Devendra Lal (1929–2012)

'*For a physicist, the best chemist there is*', thus did, J. R. Arnold introduce the quintessential Lal to the Fellowship of the US National Academy of Sciences, on his election to that body, adding, how his deep insights into the interactions between high energy particles and the tenuous footprints etched in their passage through naturally occurring chemical systems led to a trail blazing approach to study planet Earth's evolutionary dynamic as well as that of early solar system processes. Devendra Lal's insatiable curiosity, imaginative mind and indefatigable zeal which health issues could never defeat, resulted in a rich repertoire of enduring science chronicled in over 200 scientific publications that he continued to contribute to human knowledge right up to his highly private extinction on the first day of the closing month of 2012, 10 weeks short of his 84th birthday.

Lal was the fifth child born to middle class parents in the ancient city of Benaras situated on the banks of the river Ganga. Here, he received all his education, cleaving his way through the various constraints of means and circumstance to a University degree in physics by dint of an urgent curiosity and the torch of an inventive mind. His inherent strength of overcoming an apparent limitation by an imaginative solution, manifest in his boyhood strategies to earn some pocket money by making and selling ordinary objects of everyday use such as fountain pen ink and toiletries, would appear again and again in various contexts of his later scientific career. An iconic example is his use of iron hydroxide impregnated sponges and fibres for *in-situ* concentration of key trace elements and isotopes from tonnes of sea water, to track the large scale circulation in the oceans. Lal's keen sensibility to scientific possibilities in solving societal problems such as availability of clean water, often urged the trial of such promising approaches to concentrate out unwanted contaminants such as arsenic from our water sources, by designing appropriate materials.

Lal, an amateur researcher since childhood, plunged into a serious study of the composition and energy spectrum of primary cosmic rays at balloon altitudes, using specially designed nuclear emulsion stacks, under the guidance of Homi Bhabha, at the Tata Institute of Fundamental Research which he joined in 1949. Here he and his colleagues also began studying the characteristics of nuclear interactions of high energy cosmic rays and were soon joined by Bernard Peters, the co-discoverer of the heavy nuclei component in primary cosmic rays. They followed the recent discovery of *K*-mesons, the rare insignia of the strange particle physics, by the Bristol Emulsion group under Powell, by studying their production characteristics. This resulted in the widely acclaimed discovery by the TIFR trio, Lal, Pal and Peters, of the associated production of *K*-mesons with the capture of negative *K*-mesons.

The future of *K*-meson physics, however, clearly lay with Bevatron accelerators such as those at Brookhaven National Laboratory, which had already started producing *K*-mesons. Therefore, the announcement at that time of the discovery by Libby and his associates, of radiocarbon (^{14}C), produced in the atmosphere by the interaction of cosmic rays with atmospheric nitrogen, persuaded Lal and Peters to look for other similarly produced longer lived radio-nuclides, such as ^{10}Be with a half life of 1.5 million years compared to just 5,700 years of ^{14}C. Lal and his colleagues were finally able to isolate ^{10}Be from ocean sediments and detect its extremely feeble beta radioactivity. Relentlessly, they proceeded to isolate several other cosmogenic isotopes sequestered in various earth archives: ^{7}Be, ^{33}P, ^{28}Mg, ^{136}C, ^{38}S and ^{32}Si. These radionuclides covering a wide range of half lives and chemical affinities held the promise of tracking a host of dynamic Earth processes, when accelerator mass spectrometers, still in being, would become widely available. Meanwhile, realizing that a quantitative estimation of Earth and hydrological process rates using these isotopes would require a knowledge of their primary production rates in the atmosphere, Lal and Peters worked out these basic numbers that appeared in a landmark paper in the *Handbook of Physics*. Thus, he and his colleagues systematically laid the foundations of a pioneering approach, greatly refined by Lal in the past few decades, which has since been fruitfully applied to gain new knowledge and to advance our understanding of the basic processes operating in various planetary reservoirs: erosion and incision rates, ages of transitional events in the Earth's changing environment, sedimentation on the ocean floor and circulation, scavenging and precipitation in the atmosphere, with yet more possibilities in the future.

Ever alive to the revolution of possibilities, Lal turned his lately developed tools to probe cosmic-ray signatures in meteorites, especially those ingrained during their passage through the atmosphere-free space. Thus he and his colleagues expanded the arena of their enquiry far above the Earth's surface reservoirs of radionuclides into space, resulting into numbers characterizing the palaeo-intensity of cosmic rays in the galaxy and exposure history of meteorites in space. Therefore when the first rare rock samples plucked from the moon's surface were brought to Earth, Lal's laboratory became a natural choice for NASA for studying material processes induced by the gaze of solar radiation. These studies, in turn, provided new knowledge on several planetary, solar system and astrophysical processes, notably, the composition and energy spectrum of heavy iron group particles ($Z > 22$) in galactic cosmic rays and the exposure history of lunar regolith.

After 1959 when Lal spent a few months at the Scripps Institute in San Diego as a visiting researcher, he became a regular visitor and later a professor at Scripps, dividing his time between India and the US. Thus he continued even when persuaded to move to Ahmedabad as Director of the Physical Research Laboratory (PRL), uncompromisingly preserving a substantial research space in the midst of his administrative chores,

whilst simultaneously seeding new dimensions to the science-scape of PRL.

Lal's enduring contributions to scientific knowledge have been widely recognized by world academies whose fellowship he adorned with rare distinction. Many honours and awards too were showered on him, which he wore with characteristic humility and disinterestedness. A long time collaborator, P. B. Price, recounts how an undying curiosity and an adventure of ideas constantly possessed Lal. A letter that he received many years ago, whilst Lal was still in the throes of a delirious fever, expresses it eloquently, 'I have been thinking of all sorts of experiments and many in fact were a great success in my dreams. So, I thought I should write to you about several of these….'

No written account of Lal's work can capture the full range of his impassioned life and none would adequately describe the essence of its romance without the picture of his soulful companion and wife Aruna Lal who became an indistinguishable component of the colourful fabric of their life and work. Aruna's passing away in 1993 made Lal increasingly more remote even as he bore her absence stoically and plunged deeper in his work, which continued undiminished except for brief periods in and out of nursing homes. The Aruna Lal foundation that he established in her memory at PRL, Ahmedabad to support bright young students through college and to distinguish creative young minds engaged in researches of Earth and space environments, as well as endowments at TIFR and the University of California to support bright young scientists, expose another of Lal's understated passions for catalysing creativity and excellence. Many of his former students recall his persistent questioning about the novelty and originality of their work, constantly urging them by his own example to strain their scientific work towards the rigorous and the imaginative. They warmly recount how his expansive mind expressed itself in opening new vistas at every turn, explorations whose outcomes have shaped the lives of his students and colleagues, many of them carrying the torch forward to make notable scientific contributions themselves.

Devendra Lal finally departed this life in splendid isolation – his characteristic ethic winning to the end, leaving behind a host of friends and admirers whom the memory of a charismatic scientist, at once warm and remote, will forever haunt.

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Sri Niwas (1946–2012)

An abrupt end to the illustrious career of Sri Niwas, as teacher and researcher, came on 15 November 2012. He was born on 4 July 1946 in the village of Rakahat in Gorakhpur (Uttar Pradesh) to Smt Indrasana and Sri Ram Adhar Pandey.

Sri Niwas was closely associated with the Banaras Hindu University (BHU), having earned all his post-secondary degrees (B Sc Hons 1966, M Sc Geophysics 1968 and Ph D 1974) from the university. His Ph D thesis was entitled 'Theoretical treatment of some problems on electrical behaviour of layered earth system'. After earning his doctorate from BHU, Sri Niwas joined the Indian Institute of Technology Roorkee (then, University of Roorkee) as a post-doctoral fellow in 1974. He worked at the institute in various capacities: a Pool Officer (1976–1977), Lecturer (1977–1979), Reader (1980–1991) and as Professor (1991–2011). He is credited with founding the Department of Geophysics at the University of Kurukshetra in 1989. Though he superannuated from IIT Roorkee in 2011, he continued his association with the institute as a Professor-Emeritus until his demise. He served as a Visiting Professor at the Federal University, Bahia, Brazil during 2000–01. He was an excellent teacher and always championed the cause of students which is reflected in his continued and long-lasting relationship with them.

Sri Niwas, along with Vinod K. Gaur (who was then at IIT Roorkee) and several other faculty members, designed a course curriculum in geophysics with an ideal blend of both theory and practice. This served as a model for a long time and motivated other geophysics departments in the country to modernize their course structures. Apart from his contribution to the growth of geophysics education in the country, Sri Niwas also profoundly impacted research in geophysical exploration that included inversion of geophysical data, geo-electromagnetism and geo-hydrology (exploration, development and management of groundwater). He was a strong advocate of hypothesis-driven research and argued for examining a physics-based relationship between input and observation.

He pioneered applications of inverse theory to several geophysical problems in the country. He extensively used geo-electric exploration – a tool vital for imaging the near-surface subsurface, for exploring and exploiting natural resources and managing the environment. The near subsurface is taken as stratified media with layers having variable thicknesses and the main challenge lies in resolving this thickness with innovative experimental design and interpretation methodologies. Sri Niwas devised suitable, simplest approximations of system matrix function in terms of exponential