as Director of RRI, he continued to work at RRI until 2010 as Homi Bhabha National Professor and then as Emeritus Professor. He continued carrying on his scientific research with his child-like curiosity in exactly the same manner as before until his last days. He co-authored four books and over 200 scientific publications in reputed journals over his lifetime.

Kumar was a generalist – nothing ever limited his interest. Everything and every question was amenable to scientific analysis, be it why trees grow so tall or why is the night sky not bright. He was filled with wonder about the world and had an unquenchable thirst to finding answers. He would often say that he only needed to look at the beautiful star-filled night sky to be inspired to do science. His enthusiasm would rub-off on all his students and colleagues who always found his company intellectually stimulating and invigorating. He had an absolute insistence on mathematical rigour and in turn wondered at the 'unreasonable effectiveness of mathematics in physical sciences and in natural sciences in general'. For him, the very process of solving the problem was to be savoured. As his student, Anil Kumar Abburi, recalls, upon realizing a solution to a problem, Kumar said 'Give me a few minutes, I want to enjoy this moment.'

The problem of the zero-point energy fluctuations was very dear to him and he was never tired of wondering if that meant actual motion in the ground state in the sense of Nelson's stochastic mechanics, knowing fully well that such questions could not be answered within the traditional Copenhagen interpretation of quantum mechanics. He was obsessed by the possibility of a first passage time for a quantum mechanical particle in analogy to the Kramer's first passage times for a diffusive process. That he began working on these theoretical questions in early 1980s and managed to deliver a partial solution only in 2014, speaks volumes of his tenacity to seek solutions to difficult problems. General relativity was another subject especially close to his heart.

Kumar was much more than just a physicist. He was a wonderful human being, full of affection for his students and colleagues, all of whom he treated equally. He always put his students' interests ahead of his own interests. He believed in the goodness of human nature and tried to see the virtuous side of everybody. Interactions with him were most pleasant and in general, everybody came out from a meeting with him feeling happy and enlightened. Most colleagues regarded him as most outstanding, both as a scientist and a human being. In every sense, he was truly Narendra (which means *King of men* in Sanskrit).

Over the past three years, Kumar had some health issues. But he bounced back from each crisis into his vivacious jovial self, thinking about interesting aspects of life. He finally passed away in the early hours of 28 August 2017 after an illness of about ten days. The Indian physics community lost an iconic figure, leaving a vacuum in the hearts of all who knew him. He is survived by his wife, Ann Kumar, and daughters, Revathi – a physical chemist and Rohini – a mathematician.

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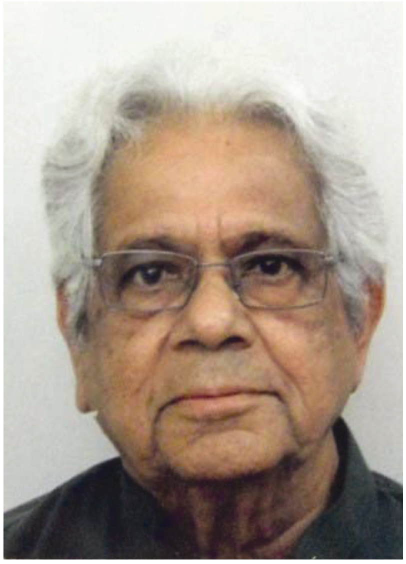
A. T. Natarajan (1928–2017)

Adayapalam T. Natarajan (ATN) whose name has became synonymous with radiation cytogenetics and biodosimetry over the past few decades, passed away on 28 August 2017 in Leiden, The Netherlands, where he had lived for over fifty years. ATN was introduced to cytogenetics by one of us (MSS) in the mid 1950s in the Botany Division of the Indian Agricultural Research Institute, New Delhi. In fact, he was the first research scholar to obtain the Degree of Doctor of Philosophy (Ph D) under the guidance of MSS. During 1964–65, ATN taught an advanced three-credit course in cytology and PCK credited this course. It thus happens that a teacher (MSS) and a student (PCK) of ATN now jointly recall their association with him and place on record their tribute to a great scientist, ardent lover of carnatic music, and a great humanist. He was an India-born international citizen.

ATN was born on 5 May 1928. Twenty years later, in 1948, he started his research career in the Department of Botany at Annamalai University in southern India. In those days, under the British system, submission of a thesis with original research was the mode to get a Master's degree. So, ATN specialized in systematic botany, describing the morphology of pollen grains in the subgroup Tubiflorae, family Solanaceae. He used to describe about his introduction to microscopy, which was a mono-ocular microscope with sunlight for illumination. Not just the microscope, but cytogenetic studies in the early 1950s at Annamalai University involved a time-consuming method of making microtome sections of wax-embedded root tips and focusing up and down with the microscope to make camera-lucida drawings.

ATN's days at Annamalai University came to an end with the appointment of a new professor of Botany there. Due to difference of opinion, he moved to the Indian Agricultural Research Institute (IARI), New Delhi, joining the postgraduate course leading to a diploma known as 'Associate of the Indian Agricultural Research Institute'. In later years, ATN reminisced that he was extremely fortunate to get a research assistant position under an enthusiastic young scientist (MSS). ATN in many short conversations bordering on nostalgia with PCK, would gratefully acknowledge the encouragement provided by MSS to do his Ph D. So, ATN became the first Ph D student under MSS.

In his biography of M.S. Swaminathan (*M.S. Swaminathan: Legend in Science and Beyond*, The World Scientific Publishing Co, Singapore, 2017) PCK has described several epoch-making research papers published jointly by ATN and MSS in top international journals like



Nature, *Science*, *Radiation Research*, *Mutation Research*, etc. In retrospect, it becomes glaringly evident that the MSS–ATN era during late 1950s and mid-1960s put the Indian research contributions to radiation and chemical clastogenesis among the very best in the international map. ATN's thesis not only got him the Ph D degree from the University of Delhi, but also a Rockefeller Foundation Fellowship to do research in USA and Sweden. During 1959–61, ATN made two important discoveries. In USA, he was a contemporary of J. Herbert Taylor who demonstrated the semi-conservative replication of DNA in plant chromosomes (*Proc. Natl. Acad. Sci. USA*, 1957, **43**, 122). ATN published an equally epoch-making paper on the quantitative evaluation of chromosome breakage following incorporation of tritiated thymidine (^{3}H-TdR) in the root-tip cells of *Viciafaba* (*Exp. Cell. Res.*, 1961, **22**, 275–281). His other noteworthy paper, contrary to the then prevalent view, was that the radiation-induced free radicals do not decay very fast in dry seeds (ATN had used barley and maize seeds) and the long-lived free radicals enhance the efficiency of chronic irradiation. This was published as the first paper in the first issue of a new journal *Radiation Botany* launched by Arnold Sparrow, an outstanding radiation botanist at Brookhaven, USA. ATN titled his epoch-making paper, 'The time intensity factor in dry seed irradiation' (*Radiation Bot.*, 1961, **1**, 1–9). However, he had a very special and fond memory of his days in Stockholm, Sweden at the Forest Research Institute and the Biochemistry Department of Stockholm University. His professional association and friendship with Prof. Lars Ehrenberg and Prof. Gunnar Ahnstrom influenced his destiny in Europe (he had a Dutch passport), both in his scientific and personal life.

Back in his laboratory at the Botany Division, IARI, in the late 1960, ATN actively collaborated with MSS. He gathered around him several brilliant young students of the PG School of IARI to carry out their doctoral research programmes under his guidance. In collaboration with MSS, ATN worked on indirect effects of ionizing radiation and published highly noteworthy papers which established that not just the direct exposure of organisms to ionizing radiation but also to the radiolytic products (i.e. hydroxyl radicals, long-lived hydroperoxides, hydrogen peroxide and oxygen super anion ($O_2^{-\bullet}$), etc.) induced chromosomal aberrations. The results of these studies have been published in leading international journals like *Science*, *Radiation Research*, *Radiation Botany*, etc. The foundation laid on indirect effects of radiation by MSS and ATN paved the way for PCK to undertake further work in this field for his doctoral research under MSS.

The book *Caffeine and Chromosomes* published by B. Kihlman in 1975 had described caffeine (present in coffee, tea and coco, etc.) as a potent radiosensitizer (i.e. it enhances the DNA damage already caused by ionizing radiations). On the other hand, the research done by PCK and his students at JNU, New Delhi had demonstrated the dramatic radioprotective action of caffeine. Hence, there developed a major controversy. In order to resolve the controversy, PCK was given a Senior Fellowship to visit Strahlenzentrum, University of Leiden, The Netherlands. ATN was very keen to lead the research to solve the controversy, not only for the scientific reason, but also for the consideration that Kihlman was his very close friend and I (PCK) was his student in New Delhi. Both ATN and PCK designed experiments using a novel way of assessing chromosomal breaks, dicentrics and translocations. ATN had just perfected a technique called 'premature chromosome condensation' (PCC) in which the long interphase chromatin fibres, which are normally condensed, are opened up. In order to avoid any bias, the actual scoring of the coded slides was done by a technician. After three months, a wealth of data was analysed and it was established beyond doubt that caffeine under oxygenated conditions protected the interphase chromosomes. ATN informed Kihlman who was extremely gracious to admit that PCK was right about caffeine being a radioprotector. It was also resolved that caffeine post-treatment of UV-irradiated cells would increase damage by inhibiting a repair enzyme called photolyase. On the other hand, when used as pre-treatment, it mops up the radiation-induced free radicals and affords radioprotection.

Yet another outstanding contribution by ATN along with Gunter Obe (*Mutation Res.*, 1978, **52**, 137–149; *Chromosoma*, 1964, **90**, 120–127) was that the single-strand breaks (ssbs) in DNA induced by ionizing radiation do not cause chromosomal aberrations, and these when converted into double-stand breaks (dsbs) result in chromosomal damage. It was absolutely ingenious to use the *Neurospora* endonuclease (which converts ssbs into dsbs) in the CHO cells *in vitro* and demonstrate that most of the ssbs are harmlessly repaired/restored and only the dsbs which are irreparable lead to the formation of chromosomal aberrations. ATN and Obe also demonstrated that restriction endonucleases (REs), which exclusively induce dsbs are potent inducers of chromosomal aberrations. This work of ATN was followed by an avalanche of publications from all parts of the world using REs for studies on the induction of chromosomal aberrations.

The year 1986 was a turning point in cytogenetic analysis when Pinkel and co-workers (Lawrence Livermore Laboratory, USA) (*Proc. Natl. Acad. Sci. USA*, 1986, **83**, 2394–2398) introduced quantitative, high-sensitive fluorescence *in situ* hybridization (FISH) using labelled DNA probes. They generated DNA probes to paint individual human chromosomes as well as parts of the chromosomes using FISH. This technique allowed detection of not only reciprocal translocations, but also the undetectable/less easily detectable non-reciprocal or incomplete translocations. While Pinkel and co-workers had developed DNA probes for human chromosomes, ATN and co-workers developed DNA probes for mouse and Chinese hamster chromosomes by chromosome sorting and microdissection (*Int. J. Radiat. Biol*., 1994, **65**, 583–590;

Cytogenet. Cell Genet., 1995, **70**, 95–101).

Armed with the new and powerful technology, ATN and co-workers explored many basic questions on the formation of radiation-induced chromosomal aberrations such as individual chromosome sensitivity, translocations versus dicentrics, rings versus inversions, reciprocal and non-reciprocal translocations, etc.

Basic research invariably gives room for varied interpretations of the data derived from similar and entirely different designs of experiments. Thus, ATN had serious disagreements with the paper published by Carrano *et al*. (*Nature*, 1978, **271**, 551–553) on the correlation between sister-chromatid exchanges (SCEs) and mutagenesis. In fact, the paper suggested that SCEs could be used as an indicator of mutagenesis. ATN disagreed with this view.

ATN has also made monumental contributions to the elucidation of two major pathways of repair of dsbs, namely non-homologous end joining (NHEJ) and homologous recombination (HR). His notable contribution in this regard is that NHEJ operates at all of the cell-cycle phases and HR largely operates in S and G_2. There is no doubt that knowledge gained from basic research should solve specific problems of humanity. Basic research conducted by ATN has been useful to assess human health problems arising from accidental exposure to ionizing radiation. In 1987, the International Atomic Energy Agency (IAEA) requested ATN to establish a Biological Dosimetry Laboratory in Rio de Janeiro, Brazil, mainly using frequencies of radiation-induced dicentrics for estimating the absorbed dose in accidents involving ionizing radiation. After the notorious Chernobyl accident in the former USSR, a relatively minor radiation accident occurred in Goiania, Brazil. The newly established Biological Dosimetry Laboratory was useful in making initial dose estimates in about 100 exposed people (*Radiat. Prot. Dosim*., 1988, **25**, 97–100). ATN also assessed the stability of translocations using FISH. An interesting finding was that the stability of translocations was only valid at low doses (<1 Gy); at higher doses, the frequencies reduced with time (*Mutation Res*., 1988, **400**, 299–312).

ATN also carried out biological dosimetric studies in the Chernobyl radiation accident on populations living in the contaminated areas (Gomel Region) and in Estonian Clean-up workers using FISH technique.

7 August 2005 marked the 80th Birthday of MSS. The *Current Science* with P. Balaram as the then editor had come forward to provide a special section in honour of MSS. ATN and PCK were the guest editors, and the title of the Special Section was 'Chromosomes to food security'. It represented the initial beginning point of MSS in cytogenetics and then his long journey to the destination of a Hunger-free world.

ATN's journey in science has covered studies on pollen grains of plants to the elucidation of molecular mechanisms in the action of ionizing radiation on mammalian (including human) chromosomes.

Despite his busy schedule ATN always made it time to come to Chennai in December every year to attend the music festival. The bonds that ATN established with MSS and his family as well as numerous friends would take a long long time to wane after his demise.

ATN is survived by his daughter and grandchildren.

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Supriya Mohan Sengupta (1932–2017)

Professor Supriya Mohan Sengupta breathed his last on 29 August 2017 in Kolkata. He has left a legacy of novel thinking and conducting innovative scientific research. While accepting the universal inevitability, we celebrate his contributions.

Ever interested in scientific and mathematical rigour, the young Sengupta realized during his fieldwork that linear averaging of azimuthal, hence circularly distributed, palaeocurrent data is statistically invalid. His appointment in the Geological Studies Unit (GSU) of the Indian Statistical Institute (ISI, Kolkata) provided him with the opportunity to do something about the then inadequacy. He collaborated with statisticians and the first paper on the solution – a short 10 pages in *Sankhya* (1966) – had an immediate impact. It is said that this paper with J. S. Rao (now known as S. Rao Jammalamadaka) convinced a Review Committee visiting ISI at the time that solutions to problems in natural sciences

needed new theoretical advances in statistics and hence the importance of maintaining GSU and other units of natural science in ISI. Several statisticians followed up on this new and interesting topic that has now blossomed as a full-fledged area of statistical research known as circular or directional statistics. This new statistics applies to all directional data such as those of wind directions, mineral lineations, plunges of folds, quartz *c*-axis orientations, etc. but has not become popular with geologists. The area is still wide open for new research.

Sengupta also inspired other colleagues to formulate a statistical device to assess the boundary between mappable units, the outcrops of which are generally disconnected in the field. This approach has not been tested extensively in geological mapping and remains an open area for further research.

Rigorous experimental sedimentology had barely past its infancy when