Shanti Swarup Bhatnagar Prize for Science and Technology 2016

The prestigious Shanti Swarup Bhatnagar (SSB) Prize for Science and Technology was instituted in the honour of the founder Director of the Council of Scientific and Industrial Research (CSIR) India, the late Shanti Swarup Bhatnagar. Each year, outstanding contributions to science and technology are recognized with this Prize. It is awarded on the basis of contributions made through work done primarily in India during the five years preceding the year of the award. The winners of 2016 Bhatnagar Prize have been announced. They are Rishikesh Narayanan and Suvendra Nath Bhattacharyya for Biological Sciences; Partha Sarathi Mukherjee for Chemical Sciences; Sunil Kumar Singh for Earth, Atmosphere, Ocean and Planetary Sciences; Avinash Kumar Agarwal and Venkata Narayana Padmanabhan for Engineering Sciences; Amalendu Krishna and Naveen Garg for Mathematical Sciences; A. S. Niyaz Ahmed for Medical Sciences, and Subramanian Anantha Ramakrishna and Sudhir Kumar Vempati for Physical Sciences. The highlights of the research work carried out by the awardees are briefly given in the following.

Biological Sciences

Rishikesh Narayanan

Rishikesh Narayanan heads the research at the Cellular Neurophysiology Laboratory (CNL) in the Molecular Biophysics Unit, Indian Institute of Science (IISc), Bengaluru. The discovery of voltage-gated ion channels in neuronal dendrites constitutes an important breakthrough in neuroscience research. Research in CNL is focused on understanding the physiological roles of these dendritically expressed channels, employing a combination of electrophysiological and computational techniques. Work in CNL has shown that these active dendritic mechanisms play a critical role in mediating location-dependence of the specific features that neurons encode, in defining the specific nature of extracellularly recorded neural potentials, and in regulating the impact of gliotransmission on neurons. Another common theme of work in CNL is degeneracy, defined as the ability of disparate structural components to elicit analogous functions. Studies from CNL have demonstrated that several disparate channel combinations could elicit analogous dendritic functional maps or synaptic plasticity profiles, providing insights into how neuronal systems might achieve robust homeostasis through several non-unique routes. Finally, work in CNL has also unveiled bidirectional interactions between the plasma membrane and the endoplasmic reticulum (ER) membrane, showing that channels on the dendritic membrane can modulate ER function, and that activation of channels on the ER membrane is sufficient to alter plasma membrane channels.

Suvendra Nath Bhattacharyya

Suvendra Nath Bhattacharyya (Molecular Genetics Division, CSIR-Indian Institute of Chemical Biology (IICB), Kolkata) has won this award for his outstanding contribution in the field of miRNA research and more specifically for the discovery of the mechanism of miRNA activity modulation in mammalian immune and cancer cells. miRNAs are tiny regulatory RNAs that by base pairing to their targets regulate the majority of the genes in higher animals. Bhattacharyya's group is currently engaged in understanding the mechanism of intercellular trafficking of these tiny gene regulators and its implication in gene regulation in diseases like cancer and diabetes. Through their recent works, published in top international journals, Bhattacharyya and his team have delineated the molecular linkage of miRNA usage and its extracellular export in animal cells. This pioneering work has been instrumental in the identification of new gene regulatory pathways that potentially could be targeted for therapeutic intervention against deadly diseases like cancer and metabolic syndrome.

Chemical Sciences

Partha Sarathi Mukherjee

Partha Sarathi Mukherjee (Department of Inorganic and Physical Chemistry, IISc) has made significant contributions to coordination-driven self-assembly. He has ingeniously used weak metal–ligand coordination interactions as driving forces to design many nanoscopic molecular architectures with well-defined shapes and sizes. Unlike metal-organic frameworks (MOFs), such architectures are discrete (not extended polymers), highly soluble in common solvents, and thermodynamically controlled products with labile metal–ligand interactions. Confined nano space of several such water-soluble molecular architectures has been successfully used for performing several organic transformations in catalytic fashion in an aqueous medium using hydrophobic reactants. Use of such water-soluble architectures as aqueous 'molecular nanovessels' allows many organic reactions to take place under mild reaction condition due to enhanced effective concentration of the reactants and stabilization of the transition states of the reactions inside the tiny nanovessels. Mukherjee's group has also shown that interior decoration of such nanovessels with appropriate functional groups helps in activating certain reactants for facile chemical transformations, nucleation of very tiny metal nanoparticles, and transportation of hydrophobic drug molecules in the aqueous medium. His group has also reported the design of several electron-rich fluorescent molecular cages and used the confined space of such cages for the recognition of electron-deficient nitroaromatic explosives in both solution and vapour phases.

Earth, Atmosphere, Ocean and Planetary Sciences

Sunil Kumar Singh

Sunil Kumar Singh (Geosciences Division, Physical Research Laboratory, Ahmedabad) has made important contributions to characterizing and quantifying

prominent surficial and oceanographic processes, particle–water interactions and submarine groundwater discharge (SGD) fluxes in estuaries, marine biogeochemistry of selected trace elements in the Indian Ocean as well as climate–weathering–tectonics in the Himalaya. His recent studies focus on the distribution of trace elements and isotopes (TEIs) in estuaries and in the Indian Ocean to characterize and quantify their source functions, internal cycling and sinks, and elucidating the impact of global change on their budgets having direct relevance to understanding oceanic biogeochemistry and application of TEIs to study water mixing and palaeoceanographic processes. His research identified particle–water interactions in the estuaries and ocean, and SGD as important sources of many trace elements in the Indian Ocean regulating its productivity. Singh and his group have carried out these studies by establishing, ultraclean sampling and measurement techniques of TEIs in sea water in India.

Singh has also contributed in the field of geochronology of sedimentary deposits and using them as a record of various geological processes such as palaeoatmospheric oxygen level. He pioneered in establishing the Re–Os chronometry in India to determine the absolute chronology of organic carbon-rich sedimentary deposits and successfully applied this method to provide first radiometric ages of black shales from Tal Formation in the Himalaya and the Lower Kaimur in the Vindhyan. These results confirmed that the Krol–Tal boundary represents the Pc–C boundary in the Himalaya and that there was a long hiatus in the sedimentary deposition between the Lower and Upper Vindhyan. This method can be used to date directly the various sedimentary sequences in India and to chronologically decipher geological records stored in them.

Singh's study in the field of erosion/weathering in the Himalaya revealed the heterogeneous nature of physical erosion over the region, being dominated by a few hot spots, the Eastern Syntaxis (Brahmaputra basin) and the Gandak (Ganga basin) regions accelerated by intense precipitation over regions of high relief. These hotspots of erosion constituting only about one-tenth of the total area of Himalaya, supply about half of the sediments transported to the Bay of Bengal and can facilitate uplift of regions around them through isostatic rebound. This study has direct relevance to the global carbon cycle as physical erosion regulates the transport and burial of organic carbon influencing the long-term climate. Singh's studies demonstrated climatically induced temporal variations in erosion distribution over the Himalaya highlighting the importance of climate in controlling erosion over glacial–interglacial timescales. This study, contrary to the conventional belief, demonstrated that increased glacial cover over the Himalaya decreases erosion.

Engineering Sciences

Venkata Narayana Padmanabhan

Venkat Padmanabhan (Microsoft Research India (MSR-India), Bengaluru) is a global thought leader in mobile and networked systems research. His research has often anticipated technology trends years ahead and has resulted in novel systems and technologies, leading to highly-cited research papers, dozens of international patents, technology transfer within Microsoft and industry-wide impact.

Upon joining Microsoft Research in the late 1990s, Padmanabhan started working on enabling localization in indoor spaces, where GPS does not function. At a time before 'wi-fi' existed, Padmanabhan envisioned a future where RF-based wireless local-area networks (WLANs) would blanket indoor spaces and recognized the opportunity to enable indoor localization 'for free' by riding on top of an RF-based WLAN. This led to the development of the radar system, which pioneered the idea of signal strength-based RF fingerprinting to relate wireless measurements to location. Radar has been hugely influential, with the research paper garnering over 8500 citations till date and the RF fingerprinting technique becoming the basis of commercial offerings.

With the advent of smartphones, Padmanabhan recognized a new opportunity to address the Achilles heel of radar – the need for (expensive) site surveys. With his team at MSR-India, he developed a pair of systems, EZ and Zee, which leveraged smartphones, with inertial sensors, for zero-effort crowdsourcing-based indoor localization, resulting in technology transfer within Microsoft.

Separately, soon after moving to MSR-India in early 2007, Padmanabhan initiated the Nericell project, motivated by the knotty traffic and road quality issues in Indian cities. Work in this area then was largely based on special-purpose sensing devices. Smartphones had been around for a few years, but lacked the inertial sensors taken for granted today. Nevertheless, Padmanabhan anticipated the inclusion of such sensors and proceeded to bridge the gap between his vision and the then-available hardware. Nericell could monitor both driving behaviour (e.g. sharp braking) and road conditions (e.g. bumps). The resulting paper was arguably the first on smartphone-based monitoring of road and traffic conditions and has been influential, with over 950 citations and several follow-on efforts, including at start-ups.

Padmanabhan has produced a string of works on battery-efficient cellular communication. While mobile operating systems have traditionally treated the cellular radio as just another bit pipe, Padmanabhan recognized the unique characteristics of the cellular radio and developed techniques such as signal-aware scheduling to enable dramatic gains in battery efficiency. The resulting research papers have received hundreds of citations.

Avinash Kumar Agarwal

Avinash Kumar Agarwal (Department of Mechanical Engineering, Indian Institute of Technology Kanpur) has carried out both fundamental as well as innovative, industrially relevant applied research in the area of IC engines, alternative fuels and emission control. He has developed two modern optical research engine test facilities, one having common rail direct injection (CRDI) engine and the other having gasoline direct injection (GDI) engine. He has carried out experiments for developing a fundamental understanding of in-cylinder flows and fuel spray droplet distribution in the combustion chamber using these optical research engines, by employing 2D, 3D and tomographic particle imaging velocimetry technique. Agarwal has carried out fundamental research to understand the 'laser ignition' of methane–air or hydrogen–air mixtures in a customized constant volume combustion chamber. His research paved way for development of

next-generation hydrogen engine for the automotive sector, which will be able to comply with Euro-VI and higher future emission norms and realize the dream of a hydrogen economy.

Agarwal has carried out extensive studies on biodiesel produced from different Indian feedstock and has extensively characterized exhaust particulates emitted by biofuels, gaseous alternative fuels and conventional fuels. Combustion, emissions and performance studies on a wide variety of engines (ranging from the simplest agricultural engine to the most modern transportation engine) were followed by wear, lubricating oil tribology, particulates and toxicity studies of primary and secondary aerosols. Field trials of biodiesel (B100)-fuelled SUVs were done in collaboration with industry partners, which boosted the confidence of Indian automotive industry about the vehicular application of biodiesel and eliminated their fears related to warranty issues with biodiesel usage. His publications in the area of biofuels have been influential and one of his papers has been cited more than 1000 times.

Agarwal developed the first prototype (globally) of the EFI system for ALCO-DLW locomotives, which is the main workhorse of the Indian Railways. He is now engaged in the development of common rail direct injection technology for locomotive engines and a prototype of LNG-fuelled locomotive, in partnership with RITES, Ministry of Railways, Government of India, is also planned to be developed in near future. This will be a fine example of industry–academia collaboration.

Agarwal's research on homogenous charge compression ignition and lubricating oil consumption control has direct implications on particulate emission reduction and engine performance. He has developed capacitance probes and dual fibre-optic probes to employ laser-induced fluorescence techniques for the determination of minimum oil film thickness during engine firing. This technology is now used as an important scientific tool to carry out this extremely challenging measurement in most severe (high temperature and pressure) environments in Automotive industry.

Mathematical Sciences

Amalendu Krishna

Amalendu Krishna's (Tata Institute of Fundamental Research, Mumbai) research is broadly related to algebraic K-theory and its applications in algebraic geometry. This subject has important applications in algebra, arithmetic, geometry, non-commutative geometry and topology. However, all these applications require computing the algebraic K-groups of various rings and geometric objects. One problem with algebraic K-theory is that these groups are often difficult to compute.

There has been extensive research on finding concrete tools to solve this problem. The theory of algebraic cycles just does that. One of Krishna's main areas of current research is to develop a theory of relative algebraic cycles which could facilitate and geometrically describe the theory of relative K-groups. The theory of additive higher chow groups and their generalizations in the form of cycles with modulus are meant to do this job recently; this has been studied extensively by Krishna.

He has also made some progress in the advancement of the theory equivariant K-groups of varieties with group actions. Here, the equivariant Riemann–Roch problem plays an important part and this was recently solved in one of his research works.

Krishna has also been studying the subject of algebraic cycles on varieties with singularities. Here, the Bloch–Srinivas conjecture plays a significant role. This conjecture was open for many years and has been now solved in another of his research works.

Naveen Garg

Naveen Garg (Computer Science and Engineering Department, IIT Delhi) has contributed primarily in the design and analysis of approximation algorithms for NP-hard combinatorial optimization problems arising in network design, scheduling, routing, facility location, etc. His earlier contributions include extending the celebrated Max-flow min-cut theorem of Ford and Fulkerson to multi-commodity flows and developing the primal–dual framework to obtain fast approximate solutions for packing and covering linear programs. Over the last few years, Garg has been working on problems arising in 'scheduling' and 'facility location', two areas which are important both to the computer science and operations research communities.

Garg has been instrumental in introducing tools from linear optimization to the design of online algorithms for job-scheduling problems. Together with his co-authors, Garg showed how 'dual-fitting' can be adapted to analyse and improve upon algorithms for minimizing weighted flow time. He also proposed a new model – of rejecting a small fraction of jobs – to design and analyse the first algorithms for maximum weighted flow time and other related problems.

On the other hand, facility location problems, especially those involving hard capacity constraints are not amenable to efficient solutions using linear optimization techniques. For over 50 years, the method of choice for solving these problems has been 'local search', which although easy to describe, tends to be notoriously hard to analyse. Garg and his co-authors provide the first tight bound for facility location problems with uniform and non-uniform capacities when the local search step involves the obvious add, delete and swap operations. Both results significantly extend existing analysis techniques for facility location problems and rely on delicate and careful accounting of local search operations.

Medical Sciences

A. S. Niyaz Ahmed

Niyaz Ahmed (Department of Biotechnology and Bioinformatics, School of Life Sciences, University of Hyderabad) has been awarded the SSB Prize for his outstanding contribution to understanding the functional epidemiology of chronic pathogens such as enteropathogenic bacteria and *Mycobacterium tuberculosis* by successfully combining the rigours of genome inspired epidemiology and deciphering the bacterial virulence mechanisms.

Ahmed is a Senior Director at the International Centre for Diarrheal Disease Research, Bangladesh, and is Fellow of the Royal Society of Chemistry (UK), Royal Society of Biology (UK) and the National Academy of Sciences, India. He has also been the recipient of the National Bioscience Award of the Government of India. His work remains highly acknowledged and well known in the area of infectious disease epidemiology and pathogen biology, including studies on multiple drug resistance in pathogenic

bacteria such as those causing tuberculosis and diarrhoeal diseases.

Physical Sciences

Subramanian Anantha Ramakrishna

Subramanian Anantha Ramakrishna (IIT, Kanpur) has been awarded the SSB Prize for his fundamental contributions in the field of metamaterials, and in developing new forms of anisotropic photonic materials.

Metamaterials are structured composite materials with extraordinary optical and electromagnetic properties not available in nature. They have made possible many effects such as near-field optical couplers for imaging with sub-wavelength resolution, perfect absorbers for absorption and emittance control, invisibility cloaks, magnetic couplers for MRI applications and many novel devices for the control of light at bands across the optical (visible) to radio frequencies.

Ramakrishna has contributed to the new understanding of the photonic properties of structured metamaterials. He has established fundamental results on focusing light using negative refractive index materials including the concept of complementary optical systems. He has given new insights to understanding metamaterial perfect absorbers at optical to infrared frequencies as highly impedance-matched antenna arrays, and developed switchable and nonlinear resonantly absorbing surfaces. He has developed new applications of anisotropic metamaterials such as blazed diffraction gratings made of nanocolumnar thin films that can act as unidirectional plasmonic couplers and waveguides. He has also developed a new class of anisotropic optical fibres that comprises nanoporous microtubes of alumina with a qualitatively new mode structure. These anisotropic metamaterials can be rapidly fabricated on large scales using novel inexpensive methods.

Sudhir Kumar Vempati

Sudhir Kumar Vempati (Centre for High Energy Physics, IISc) and his team focus on studying the implications of flavour violation in the leptonic sector on other phenomenological searches such as dark matter or at CERN Large Hadron Collider (LHC) within the context of supersymmetric theories and extra dimensional models.

Flavour is an important part of our lives, especially in food. Surprisingly, it plays an important role in physics too. At the most fundamental level, Nature is described by quarks and leptons, and interactions between them. Quarks come in six different 'flavours' spanning over three generations and so do leptons (Figure 1). Within a generation, the flavour transitions happen through weak interactions. The rules of weak, strong and electromagnetic interactions are given by the Standard Model of particle physics. Inter-generational flavour transitions are highly suppressed and rare in the quark sector. Transitions between the charged leptons are amongst the rarest of the rare. Unlike in the quark sector, they have not been discovered experimentally yet. Neutrino masses are not explained within the framework of the Standard Model. Extensions of the Standard Model are required.

Neutrinos are not the only reason why one looks for extensions of the Standard Model. With the discovery of the Higgs boson, the quest for a technically natural quantum field theory with a fundamental scalar has become even more important. This requires that the Standard Model be encompassed in a much larger framework with additional symmetries like supersymmetry or with extra space dimensions, to name a few. Another reason to seek for such extensions is dark

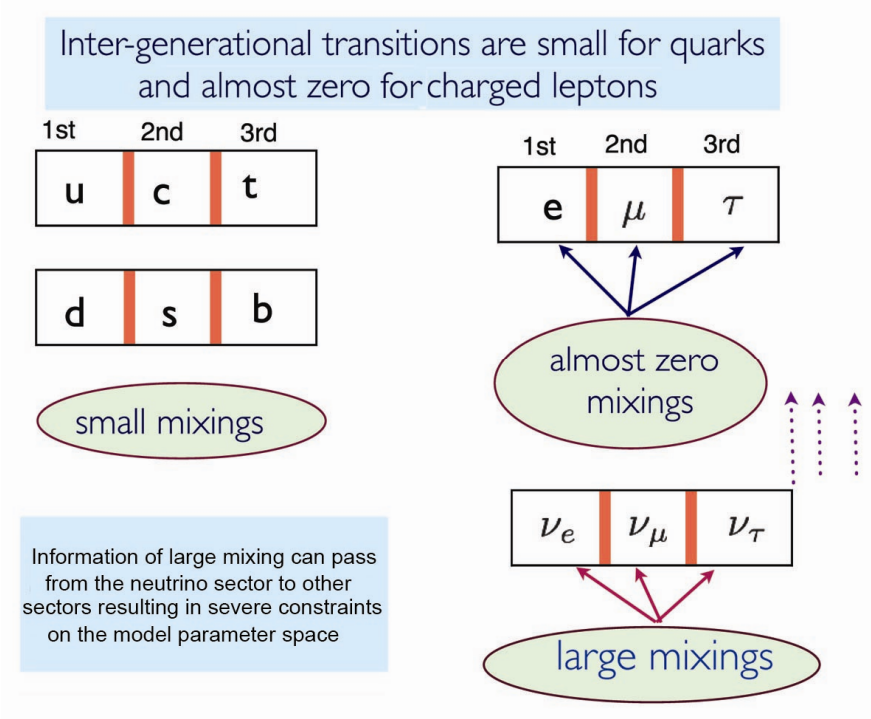

Figure 1.

matter. None of the quarks or leptons can form dark matter. A new particle is required. Frameworks like supersymmetry or extra dimensions do contain additional fundamental particles, one of which could form dark matter. Neutrino masses can also be accommodated through various schemes in these frameworks. However, it turns out that most of the schemes which generate neutrino masses and their mixing will also introduce flavour-violating transitions in the charged leptonic sector, which puts severe constraints on these frameworks.

Computing accurate supersymmetric mass spectra in various models of supersymmetry breaking is the need of the hour, especially in the light of LHC data. Computation of the supersymmetric mass spectrum at high precision is a difficult task which involves several coupled nonlinear differential equations, matrix diagonalizations, loop functions, stability analysis, minimization and iterative techniques, etc. This is typically done by huge computer programs called spectrum generators. The presently available spectrum generators, however, are not suitable to handle flavour violation or non-zero neutrino masses through see-saw mechanisms. However, it is important to have such a code to deal with the current data either from LHC or from flavour physics or dark matter. For example, a small amount of flavour violation present in the squark sector can completely remove the 'strong' constraints on many supersymmetric models from branching ratio of ($b \to s^+$ photon). And, more importantly, realistic models of supersymmetry breaking do predict some flavour violation in the soft terms. To fill this gap, Vempathi and his group embarked upon constructing a spectrum generator with full flavour violation as well as including see-saw mechanism. Such a code is not a straightforward extension of the existing codes, as to put it in a loose manner, every coupling has to be replaced by a matrix and this complicates the code several folds. In this case, the code was developed using an original smaller code (1-loop RGE with flavour violation). The new code (written along with D. Chowdhury and R. Garani) (full two loops, one-loop thresholds, etc.) took about two years to complete and the first version was out in September 2011. The upgraded version 2 of the code was also accepted for publication. This is perhaps the first such publicly available code from India, which could be useful to both theoreticians as well as experimentalists worldwide. The code was useful in studying the implications of the Higgs and supersymmetric data from LHC on various supersymmetric models.

One of the popular extra-dimensional models is the so-called Randall–Sundrum (RS) models. The RS models are considered to be models of flavour. However, most RS models where the fermions are localized in the bulk do violate the current flavour-violating constraints. This is especially true in the leptonic sector where accommodation for non-zero neutrino masses invariably seems to be leading to large lepton flavour violation.

Furthermore, several contradictory statements exist in the literature regarding the fitting of neutrino masses. Together with Abhishek Iyer, Vempati and his group embarked on a detailed analysis which fitted the neutrinos as well as satisfied the flavour-violating constraints. Three possible models for neutrino mass generation were considered: higher dimensional operators, Dirac masses and Majorana masses. The O(1) Yukawa parameters were also varied in deriving the fits. The group found that higher-dimensional operators would require large negative bulk parameters, indicating that they are largely composite fermions if interpreted in terms of AdS/CFT correspondence. Dirac and Majorana cases give reasonably nice fits within 'acceptable' range for the bulk parameters. However, flavour-violating constraints in these cases are very strong ruling out most of the parameter space. Vempati and his group showed that if minimal flavour violation paradigm is assumed on the Yukawa couplings, flavour-violating constraints can be evaded in both these cases. Another important work in this direction has been 'hiding' the violation of the lepton number in the bulk, with neutrinos getting Dirac-type masses.

Infosys prize in physical sciences

Anil Bhardwaj, a distinguished planetary scientist who has made outstanding contributions through extensive studies of planetary systems/atmospheres, has been awarded the prestigious Infosys prize 2016 for his fundamental contributions, many of which are considered as 'benchmarks' in the field.

Bhardwaj was born in 1967 at Mursan, Aligarh district, Uttar Pradesh, India. He obtained his B Sc and M Sc degrees from Lucknow University in 1985 and 1987, and his Ph D degree from at the Institute of Technology, Banaras Hindu University, Varanasi, in 1992 working on airglow and auroral processes in the planetary atmospheres, mainly emphasizing on the outer planets and also comets.

After a brief stint as a Research Associate, Bhardwaj started his independent research career in 1993 at the Space Physics Laboratory, the autonomous research wing of ISRO's Vikram Sarabhai Space Centre (VSSC), Thiruvananthapuram.

In the initial years he concentrated on the development of coupled chemistry-transport models for cometary coma, with specific emphasis on the role of the so called 'auroral electrons' – a terminology introduced by him for comets 'for the first time' – in the inner coma of comets like Halley and Ikeya-Zhang.

Many of Bhardwaj's model predictions have turned out to be as anticipated and his model results have been treated as 'benchmark' values by ESA and NASA for their ROSETTA and Deep-Impact missions.

Bhardwaj gradually expanded the horizon of his activities to include multi-spectral (covering the whole range of the electromagnetic spectrum from X-rays to radio waves) observations of outer planets from space. Through these unique efforts, he accomplished several landmark discoveries like X-rays from the rings of Saturn (which were explained to be due to oxygen K-alpha emissions