter-University Centre for Astronomy and Astrophysics (IUCAA) set up in 1992 with Jayant Narlikar as the founding director, on the Pune University campus and in close proximity of the Giant Meterwave Radio Telescope at Narayangaon in Maharashtra. IUCAA maintains a 2 m optical telescope at Girawali nearby, and operates the 'Virtual Observatory Project'. Besides providing facilities to the universities, IUCAA is involved in the popularization of astronomy and other sciences.

Yash brought in, two more innovations that would positively impact the educational profile of the country. First was the Information and Library Network (INFLIBNET), which connects the libraries of a large number of universities, thereby providing a wider access to students and research workers, and stimulating interaction and cooperation amongst them. The second was to change the status of many of the national laboratories and institutes into 'deemed universities', allowing greater number of students to benefit from the state-of-the-art equipment and from interactions with the excellent research scientists in these places.

President Pratibha Patil conferred the Lal Bahadur Shastri National Award 2011 on Prof. Yash Pal.

President Pranab Mukherjee presenting Padma Vibhhushan to Prof. Yashpal at Padma Awards 2013 at the Rashtrapati Bhavan in New Delhi.

It is important to mention the other two ideas he worked on as well, even though their relevance to education in India has not been realized fully. Scientists, like everybody else, have realized that the realm of knowledge has become so wide that only the specialist understands his particular narrow field of study and often not what is happening even in nearby fields. Yash Pal felt that real education and real progress could occur if and only if a wider interdisciplinary awareness is present. He wanted to move away from highly specialized education at the university and diversify the curricula, and lower the barriers between departments within the universities. He felt that a student should get an education in liberal arts, choosing the subjects of his study as physics, philosophy and dance if he so wishes, and not be narrowly confined to study only closely related fields. The second idea is that, education should not be the privilege of the very few who could afford it. India should educate the people living in the poorest and most isolated villages and this should be achieved through the mobilization of university professors and students who could go into these villages and study the conditions and find out what kind of education is relevant. He could not achieve this mobilization. However, he found the means to bring about a change in his own inimitable way.

Science and education for all

His concern with the people of India and the attitude of inclusiveness was no fetish or a political posture, but stemmed from a genuine concern and a heightened awareness created in the crucible of the independence movement. In fact, his universal appeal, whether amongst school children, villagers, scientists or with international diplomats or senior statesmen like Indira Gandhi and Rajiv Gandhi arose from his true conviction and sincerity about what he was saying and what he believed. Even after he demitted his office as Chairman of UGC, he joined a programme of national regeneration, Bharat Jan Gyan Vigyan Jatha – under the auspices of the National Council for Science and Technology Communication (NCSTC), mainly due to the initiatives taken by P. N. Hakser, who had served as the Principle Secretary of the Government of India, under Prime Minister Indira Gandhi.

Yash Pal as the Chairman of NCSTC did not feel alienated with other organizations that were also trying to bring education and science into the lives of the underprivileged people. NCSTC in itself, almost from its very inception, was a transformative kind of a movement involving several tens of thousands of villages. To him only the objective mattered, not which organization got the credit. From very early on, he was a popular personality on the television programmes, the great explicateur, with an easy command over the Hindi and the English languages, besides many others.

With his charismatic personality and his desire to communicate science to everyone, especially to the children and youth, Yash Pal was naturally drawn into 'Turning Point', a television serial in which he would answer questions about the scientific bases for everyday phenomena that children had observed. They would send him letters, hundreds of them every day, and he would pick a few that he would answer during the programme. At one time, M. G. K. Menon had suggested that such programmes should be telecast by Doordarshan and with Yash Pal's zeal it had become a reality – over 150 episodes had been broadcast before it gave way to other similar programmes. In these episodes too his emphasis was more on the process of enquiry and learning on the answer itself. His engagement with children and science has continued in a variety of ways. He has put in great effort to make primary and early stages of education relevant and not just a burden of facts without meaning.

Amidst this great effort he invested into education and popularization of science, Yash Pal managed to keep close contact with major research projects in the fields of his interest. He served as the Chairman of the Project Management Board for the establishment of the 2 m Chandra Telescope for optical and infrared astronomy, at an altitude of 15,000 ft in Hanle, Ladakh and the construction of Ultra-Violet Imaging Telescope (UVIT), to be launched into space orbit soon by ISRO, two of the most noteworthy indigenous efforts in astronomy.

He experiences a deep spiritual joy seeing the beautiful and logical connections between the microscopic and macroscopic worlds, in the connections between the living and the non-living and indeed amongst all ramifications of Nature. It is this all-embracing connection that he feels towards one and all, that makes Yash Pal unique, and it is this bond that gives him the energy to participate and contribute wonderfully to the life around him.

1. Cowsik, R., *Curr. Sci.*, 2013, **105**, 522–526.

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