Infosys Science Foundation

Infosys Prize 2019

Boom!

If you are very lucky, you may have on some starry night,
gazed up at the vast cosmic ocean and spotted a brilliant flicker of light shining infinitely brighter than all. That flash of light you saw was an elusive supernova – an explosion of a massive supergiant star, shining with the brightness of a billion suns. Its light travelled hundreds of millennia across the universe to reach you. Surreal?

Astronomers, Physicists and Mathematicians have spent immense amounts of effort unravelling the mystery of a supernova. The magnitude of these cataclysmic bursts. The repercussions for life on earth. Their impact on the cosmos. Why they occur, and when they are likely to happen! One such discovery revealed that when a white dwarf star takes on enough mass, it reaches a certain critical threshold and detonates in a supernova. This is called the Chandrasekhar Limit, named after the scientist who discovered this.

Nothing drives home the sobering thought of our insignificance, our fleeting reality in the history of the cosmos, as a supernova does. And yet our very existence is inextricably tied to them. Supernovae are among the few sources of heavy elements and much of the building blocks of the universe, including oxygen, hydrogen, and iron. And you and me, we all carry remnants of these distant explosions within our own bodies. Let that sink in.

Isn't it incredible, how we, and the universe around us,
are so intrinsically interconnected?

ENGINEERING AND COMPUTER SCIENCE

SUNITA SARAWAGI
Institute Chair Professor, Computer Science and Engineering,
Indian Institute of Technology, Bombay, India

The Infosys Prize 2019 in Engineering and Computer Science is awarded to Prof. Sunita Sarawagi for her research in databases, data mining, machine learning and natural language processing, and for important applications of these research techniques. The prize recognizes her pioneering work in developing information extraction techniques for unstructured data.

Prof. Sunita Sarawagi is Institute Chair Professor in Computer Science and Engineering at IIT-Bombay.

Prof. Sarawagi received her B.Tech. in Computer Science from IIT- Kharagpur in 1991. She received her M.Sc. and Ph.D., in Computer Science from the University of California, Berkeley. Following her Ph.D. Sarawagi did stints at IBM Almaden Research Center and Carnegie Mellon, and joined IIT-Bombay in 1999.

Between July 2014 and July 2016, Sarawagi was Visiting Scientist at Google Inc. where she worked on deep learning models for personalizing and diversifying YouTube and Play recommendations, improving a conversation assistance engine, and extracting attributes of classes from the Knowledge Graph.

Among her many awards is the IBM Faculty Award (2003 and 2008). She is a Fellow of the Indian National Academy of Engineering (INAE) (2013) and also has several patents to her name.

ABOUT SARAWAGI'S WORK AND ITS IMPACT

Prof. Sunita Sarawagi's research is based on the development of fundamental principles and has had profound practical impact. Both these characteristics can be illustrated using just two examples from Prof. Sarawagi's many papers.

Postal addresses have structure: country, state, PIN, city, street, and so on. However, postal addresses that appear on the web and in other repositories are continuous text and often have some of these attributes missing. A challenge is to convert such unstructured text into structured information, which is much more efficient for handling queries and other applications.

Previous work on this problem had taken largely *ad hoc* approaches that were often labor-intensive. Prof. Sarawagi extended the theory of Hidden Markov Models (HMM) to solve this problem automatically. She and her colleagues created a software package, DATAMOLD, which has been used by many companies to improve address structuring in India.

The second example is Sarawagi's work on extracting numerical information from unstructured text containing numbers on the web. Examples of queries with numerical answers are: "What is Microsoft's revenue?" and "How many calories in a pizza?" The queries are imprecise: What size pizza and with what toppings? What are the units: calories or kilocalories? Nevertheless, users post many such questions to search engines and expect an answer.

Sarawagi and her colleagues developed QuTree to deal with units, and a probabilistic model for collective consensus. They implemented a family of algorithms, tested them, and reported the results of their algorithms comparing them with ground truth (such as values reported by the World Bank). These papers exhibit a systematic approach to building foundational models and theories, and then develop software and carry out testing on critical problems.

CITATION BY THE JURY

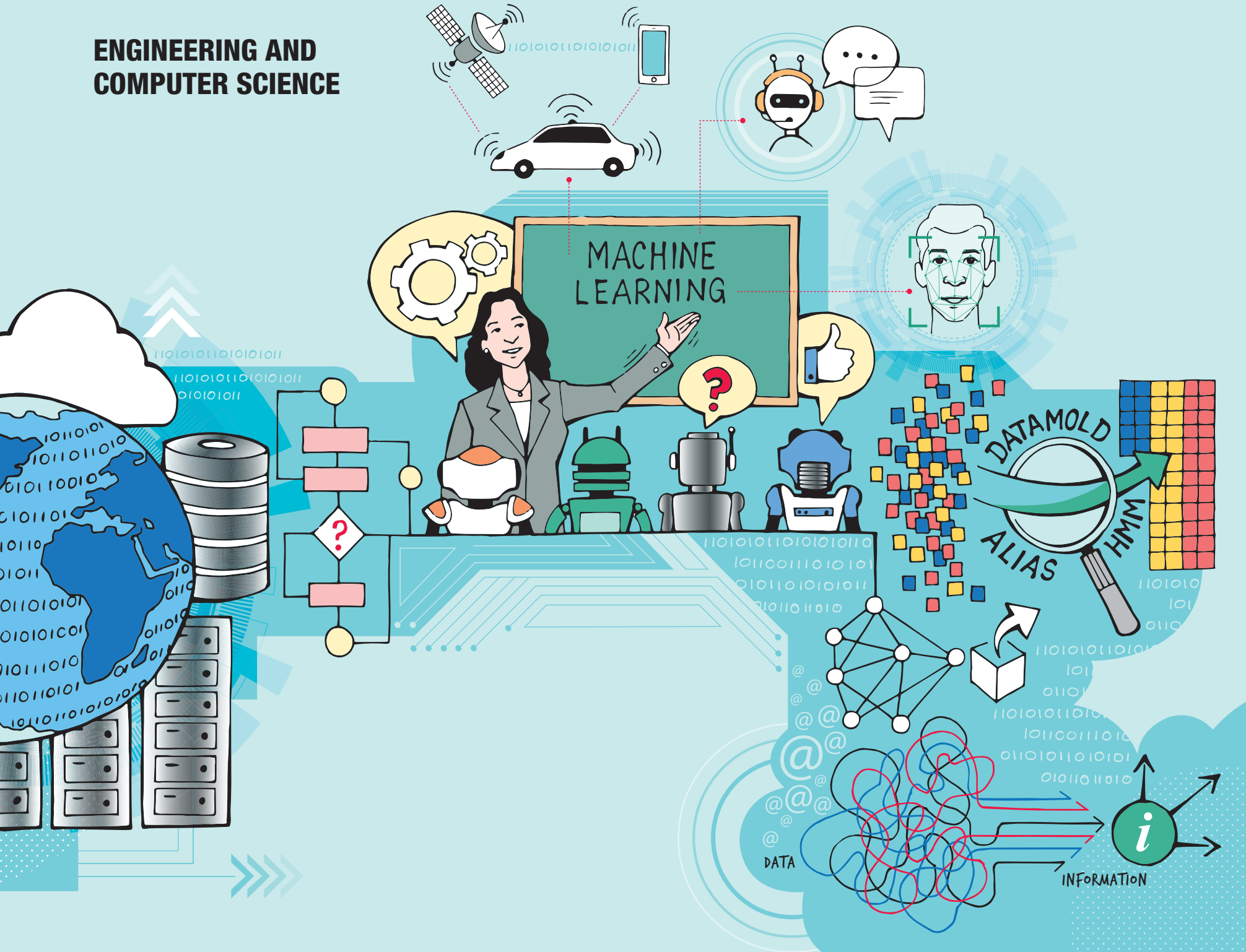
Prof. Sunita Sarawagi was one of the earliest researchers to develop information extraction techniques that went beyond the world of structured databases to the kind of unstructured data one finds on the World Wide Web. This necessitated the use of novel machine learning techniques for extraction of information from natural language text. Sarawagi and colleagues showed how one could extract and analyze unstructured numerical data on the web and other sources. She developed the formalism of semi-Markov conditional random fields for the task of segmenting out sequences of words which might correspond to "named entities" such as company names or job titles.

Sarawagi's research has had valuable practical applications such as the development of software for cleaning and structuring Indian addresses, as well as de-duplicating them.

"Congratulations Sunita Sarawagi for winning the Infosys Prize in Engineering and Computer Science. Your pioneering research in using machine learning to analyze and understand unstructured data makes it possible to use the wealth of information on the world wide web and other sources for the betterment of society and for creating new businesses. You richly deserve this award."

– Arvind

ENGINEERING AND COMPUTER SCIENCE



INFORMATION IN THE AGE OF DATA

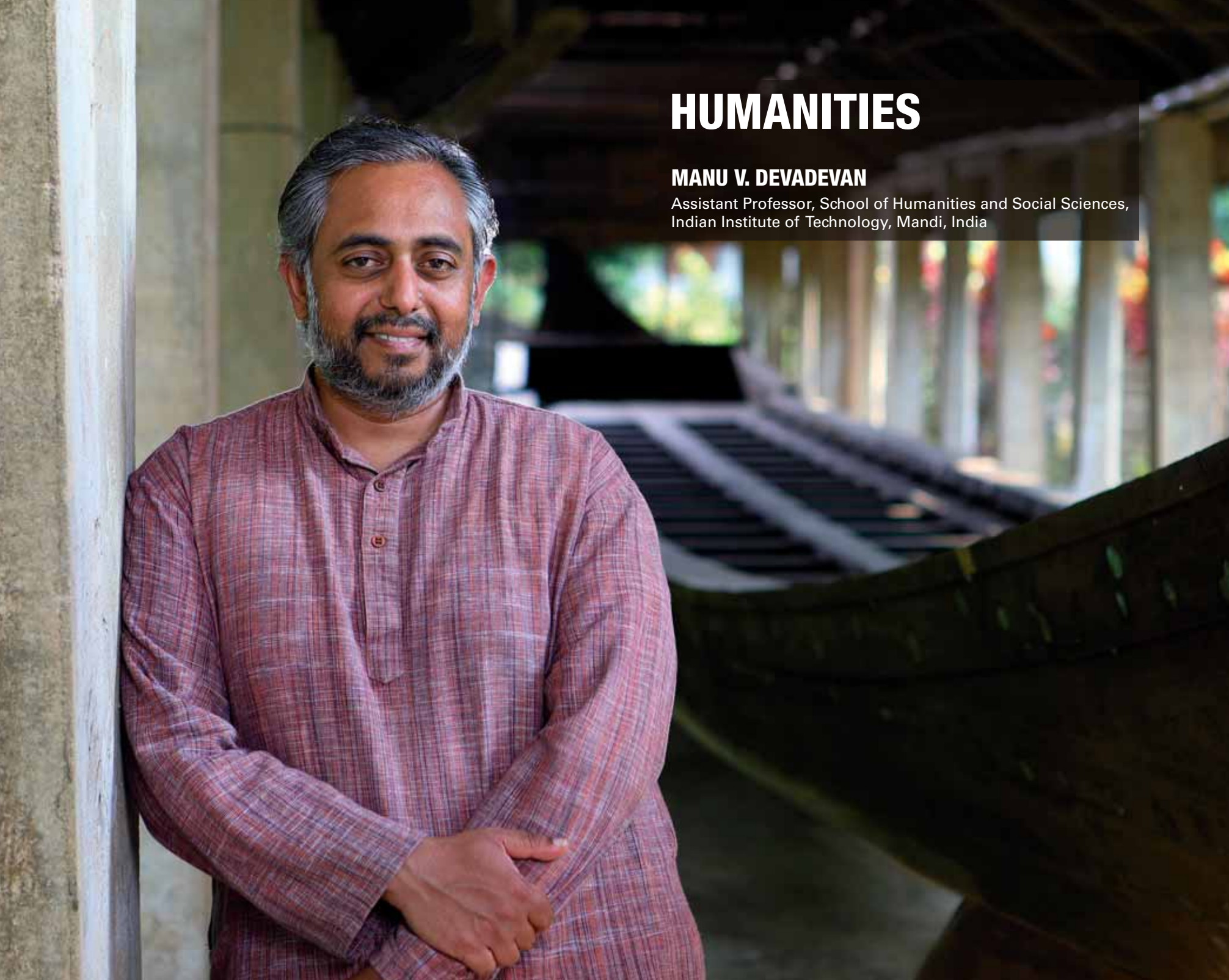
We live in the age of data. According to one report in 2018, 2.5 quintillion bytes of data were created each day. This figure grows every day.

With all this data being generated how do we make sense of it all? How do we go about extracting relevant information from these vast oceans of data? This is where machine learning comes in. Machine Learning is the science of teaching computers with examples where explicit programming is difficult. Machine Learning is behind the recent success stories we hear about machines driving cars, chatting like humans, and recognizing your face in a photo.

Prof. Sunita Sarawagi's research involves machine learning where she teaches machines through examples to automate tasks that humans find too tedious. This includes cleaning up badly written addresses into a proper structure and detecting duplicate addresses in large lists such as those kept by the income tax department. Prof. Sarawagi and her collaborators developed a software package called DATAMOLD which efficiently improves address structuring. Sarawagi employed the theory of Hidden Markov Models to create this solution for unstructured data. HMMs are a class of probabilistic graphical model that allow us to predict a sequence of unknown (hidden) variables from a set of observed variables. She developed a software package called ALIAS that can efficiently dig out mutants of addresses in a dataset of millions of addresses.

Prof. Sarawagi developed algorithms for extracting factual answers to questions from noisy tables on the world wide web. She showed how a machine can self-teach itself by harnessing the diverse redundant ways in which information is distributed over the Web. She along with collaborators developed a new type of model called the Semi-Markov Conditional Random Field that was key to developing such an extractor.

Prof. Sarawagi's research has huge implications in a world where vast quantities of data need to be converted into useful information that can then be used for everything from new business ideas to real social change.



HUMANITIES

MANU V. DEVADEVAN
Assistant Professor, School of Humanities and Social Sciences,
Indian Institute of Technology, Mandi, India

The Infosys Prize 2019 for Humanities is awarded to Dr. Manu V. Devadevan for his highly original and wide-ranging work on pre-modern South India. His book, *A Prehistory of Hinduism,* offers a powerful and refreshing new approach to the study of the cultural history of India, based on his profound knowledge of sources in multiple languages.

Dr. Manu Devadevan is an accomplished historian and literary scholar. Dr. Devadevan currently teaches history at the IIT-Mandi. He received his academic training at Annamalai University, Jawaharlal Nehru University, and Mangalore University.

Devadevan's research interests extend beyond pre-modern history to include cultural and literary practices in South India, South Indian epigraphy, and political and economic processes in pre-modern South Asia. He has published scholarly works in both Kannada and English. His most recent book is A Prehistory of Hinduism (2016).

Devadevan's journal articles in English include 'Lying on the Edge of the Burning Ground: Rethinking Tinais,' Journal of the Economic and Social History of the Orient (2006); 'From Lineage to Territory: The Making of Territorial Self-Consciousness in Kalinga,' Indian Historical Review (2017), and 'From the Cult of Chivalry to the Cult of the Personality: The Seventh-Century Transformation in Pallava Statecraft,' Studies in History (2017).

Devadevan is also a prolific translator into English, Malayalam, and Kannada.

ABOUT DEVADEVAN'S WORK AND ITS IMPACT

Dr. Manu Devadevan was trained in Sociology at Annamalai University, in History at JNU, and completed his Ph.D. from Mangalore University under the guidance of Prof. Kesavan Veluthat. He has a very broad set of interests as well as areas of expertise, resulting in part from his mastery of different bodies of sources in multiple languages, such as Kannada, Malayalam, Tamil, Telugu, Sanskrit, and Odiya. He has published widely in Kannada and English, both in the form of learned essays and books, and history books for use in schools.

In studies ranging from Pallava kingship, *Kudiyattam* theatre, the history of mathematics and astronomy in India, the Jagannatha temple in Puri, and above all the masterly *A Prehistory of Hinduism* (2016), Devadevan has offered a revisionist paradigm for the study of pre-modern India. He also possesses a mastery of the more technical skills required in the study of medieval history, especially in the analysis of epigraphic material. Devadevan is also engaged in a set of exciting projects, on the regional origins of medieval India, history writing in pre-colonial Kerala, and the history of medieval Odisha (focusing on the Jagannatha cult).

Devadevan's work bridges the divide between history and artistic domains, based on his imaginative interpretation of materials from theatre, literature, ritual and religious fields. His work, which has already had a significant impact on studies of South India, is coming to be more widely recognized in India as well as abroad. His work, marked by an irreverent and skeptical sensibility, is among the most exciting to emerge in recent years in the study of Indian history.

CITATION BY THE JURY

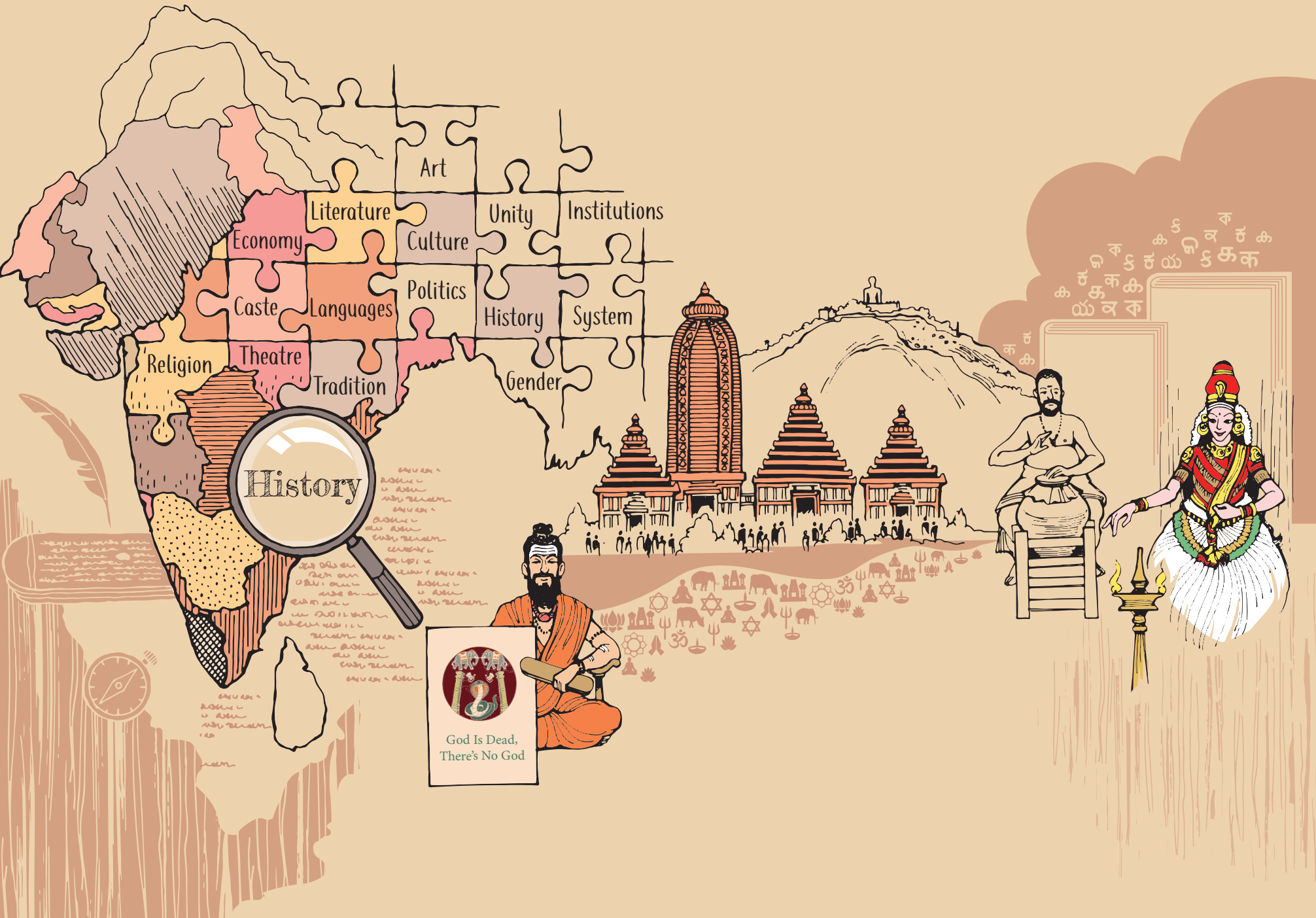
Dr. Devadevan is an unusual and important figure from the younger generation of historians trained in India. He has published scholarly work in Kannada and English, most notably his 2016 book, *A Prehistory of Hinduism*. In this work, Devadevan critically reinterprets much of the conventional wisdom about the cultural, religious, and social history of the Deccan and South India.

Devadevan writes a cultural history solidly grounded in its social and economic contexts, and is able thereby to reinterpret major moments of transformation from a broad regional perspective. He offers new conceptual tools for historians of the region, while building on deep traditions of historical writing inherited from his teachers. He is one of the most creative and exciting historians now working in India.

"I congratulate Manu Devadevan for having won the Infosys Humanities Prize. You greatly deserve this prize for having deepened our understanding of the social and cultural history of South India in the pre-modern period and for your remarkable revisions of the conventional wisdoms of this history. I join the entire panel of jurors for the Infosys Prize in the Humanities in congratulating you warmly for this remarkable achievement."

– Akeel Bilgrami

HUMANITIES


Art
Literature
Unity
Institutions
Economy
Culture
Caste
Languages
Politics
History
System
Religion
Theatre
Tradition
Gender
History
God Is Dead,
There's No God

THE MAKING OF INDIA

The history of India has been a field of vibrant research for almost two centuries now. Over time new questions have been asked, new sources of information unearthed, and new avenues of understanding explored.

What is India? Is it a civilization, an idea, or a mere geographic mass? Why has India been a fertile ground and receptacle for numerous religions? How did languages and linguistic identities evolve here? Where did caste as an institution have its historical roots and what is its relationship with gender? How were territorial identities, pilgrimage centers, and political and sacred geographies formed? What were the structures of power in the Indian subcontinent? Are there ways of fruitfully embedding forms of art, literature and theatre into the larger narrative of Indian history? What assessments can we make of the history of intellectual life in India?

Dr. Manu V. Devadevan is a historian whose work addresses these fundamental questions in Indian history. He studies the evolution of institutions, ideas and identities in India across time to understand how they emerged, developed and underwent transformations. His work explores historical processes by placing them against the backdrop of the political economy to provide forceful economic explanations for non-economic facets of history.

Dr. Devadevan's book, *A Prehistory of Hinduism*, charts the course of evolution of the religious processes that would eventually be known as Hinduism from the early 19th century. The book covers the period from the 11th to the 19th centuries in the Deccan region, focusing on present-day Karnataka and parts of southern Maharashtra. It examines the processes in the light of economic factors such as the agrarian system, class structure, and relations of land, labor, property and production.

Dr. Devadevan has shed light on the rise of pilgrimage centers such as Puri in Odisha and Shravanabelagola in Karnataka. His reassessment of the *Kudiyattam* theatre of Kerala and his exploration of the aesthetics of kavya literature bring scholarship in these fields to new frontiers. Dr. Devadevan has done pioneering work on the origin of the caste system, the rise of vernacular languages, the making of territorial identities, and the structural foundations of statecraft. His reflections on the invention of zero is a major contribution to the history of science.

LIFE SCIENCES

MANJULA REDDY
Chief Scientist, Centre for Cellular and Molecular Biology, Hyderabad, India

The Infosys Prize 2019 in Life Sciences is awarded to Dr. Manjula Reddy for her groundbreaking discoveries concerning the structure and synthesis of cell walls in bacteria. Through elegant genetic and biochemical analyses, Dr. Reddy and her colleagues have revealed critical steps of cell wall growth that are fundamental for understanding bacterial biology and have important implications for developing new classes of antibiotics to combat drug-resistant microbes.

Dr. Manjula Reddy is Chief Scientist at the Centre for Cellular and Molecular Biology (CCMB), Hyderabad. She received her Ph.D. in 2002 from CCMB and did a postdoctoral fellowship at the Fred Hutchinson Cancer Research Center, Seattle. She was appointed as Scientist at CCMB in 2002, and as Independent Investigator in 2007.

Dr. Reddy is a member of the Telengana Academy of Sciences and the Guha Research Conference. She serves on the editorial board of the Journal of Bacteriology.

ABOUT REDDY'S WORK AND ITS IMPACT

A single cell of a bacterial pathogen can grow in a food-filled environment and at human body temperature in just 20 minutes, by remodeling its membrane and cell wall. Dr. Manjula Reddy's work has provided critical new insights into this rapid body-remodeling.

Current antibiotics target functions such as ribosomes for protein synthesis, DNA replication, and cell wall synthesis – the final steps of wall formation, when each peptide forms a covalent linkage to its neighbor. This linkage step, and the enzyme that forms the linkage, is the target of antibiotics like penicillin.

Dr. Reddy examined the first steps of cell growth involving cleavage of the existing peptide-peptide bond. Bacterial cells are surrounded by a continuous meshwork of cell wall and their growth and division are tied to the expansion and splitting of the wall matrix. The bonds in this meshwork need to be broken in order to make space for the insertion of new material to grow the wall. This realization predicted that cell wall enzymes that cleave the wall would be essential for bacterial growth. Reddy was the first to identify these enzymes. She discovered that one of the 'spacemaker' enzymes is regulated by a protease and an adapter that targets the enzyme to the protease, perhaps the first example of a broadly utilized mechanism for regulating enzymes at the cell surface. Reddy has reported multiple enzymes that cleave the bacterial cell wall. Loss of these endopeptidases results in structural instability and the cell explodes. These cell wall enzymes are conserved in many bacteria that cause disease.

Reddy's discoveries have changed the arc of microbiology and raised the hope of new classes of antibiotics to counter antibiotic-resistant microbes.

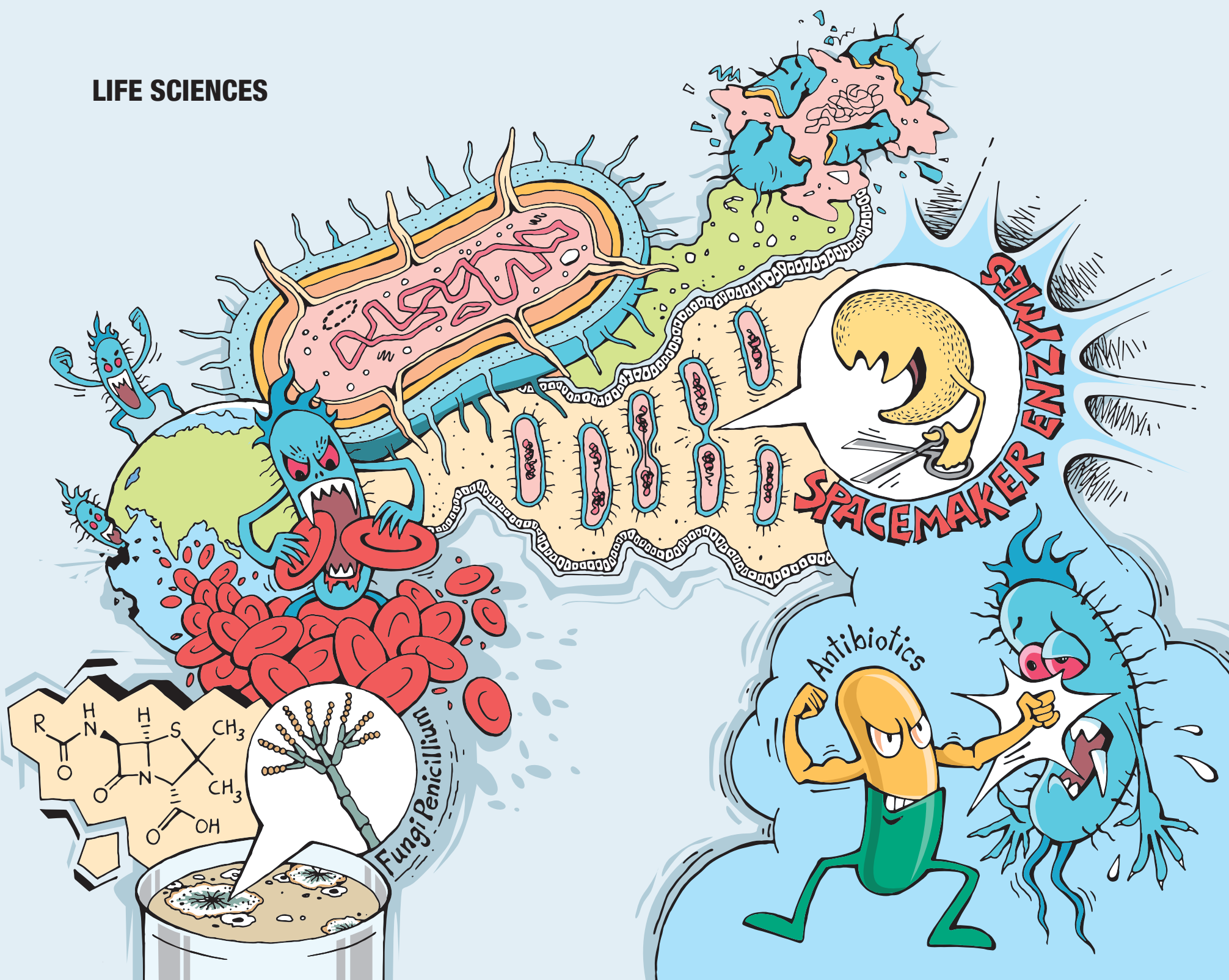
CITATION BY THE JURY

The Infosys Prize 2019 in Life Sciences is awarded to Dr. Manjula Reddy for her groundbreaking discoveries concerning the structure and growth of cell walls in bacteria. Because bacterial cells are surrounded by a continuous meshwork of cell wall, their growth and division are intimately tied to the expansion and splitting of the wall matrix – bonds in the meshwork would need to be broken in order to make space for the insertion of new material to grow the wall.

Dr. Reddy has identified enzymes that cleave the cell wall, and discovered novel mechanisms by which 'spacemaker' enzymes function. Her bold and creative experiments provide novel insights into bacterial growth, and suggest new ways to target antibiotic-resistant microbes.

"I congratulate Manjula Reddy for being the winner of the 2019 Infosys Prize in Life Sciences. Your work on the development and growth of cell wall in bacteria has really transformed the field. Your elevated experiments describing the first stages of cell growth are likely to lead to new antibiotics and address the growing concern about antibiotic resistant bacteria. On behalf of the jury for Life Sciences I warmly congratulate you on being this year's award winner."

– Mriganka Sur


SPACEMAKER ENZYMES
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THE WAR ON SUPERBUGS

In 1928 when Alexander Fleming accidentally discovered the green mold in his petri dish which then led to the discovery of penicillin, the world breathed a sigh of relief, confident that we had finally won the war against bacteria.

Cut to 2019 and we are confronted every day with headlines about superbugs killing thousands. The rampant use of antibiotics has led microbes to develop resistance to the drugs used to kill them. And so the hunt for more effective antibiotics is on once again.

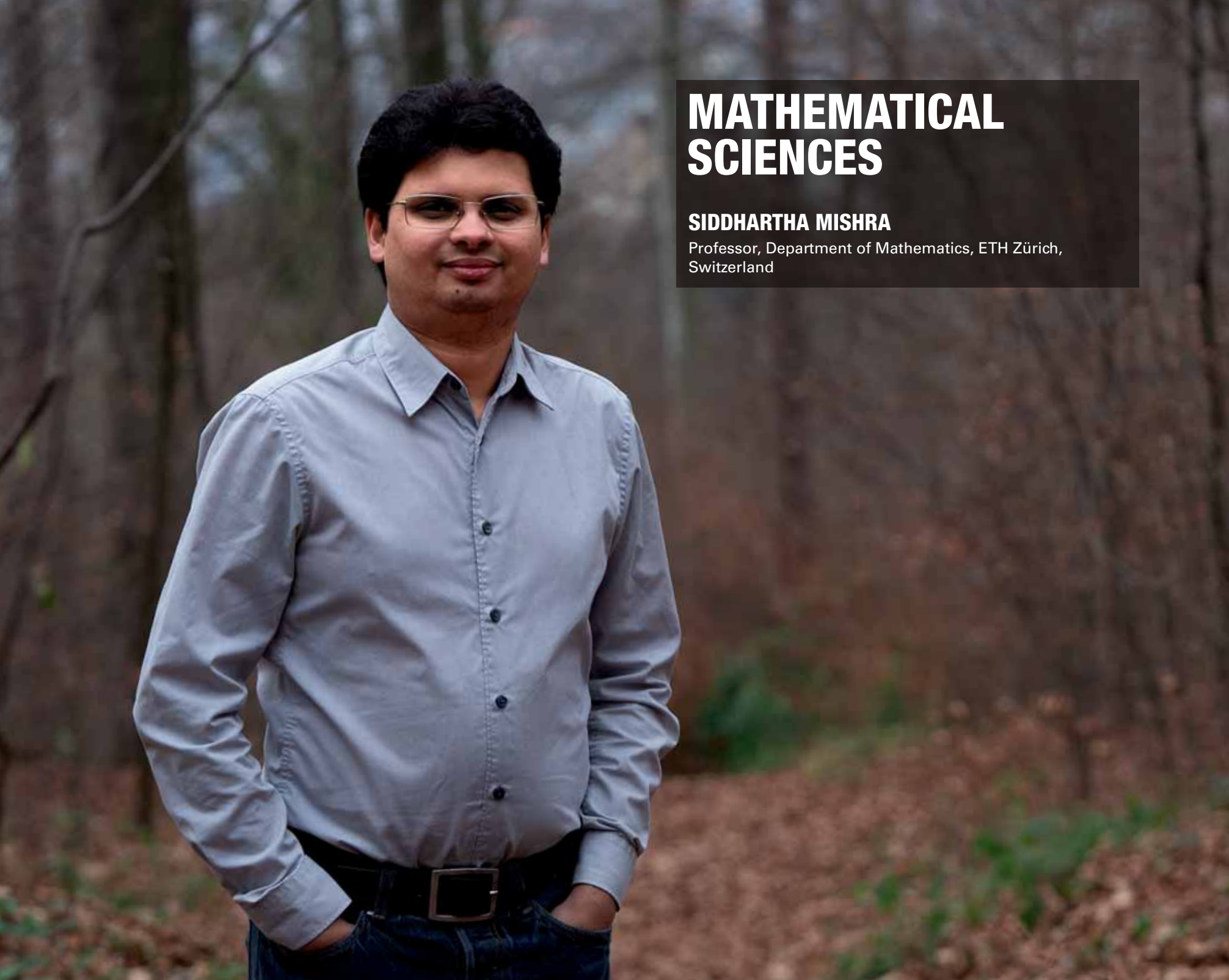
As with any conflict, knowing your opponent is half the battle won. After all this time, what do we know about bacteria?

Even though they are single-celled organisms, bacteria are extremely well-equipped to handle the harshest of conditions. Their protective cell-wall is made of a material called peptidoglycan (PG) layer which is a complex mesh of two kinds of molecules—glycans, made up of N-acetylglucosamine (NAG) and N-acetylmuramic acid (NAM) polymers and small peptide chains that connect the glycan strands.

At normal human body temperatures, bacteria multiply by cell division every 20 minutes. This happens by bacterial cells growing in size, during which time all the material inside the cell grows as well. Eventually one cell divides to become two daughter cells. This cell growth and division become possible because the PG layer of the cell wall is able to accommodate the expansion.

Now imagine what would happen if the PG layer does not increase in size as growth happens. The cell would simply burst open and die. How does the bacterial cell prevent this? Every living cell has protein molecules called enzymes which help along the reactions needed to support life. To prevent destruction during the expansion, bacteria use enzymes called hydrolases which 'cut' open the PG layer to make 'space'. Hence, they are also called ‘spacemaker’ enzymes. The cell is now able to accommodate more material to build the extra amount of PG which will then become part of the daughter cells. Other enzymes in the cell then help in combining the newly added glycan strands into the existing PG.

Dr. Manjula Reddy's work as a microbial geneticist involves understanding these enzymes that are involved in breaking and stitching together the cell-wall during bacterial cell multiplication. This would then help in manufacturing drugs that could specifically target these enzymes. The potential benefits of Dr. Reddy's work have huge implications for the future of mankind and our battle against deadly bacteria.



MATHEMATICAL SCIENCES

SIDDHARTHA MISHRA
Professor, Department of Mathematics, ETH Zürich, Switzerland

The Infosys Prize 2019 in Mathematics is awarded to Prof. Siddhartha Mishra for his outstanding contributions to applied mathematics, in particular for designing computational methods that solve nonlinear partial differential equations arising in different areas, analyzing their effectiveness and designing algorithms to implement them.

Prof. Siddhartha Mishra received an honors degree in Mathematics and Physics from Utkal University in Bhubaneswar in 2000. After his graduation he joined the Applied Mathematics program run jointly by IISc and TIFR in Bengaluru. By 2005 he had earned an M.Sc. and a Ph.D. from both.

Prof. Mishra was a Postdoctoral Fellow at University of Oslo (2005-2009) and then an Assistant Professor at ETH Zürich (2009-2011). He returned briefly to Oslo for a year and then went back to Zürich in 2012 as an Associate Professor and became a full Professor in 2015.

Mishra is the recipient of many awards including the Richard von Mises Prize (2015), the Jacques Louis Lions Award (2018), and the ICIAM Collatz Prize (2019). He was an invited speaker at the International Congress of Mathematicians held in Rio de Janeiro in 2018.

ABOUT MISHRA'S WORK AND ITS IMPACT

The evolution of many physical phenomena are modeled mathematically by differential equations that propagate the initial data forward. The important mathematical issue is establishing the existence and uniqueness of solutions to these equations. The notion of what constitutes a solution has to be carefully formulated. Some of these questions are still unresolved.

On the other hand, in the real world one needs numerical solutions. That requires the applied mathematician to develop computational methods, i.e. algorithms that yield approximations, analyze their effectiveness, and implement them. The initial condition may not be known with any precision and we may only have statistical information about it. Sometimes the numerical calculations can even provide a clue as to the qualitative behavior of the actual solution.

Prof. Siddhartha Mishra has made important contributions to all these aspects of applied mathematics. He has designed stable difference schemes for approximating the solutions of hyperbolic systems of conservation laws providing some of the first examples of numerical methods for such systems with rigorous stability properties. He has provided a proof of the stability of certain common schemes used in fluid mechanics and image processing.

Prof. Mishra's schemes are being used in astrophysics for calculations of exploding supernovae and propagation of Alfven waves in the solar chromosphere and corona and in climate studies for the simulation of the dynamics of clouds. Powerful numerical methods will continue to have a significant impact on the study of complex systems and understanding of their behavior over time.

CITATION BY THE JURY

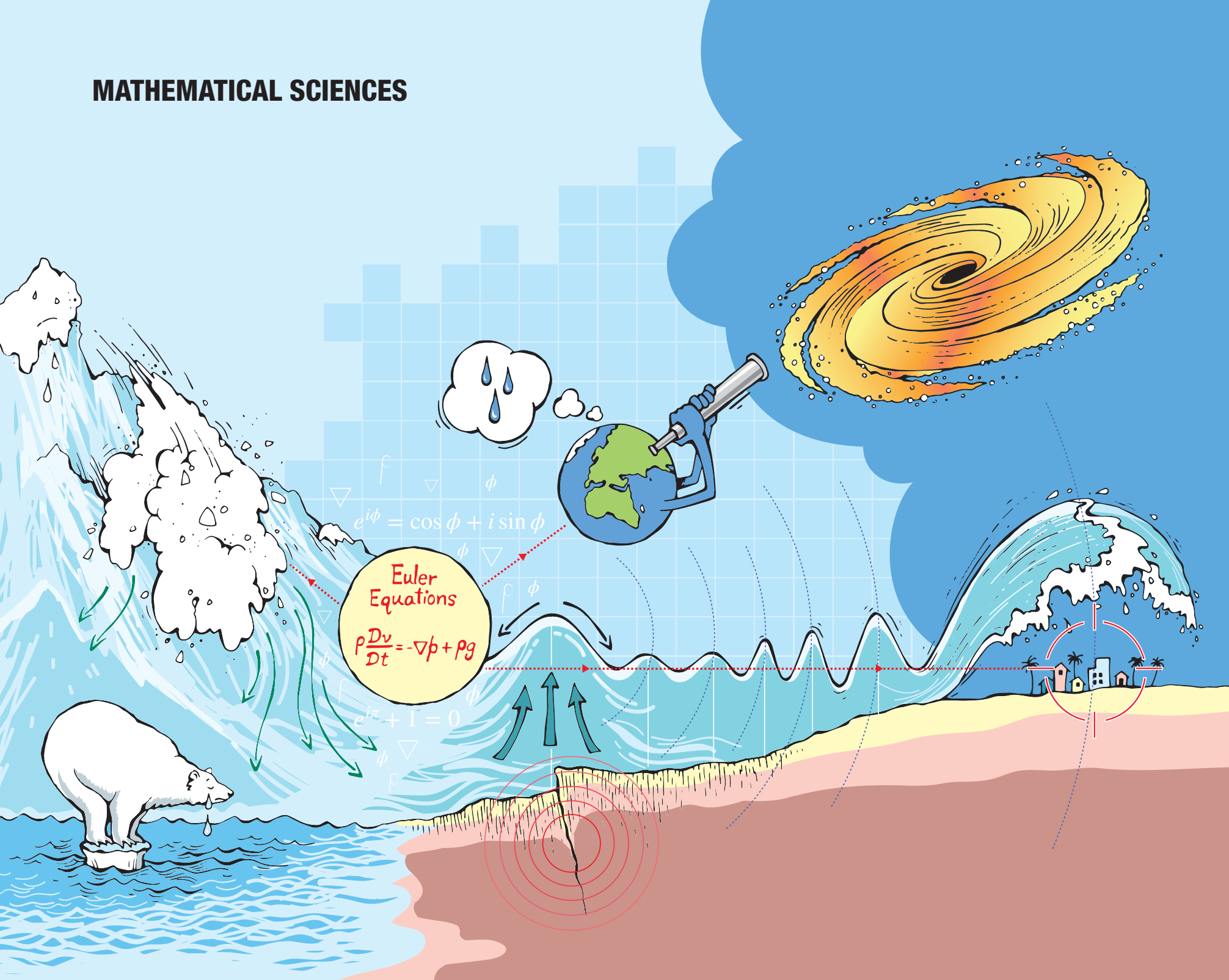
Many physical phenomena are modeled by some kind of fluid flow whose mathematical description involves nonlinear partial differential equations. Mathematicians prove, if they can, the existence and uniqueness of solutions to these equations. In the real world we need numerical solutions. They involve initial data which is often not precise and perhaps only statistical in nature. We need methods that propagate the data forward and provide an answer.

The problem is often difficult because the solutions are not smooth and develop shocks that need to be tracked accurately. Such problems occur in aerodynamics, ocean waves, weather prediction, and many other areas. Prof. Siddhartha Mishra has made outstanding contributions by constructing numerical methods, analyzing mathematically their effectiveness, and implementing them to solve concrete real-world problems.

"I want to congratulate Sid Mishra for being awarded the Infosys Prize in Mathematics this year. He has been recognized for his work in applied mathematics particularly his contributions to devising numerical tools for solving problems in the real world."

– Srinivasa S.R. Varadhan

MATHEMATICAL SCIENCES



MAKING SENSE OF NATURE WITH MATHEMATICS

Imagine being able to predict when and where a tsunami wave will hit. Or being able to predict the path of an avalanche. Think of how much destruction could be prevented by predicting these natural phenomena accurately. What if mathematics provided a way of understanding them? What if mathematics and all the computing power available to us could tell us if there are planets in galaxies far away that could support human life?

In the 18th century the Swiss mathematician Leonhard Euler developed an equation to describe the properties of liquids and gases which have no viscosity.

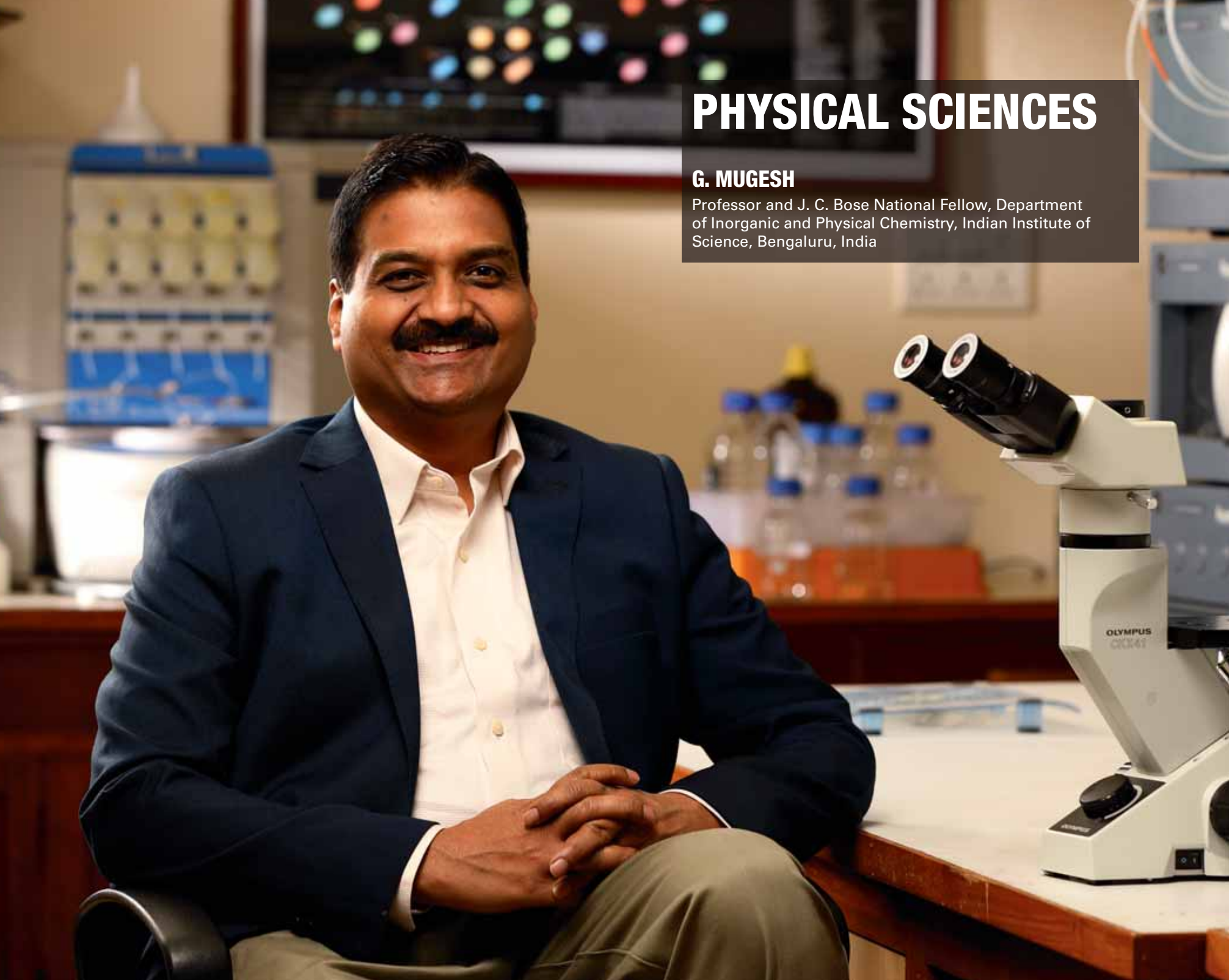
The Euler equations are applied widely in natural and engineering sciences to understand phenomenon that involve fluid flows. Natural phenomena from avalanches to tsunamis to collapsing supernovas and solar waves can be studied using these equations. How is this even possible? As with any problem, breaking them down into solvable smaller questions helps. In the case of these natural phenomena, we know that they are essentially constituted of movement of fluids—snow, water or gases. This is where the Euler equations come into play.

Prof. Siddhartha Mishra uses a combination of equations and algorithms to better understand the movement of avalanches.

This mathematical modeling step involves Mishra and his collaborators using partial differential equations to describe the movement of the powdery snow in avalanches and then designing algorithms which would allow for near exact simulations of these avalanches on computers. The complexity of these mathematical models means that the simulations might have to be performed on supercomputers.

These methods are used to calculate the impact of a tsunami wave triggered by an earthquake. The real-world importance of Mishra's work includes being able to predict a tsunami triggered by an earthquake, which would be enormously useful for engineers and for designing accurate risk maps.

The scope of Prof. Mishra's work is enormous. These simulations can be used in a wide range of scenarios that involve urgent problems such as climate change. Mishra's work could potentially also be used to simulate the climate on newly discovered exoplanets. This could then help scientists to know which planets are habitable.



PHYSICAL SCIENCES

G. MUGESH

Professor and J. C. Bose National Fellow, Department of Inorganic and Physical Chemistry, Indian Institute of Science, Bengaluru, India

The Infosys Prize 2019 in Physical Sciences is awarded to Prof. G. Mugesh for his seminal work in the chemical synthesis of small molecules and nanomaterials for biomedical applications. His work has contributed to the understanding of the role of trace elements, selenium and iodine, in thyroid hormone activation and metabolism, and this research has led to major medical advances.

Prof. G. Mugesh is a professor in the Inorganic and Physical Chemistry Department at the Indian Institute of Science, Bengaluru. He obtained his B.Sc. from the University of Madras, M.Sc. from the Bharathidasan University, and Ph.D. from the Indian Institute of Technology, Bombay.

Prof. Mugesh was a Humboldt Fellow (2001); a Visiting Fellow (Institute of Biochemistry and Molecular Biology, Heinrich-Heine University, Duesseldorf, Germany); and a Skaggs Postdoctoral Fellow (Skaggs Institute for Chemical Biology, The Scripps Research Institute, La Jolla, California, USA) before taking up his current post in Bengaluru.

Mugesh's many recognitions include the Shanti Swarup Bhatnagar Prize (2012). He is also fellow of the Indian Academy of Sciences (2010); National Academy of Sciences (2010); UK's Royal Society of Chemistry (2013); and Indian National Science Academy (2016). He has delivered numerous named lectures and has served on the editorial boards of many Indian and international journals.

ABOUT MUGESH'S WORK AND ITS IMPACT

Prof. G. Mugesh is an internationally renowned chemical biologist whose work ranges from the fundamental chemical synthesis and understanding of biochemical mechanisms at the molecular level to practical medical applications. He has made pioneering contributions in the areas of Biomimetic Redox Modulators, Thyroid Hormone Metabolism, and nanomaterials. His broad research encompasses artificial enzymes including nanozymes in cellular redox signaling. His work on the design and synthesis of small molecules that functionally mimic the selenoenzymes in mammalian cells has received worldwide attention.

Prof. Mugesh has made seminal contributions to our understanding of the role of trace elements, such as selenium and iodine, in human health. His group has pioneered the idea of using artificial enzymes (those not present in nature, but which can be synthesized to act as catalysts for biologically important reactions) to modulate cellular processes under oxidative stress conditions.

Recent research in Mugesh's laboratory is aimed at the use of halogen bonding as a strategy to efficiently deliver proteins and synthetic small molecules into human cells across the plasma membrane. Cellular delivery of proteins and small molecules is a major challenge in drug discovery, and biomedical research. Mugesh's strategy to use the halogen bond-mediated cellular uptake paves the way for the efficient delivery of therapeutic proteins and small molecule drugs into human cells.

CITATION BY THE JURY

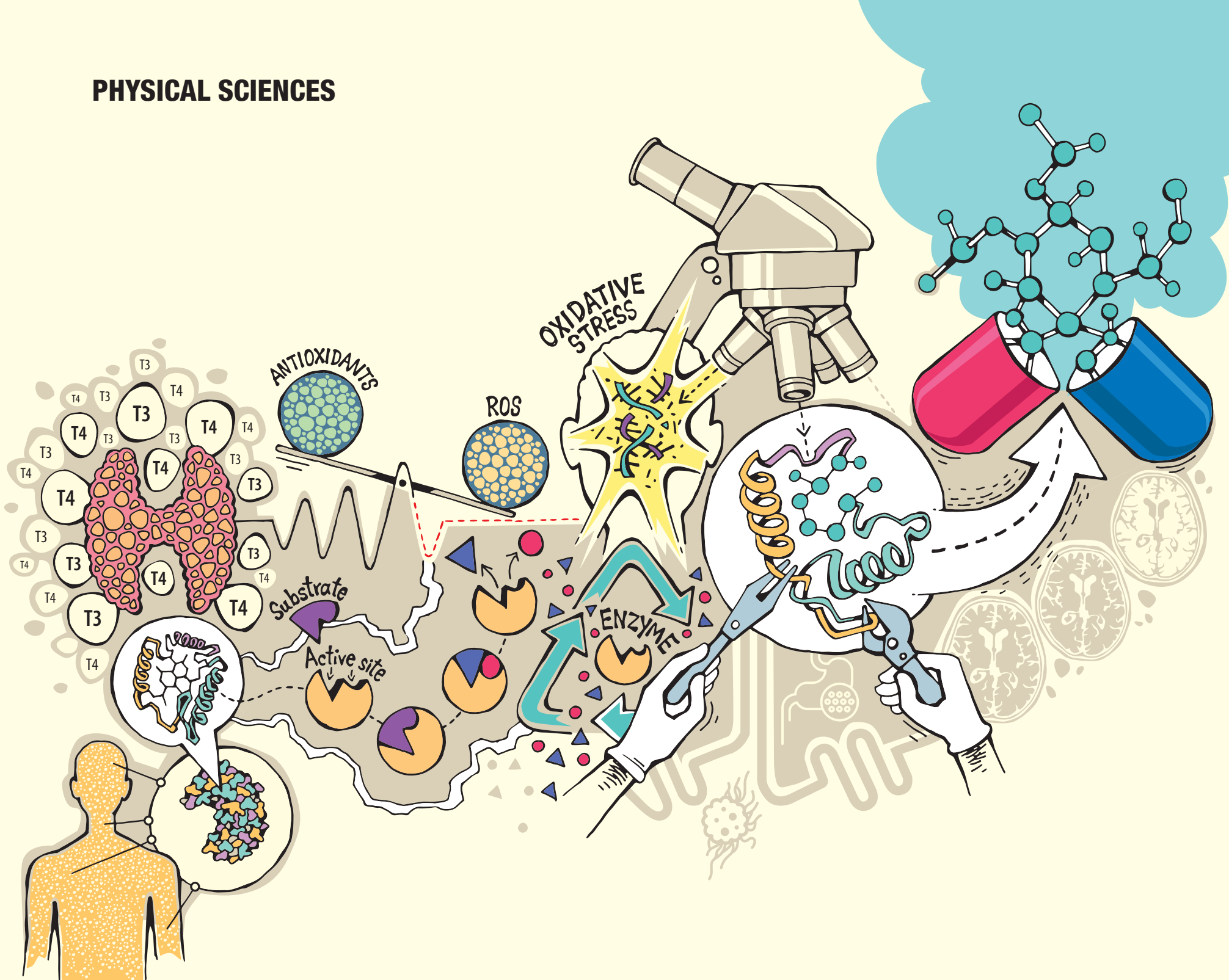
Prof. G. Mugesh has made pioneering contributions to Biomimetic Redox Modulators, Thyroid Hormone Metabolism, and nanomaterials. He has made seminal contributions to the understanding of the importance of trace elements, such as selenium and iodine, in thyroid hormone activation and metabolism. His work on artificial enzymes including nanozymes that modulate the cellular redox signaling has attracted worldwide attention.

Prof. Mugesh's work ranges from the fundamental chemical synthesis and mechanisms of understanding at the molecular level to practical medical applications. The recent discovery from his laboratory, that proteins and synthetic small molecules can be delivered into human cells across the plasma membrane by utilizing halogen bonding, has direct applications to human health. This novel strategy can be used for the efficient delivery of proteins and small molecule for therapeutic applications.

"Congratulations Mugesh on being awarded the 2019 Infosys Prize in Physical Sciences. Your work is fundamental and also has practical applications. With your command of chemistry, you're able to synthesize chemicals such as enzymes for biological use. At the same time, you have also developed a clever technique to transport these chemicals efficiently to specific sites. The application for activating thyroid is of considerable value as an instance."

– Shrinivas Kulkarni

PHYSICAL SCIENCES



THE SPARKS THAT FIRE LIFE

Have you ever wondered what enables life? How is it that as you sit here reading this, you're able to breathe and your heart continues to beat while your muscles hold your body in position? Of the many things that keeps it all together are tiny protein molecules called enzymes. They are the stuff of life itself and an absence or malfunctioning have disastrous consequences.

Prof. Mugesh is a chemical biologist. Chemical biology is a discipline that uses chemical techniques, and small molecules produced using synthetic chemistry in order to study and manipulate biological systems. Prof. Mugesh's lab works to create artificial enzymes including small molecules and nanomaterials that could help understand biological processes such as thyroid hormone metabolism and cellular redox signalling.

Redox signalling is a process in which free radicals, reactive oxygen species, and other compounds act as biological messengers. Reactive oxygen is an unstable molecule containing oxygen that easily reacts with other molecules in a cell, a build-up of which can cause damage to DNA and can even lead to cell death.

Enzymes are the proteins that aid everything from digesting food to creating DNA, by speeding up chemical reactions in the body. Even without enzymes these chemical reactions could still occur but they would be too small to support life. The cells of the human body contain hundreds of enzymes that control cell activity and even defend them from invasion by microbes like bacteria and viruses.

All enzymes have some common features. They have an active site, which is a groove in the enzyme molecule where the substrate is captured and broken down or combined together depending on the reaction. Enzymes are also specific when it comes to the molecules they bind with. This specificity is crucial to keep bodily processes going. The third characteristic of enzymes is that they are recycled. This means that only a small amount of enzyme is required for thousands of reactions.

An artificial enzyme is a synthetic molecule or nanomaterial (nanozyme) that recreates some function of an enzyme. They have been widely explored for various applications, such as bio sensing, bio imaging, tumor diagnosis and therapy.

Research into artificial enzymes took off from the late 90s and in 2014 scientists announced that they had managed to produce active enzymes that were made from molecules that do not occur anywhere in nature. These molecules hold the key to new diagnostic tools and drugs.

Prof. Mugesh's contributions to this burgeoning field include pioneering the idea of using artificial enzymes to modulate cellular processes under conditions of oxidative stress. His lab has also found methods to efficiently deliver therapeutic proteins and drugs into human cells. These path-breaking discoveries pave the way for new drug delivery systems and diagnostic tools of the future.

SOCIAL SCIENCES

ANAND PANDIAN

Professor, Department of Anthropology, Krieger School of Arts & Sciences, Johns Hopkins University, Baltimore, USA

The Infosys Prize 2019 in Social Sciences is awarded to Prof. Anand Pandian for his brilliantly imaginative work on ethics, selfhood and the creative process. Prof. Pandian's research is notable for its originality and virtuosity. His writing pushes the boundaries of how anthropologists render into words the worlds they encounter. Innovative in concept and structure, and impeccably crafted, his work breaks new ground.

Anand Pandian is Professor of Anthropology at the Krieger School of Arts & Sciences at Johns Hopkins University. Prof. Anand Pandian graduated summa cum laude from Amherst College in 1994 with a B.A. in Political Ecology. He received his M.A. in Sociocultural Anthropology from University of California, Berkeley in 1999.

After receiving his Ph.D. in Sociocultural Anthropology from UC, Berkeley in 2004, he was visiting faculty at Hamilton College. From 2005-2007, Prof. Pandian was Johal Chair in Indian Studies and Assistant Professor of Anthropology, University of British Columbia following which he joined the faculty of JHU in 2007.

ABOUT PANDIAN'S WORK AND ITS IMPACT

Prof. Anand Pandian's work is outstanding for the originality it brings to established fields of research. His monograph, *Crooked Stalks: Cultivating virtue in South India* (2009) synthesizes important and well-studied subjects: caste-based identities, agrarian political economy, and ecology in Tamil Nadu. But he injects into them a fresh ingredient: morality and the aspiration to be a better person.

This novel perspective transforms conventional understandings of development as the pursuit of material well-being, orchestrated from above through state programs, to highlight local histories of self-making. The question of ethical personhood is now a growing concern in anthropology, and Prof. Pandian is among the first scholars to treat it as a secular aspiration.

Pandian's writings on Tamil film-making move film studies beyond textual criticism and a preoccupation with political effects to an intensive engagement with the affects created by cinema and the artisanal craftwork that produces these affects. *Reel World: An Anthropology of Creation* (2015) achieves the difficult feat of capturing the creative process of individuals working in a complex and uncertain collective medium. While attentive to the formal properties of cinema, Pandian evokes the experiential textures of the medium through prose that conjures up the lived reality as well as fantasy world of film makers. Pandian's contribution to an anthropology of the senses charts a path for other studies of popular culture.

Pandian is known for his careful attention to the craft of anthropology. His edited volumes experiment with expanding the boundaries of the discipline to encompass literary modes of rendering selves and worlds.

CITATION BY THE JURY

Prof. Anand Pandian's brilliantly imaginative work on ethics, selfhood and the creative process is notable for its originality, virtuosity and deep thoughtfulness. Pandian's books and articles break new ground: innovative in concept and structure, and impeccably crafted.

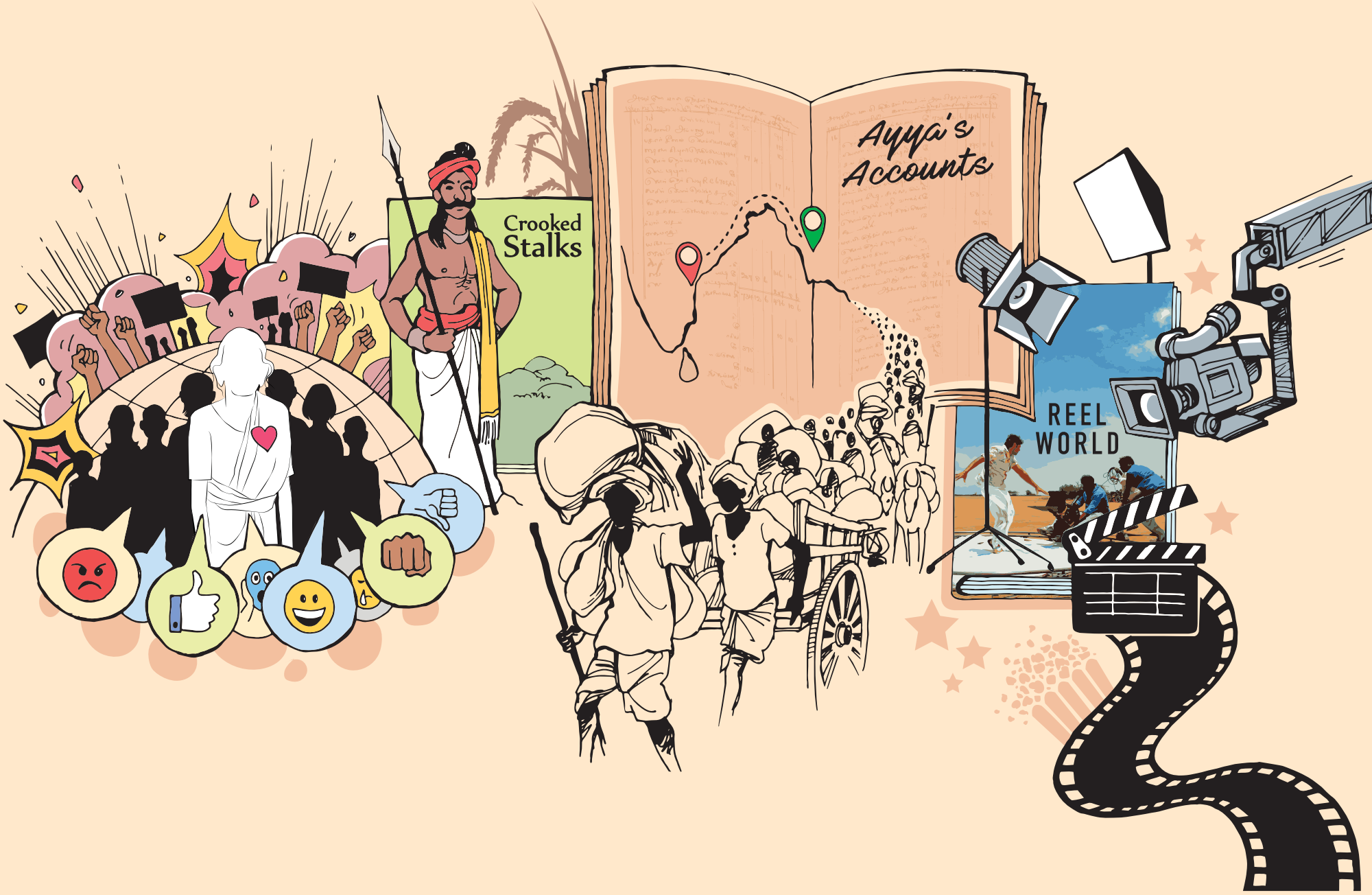
Pandian's impeccable research draws upon intensive fieldwork, classical Tamil texts, the colonial archive as well as contemporary popular culture. He is also prodigiously productive.

Pandian's edited volumes experiment with ethnographic writing, pushing the boundaries of how anthropologists render into words the worlds they encounter.

"Anand Pandian is among the most creative anthropologists of his generation. He is known for pushing the frontiers of the discipline and for the mastery of his craftsmanship. He has shed new light on caste-based identities and agrarian political economy and ecology by focusing on the moral dimensions of development. I congratulate Anand Pandian for the brilliance of his research and his ethical commitment to illuminating the human condition."

– Kaushik Basu

SOCIAL SCIENCES



HUMANITY AT ITS LIMITS

In a world of intense uncertainty, social strife, and ecological upheaval, what can happen to our sense of humanity? For the field of anthropology, this question is essential. People respond to challenging circumstances in many ways. They rely on the lessons of literary and moral traditions, on the familiar habits of everyday life, on the ebb and flow of feelings and desires. These resources are often enough to meet the challenges at hand. But there are also times of serious breakdown and moral impasse.

Anthropologists examine other ways of living and relating to one another, with the hope of shedding light on how to meet a difficult world with curiosity and care. Anthropology takes people into distant and unfamiliar places. The discipline expects that researchers will spend substantial time in these places, gradually learning to live as others do, developing an intimate sense of their experience, and trying to convey the texture of those lives through vivid and engaging stories.

This method runs throughout the work of Prof. Anand Pandian. His first book, *Crooked Stalks*, focuses on a Tamil community classified as criminal by nature in the colonial era. Tracing the weight of that history on the present, Pandian shows how farmers, shepherds, and laborers in rural Tamil Nadu think of agriculture as an arena of ethical life. A subsequent book, *Reel World*, took the anthropologist into the frenetic environment of filmmaking in Tamil cinema. Trailing directors, actors, designers and cameramen in and out of studios and shooting locales, Pandian captures the improvisational nature of creative process.

Ecology and environment are abiding themes in Pandian's work. His writings explore various ways to reconcile the tugs of human aspiration with the material conditions and limits in which people live and strive. These tensions come alive in *Ayya's Accounts*, a book written about his grandfather's century of life in India, Burma, and the United States. Pandian has been writing more recently about walls and boundaries in everyday America, trying to make sense of why so many there shut themselves off from the rest of the world. His latest book project explores decay as the underside of growth, the danger of neglecting the reality that things inevitably come apart: bodies and economies, plastic and waste.

In a classically anthropological spirit, all these works try to reimagine what seems natural and familiar from the vantage point of someplace outside.

JURY CHAIRS

ENGINEERING AND COMPUTER SCIENCE

Arvind

Jury Chair

Prof. Arvind is the Johnson Professor of Computer Science and Engineering, Computer Science and Artificial Intelligence Laboratory, Massachusetts Institute of Technology. His work was instrumental in the development of dynamic dataflow architectures and associated parallel programming languages. He developed the Bluespec language for the synthesis and verification of large digital systems. Prof. Arvind has received numerous awards and honors, and they include the IEEE Charles Babbage Outstanding Scientist Award (1994); Distinguished Alumnus Award, IIT Kanpur (1999); Outstanding Achievement Award, University of Minnesota (2008); and IEEE Computer Society Harry H. Goode Memorial Award (2012).

Jurors

Jayathi Y. Murthy

Dean, Henry Samueli School of Engineering and Applied Science and Distinguished Professor, Department of Mechanical and Aerospace Engineering at the University of California, Los Angeles, USA

K. Mani Chandy

Simon Ramo Emeritus Professor, California Institute of Technology, USA

Sudhir Jain

Director, Indian Institute of Technology Gandhinagar (IITGN), Ahmedabad and Professor, IIT-Kanpur, India

Dhananjaya Dendukuri

CEO & Co-Founder, Achira Labs Pvt. Ltd., Bengaluru, India

Jitendra Malik

Arthur J. Chick Professor Department of Electrical Engineering & Computer Science, University of California, Berkeley and Director of Research at Facebook AI Research, Menlo Park, USA

HUMANITIES

Akeel Bilgrami

Jury Chair

Akeel Bilgrami is the Sidney Morgenbesser Professor of Philosophy and Professor, Committee on Global Thought, Columbia University. He is the author of the books, *Belief and Meaning, Self-Knowledge and Resentment, and Secularism, Identity, and Enchantment* and is currently writing a book on Gandhi's philosophy as well as a longer work on the nature of practical reason. At Columbia he has been the Chairman of the Philosophy Department from 1994-98, the Director of the Heyman Centre for the Humanities from Dec 2003-2010, and the Director of the South Asian Institute from 2013-2016. He was elected Cullman Fellow at the New York Public Library, held the Radhakrishnan Chair in India, visiting professorships at Oxford University and Yale University, and has been the recipient of fellowships and grants from the Mellon Foundation, Ford Foundation, National Endowment of the Humanities, as well as the Luce Foundation. He is also the President of the Trustees and the Executive Editor of *The Journal of Philosophy*.

Jurors

David Shulman

Professor Emeritus, Hebrew University, Jerusalem and a member of the Israel Academy of Sciences and Humanities, Israel

Vidya Dehejia

Barbara Stoler Miller Professor of Indian and South Asian Art, Department of Art History and Archaeology, Columbia University, USA

Diana L. Eck

Professor of Comparative Religion and Indian Studies, Fredric Wertham Professor of Law and Psychiatry in Society in the Faculty of Arts and Sciences and Master of the Lowell House, Harvard University, USA

Sanjay Subrahmanyam

Distinguished Professor and Irving and Jean Stone Endowed Chair in Social Sciences, University of California, Los Angeles, USA

Rajeswari Sunder Rajan

Global Distinguished Professor, Faculty of Arts and Science, New York University, USA

LIFE SCIENCES

Mriganka Sur

Jury Chair

Mriganka Sur is the Newton Professor of Neuroscience; Director, Simons Center for the Social Brain; and Investigator, Picower Institute for Learning and Memory, at the Massachusetts Institute of Technology. He was head of the MIT Department of Brain and Cognitive Sciences for 15 years. The McGovern Institute for Brain Research was founded under his leadership. At MIT, Sur received the Hans-Lukas Teuber Scholar Award in the Brain Sciences (1997), the Sherman Fairchild Chair (1998), and the Newton Chair (2008). He is an elected Fellow of the Royal Society (UK), the US National Academy of Medicine, the American Academy of Arts and Sciences, the American Association for the Advancement of Science, The World Academy of Sciences, and the Indian National Science Academy.

Jurors

Caroline Dean

Royal Society Professor – Cell and Developmental Biology, John Innes Centre, Norwich, UK

Ketan J. Patel

Scientist and Investigator at the Medical Research Council (MRC) Laboratory of Molecular Biology (LMB), University of Cambridge, UK

Paola Arlotta

Chair, Harvard Department of Stem Cell and Regenerative Biology; Golub Family Professor of Stem Cell and Regenerative Biology, Harvard University and Associate Member, Stanley Center for Psychiatric Research, Broad Institute, USA

Eric S. Lander

Professor of Biology; Professor of Systems Biology, Harvard Medical School; Founding Director, Broad Institute of MIT and Harvard, USA

John Kuriyan

Professor, Department of Molecular and Cell Biology and Department of Chemistry, University of California, USA

MATHEMATICAL SCIENCES

Srinivasa S. R. Varadhan

Jury Chair

Srinivasa S. R. Varadhan is Professor of Mathematics and Frank J. Gould Professor of Science at the Courant Institute of Mathematical Sciences, New York University (NYU), New York, USA. His awards and honors include the National Medal of Science (2010) from US President Barack Obama, the highest honor bestowed by the United States government on scientists, engineers and inventors. He is also the winner of the Abel Prize (2007), the Leroy Steele Prize (1996), the Margaret and Herman Sokol Award of the Faculty of Arts and Sciences, New York University (1995), and the Birkhoff Prize (1994). He also has honorary degrees from the Chennai Mathematical Institute (2008), the Indian Statistical Institute in Kolkata, India (2004), Université Pierre et Marie Curie in Paris (2003), and from Duke University, USA (2016).

Jurors

M.S. Raghunathan

Distinguished Visiting Professor, Centre of Excellence in Basic Sciences, Kalina, Mumbai, India

Chandrashekhar Khare

Professor of Mathematics, University of California, Los Angeles, USA

Claire Voisin

Professor, Collège de France, Paris, France

Sanjeev Arora

Charles C. Fitzmorris Professor in Computer Science, Princeton University, USA

Parimala Raman

Arts & Sciences Distinguished Professor of Mathematics, Emory University, USA

PHYSICAL SCIENCES

Shrinivas Kulkarni

Jury Chair

Shrinivas Kulkarni is the George Ellery Hale Professor of Astronomy and Planetary Science at the California Institute of Technology (Caltech), USA. His primary interests are the study of compact objects (neutron stars and gamma-ray bursts) and the search for extra-solar planets through interferometric and adaptive techniques. He serves as the Interdisciplinary Scientist for the Space Interferometry Mission (SIM) and is co-Principal Investigator of the Planet Search Key Project (also on SIM). He has been awarded the Alan T. Waterman Prize of the NSF, a fellowship from the David and Lucile Packard Foundation, a Presidential Young Investigator award from the NSF and the Helen B. Warner award of the American Astronomical Society and the Jansky Prize of Associated Universities, Inc. He was also elected a Fellow of the American Academy of Arts and Sciences (1994), Fellow of the Royal Society of London (2001) and Fellow of the National Academy of Sciences (2003) and foreign member of the Royal Netherlands Academy of Arts and Sciences (2016). In 2017, he won the Dan David Prize for his contribution to the emerging field of Time Domain Astronomy.

Jurors

Rana Adhikari
Professor of Physics, California Institute of Technology, USA

Ajay K. Sood
DST Year of Science Professor, Department of Physics, Indian Institute of Science, Bengaluru, India

Carol Robinson
Chair, Doctor Lee's Professor of Chemistry, University of Oxford, UK

A. R. Ravishankara
University Distinguished Professor, Departments of Chemistry and Atmospheric Science, Colorado State University, USA

Subir Sachdev
Herchel Smith Professor of Physics, Harvard University, USA

SOCIAL SCIENCES

Kaushik Basu

Jury Chair

Kaushik Basu is Professor of Economics and the C. Marks Professor of International Studies at Cornell University. He is a former Chief Economist and Senior Vice President of the World Bank. Prior to joining the World Bank, he served as Chief Economic Adviser to the Government of India. A Fellow of the Econometric Society, he has published widely in the areas of Development Economics, Industrial Organization, Game Theory and Welfare Economics. His books include *Analytical Development Economics (1997), Prelude to Political Economy: A Study of the Social and Political Foundations of Economics (2000), Of People, Of Places: Sketches from an Economist's Notebook (1994), Beyond the Invisible Hand: Groundwork for a New Economics (2011), An Economist's Miscellany (2011)*, and *The Republic of Beliefs (2018)*. In May 2008, he was awarded the Padma Bhushan by the Government of India.

Jurors

Avinash Dixit
John J. F. Sherrerd '52 University Professor of Economics Emeritus, Princeton University, USA

Amita Baviskar
Professor, Sociology Unit, Institute of Economic Growth, Delhi, India

Andrew Willford
Professor of Anthropology, Cornell University and Chair of Cornell's Institutional Review Board, USA

Srinath Raghavan
Professor of International Relations and History, Ashoka University, Sonipat, India

Rajeev Bhargava
Political theorist and Director, Institute of Indian Thought, Centre for the Study of Developing Societies, Delhi, India

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THE INFOSYS SCIENCE FOUNDATION

SECURING INDIA'S SCIENTIFIC FUTURE

The Infosys Science Foundation is a not-for-profit trust set up in 2009. It confers the Infosys Prize to honor outstanding achievements across six categories of research: Engineering and Computer Science, Humanities, Life Sciences, Mathematical Sciences, Physical Sciences and Social Sciences. A jury comprising eminent leaders in each of these fields evaluates the achievements of nominees against the standards of international research, placing the winners on par with the finest researchers in the world. The prize consists of a gold medal, a citation, and a purse of US $100,000.

With the belief that sharing knowledge across various disciplines will encourage innovative collaboration, we are hosting the inaugural Infosys Prize Winners' Symposium this year. Laureates across all categories will present their prize winning work. We hope this will grow into a space for presenters and audience to learn about exciting possibilities beyond the ambit of their own field.

In keeping with its mission of spreading the culture of science, the Foundation conducts the Infosys Prize Lectures – a series of public talks, by jurors and laureates of the Infosys Prize. These talks aim to inspire and inform young researchers and students on current research, and open up a world of possibilities for them. Through its other initiatives, the Infosys Science Foundation seeks to bring more young Indians into the realm of research. Log on to www.infosys-science-foundation.com to know more.

Infosys Science Foundation
Infosys Prize

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