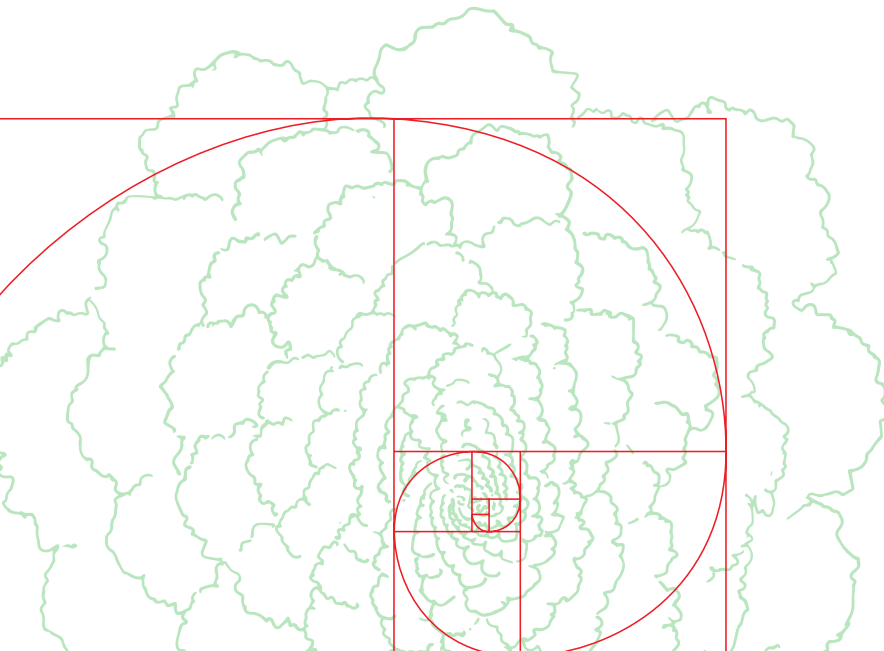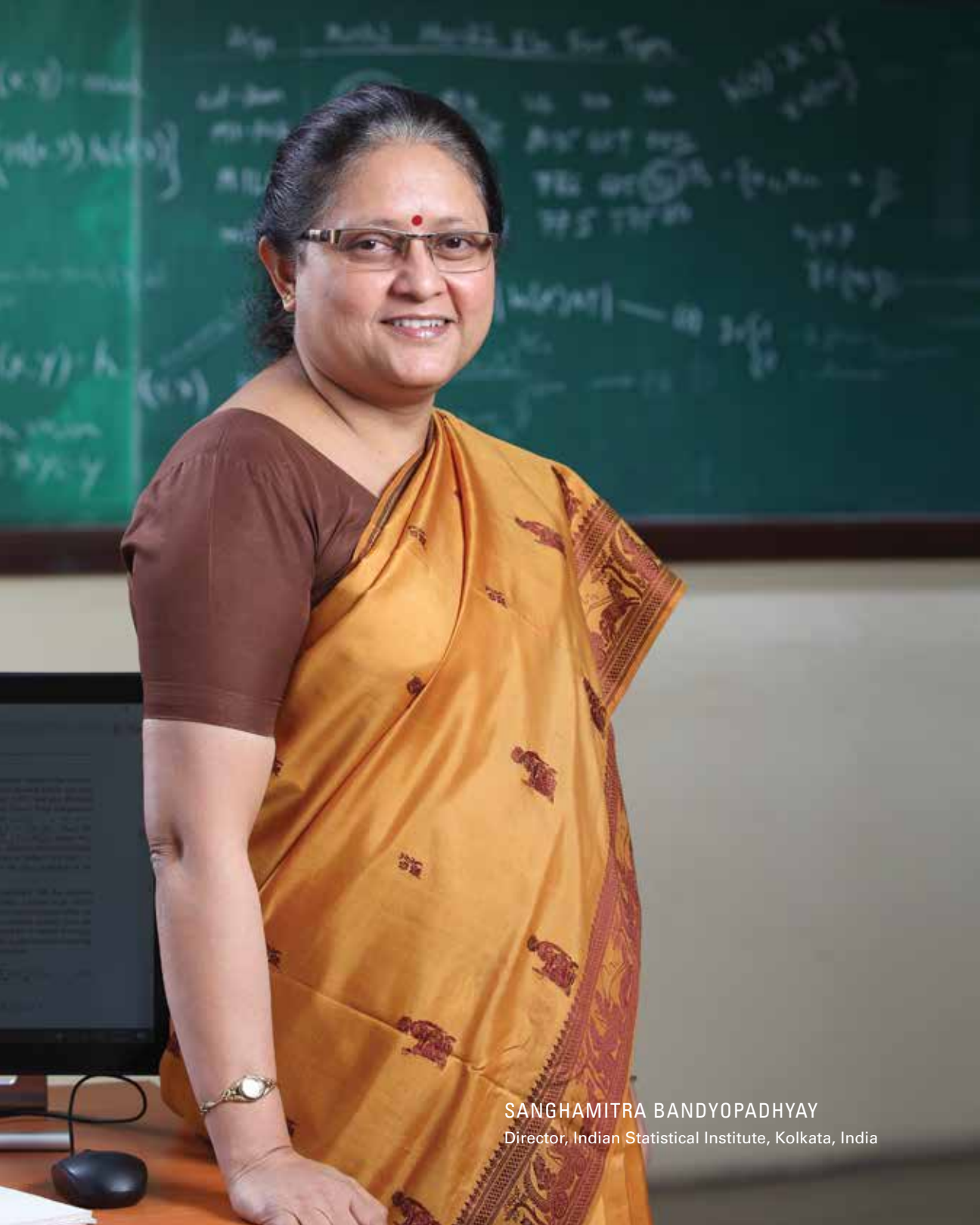# INFOSYS PRIZE 2017

The Romanesco broccoli has fascinated photographers the world over. The brilliant chartreuse and the mesmerizing spiral spines belong to an edible flower bud of the species *Brassica oleracea*. Grown in Italy since the 16th century, this broccoli-cauliflower hybrid is nutritionally rich, with a delicate nutty flavor. Romanesco thus demands as much interest from chefs as from botanists and researchers.

But it doesn't stop there – peer closely and you will see just how incredible it really is. For it is one of the earth's most stunning natural fractals. In other words, each of its buds is composed of a series of smaller buds, all arranged in yet another logarithmic spiral. The same pattern continues at several diminishing size levels. Studies of fractals found in nature, such as a snowflake or lightning bolts or indeed the Romanesco broccoli, trace a path to modern applications in computer graphics. We tend to divide and study distinct subjects – physics, biology, math, engineering and so on – only to find one interconnected universe.

And it gets even more bizarre. The number of spirals on the head of a Romanesco broccoli is a natural approximation of the Fibonacci number. Named after the Italian mathematician, the Fibonacci spiral is a logarithmic spiral where every quarter turn is farther from the origin by a factor of phi, the golden ratio. How about that for a little bit of math in your soup?

SANGHAMITRA BANDYOPADHYAY
Director, Indian Statistical Institute, Kolkata, India

ENGINEERING AND COMPUTER SCIENCE

The Infosys Prize 2017 in Engineering and Computer Science is awarded to Prof. Sanghamitra Bandyopadhyay for her scholarly record in algorithmic optimization and for its significant impact on biological data analysis. She has discovered a genetic marker for breast cancer, determination of co-occurrence of HIV and cancers, and the role of white matter in Alzheimer's disease.

SCOPE AND IMPACT OF WORK

Prof. Sanghamitra Bandyopadhyay's scholarship concerns the design of new computer algorithms that enable us to automatically search for patterns and knowledge in large data sets. Modern scientific instruments such as sequencers and information networks generate prodigious amounts of data that need to be analyzed quickly, sometimes at real-time speeds, to discover interesting patterns that can be used by scientists and engineers to make new discoveries, and improve health and social services.

Prof. Bandyopadhyay's methodological advances in clustering algorithms improve the time computer programs take to converge to an optimal solution while improving the quality of solution in view of multiple competing objectives. This ability to quickly evaluate multi-criteria clustering alternatives efficiently is key to its use in feature selection, gene selection, microarray data clustering, finding protein modules, segmenting remote sensing images, process plan generation in reconfigurable manufacturing systems and in selection of views in data warehousing.

Bandyopadhyay has advanced evolutionary algorithms with applications in image analysis, bioinformatics analysis, and gene regulatory networks, to name a few. Her work has found application in building software used at the Sandia National Laboratories in the US in detecting water contamination. Her work has enabled biomedical researchers to make best predictions about regulation that with microRNAs is specific to the tissue being analyzed.

Based on these predictions and further analyses, Bandyopadhyay identified a new genetic marker for breast cancer that was later validated through laboratory experiments. Her work has also explored disease mechanisms related to HIV-1 and Alzheimer's.

CITATION BY THE JURY

The Infosys Prize in Engineering and Computer Science is awarded to Prof. Sanghamitra Bandyopadhyay for the design of new computer algorithms that enable us to search for patterns and knowledge in vast amounts of data generated, for example, by scientific instruments such as genomic sequencers.

Prof. Bandyopadhyay has devised methods to discover structure in data sets and identify clusters and developed search techniques that use multiple optimization criteria with provable bounds on the quality and the speed with which these results are found.

Bandyopadhyay has expertly applied these skills in biological data analyses where she has made multiple discoveries related to genomic expressions in cancer, HIV and Alzheimer's disease. Her research is an excellent example of new scientific discoveries, such as a genetic marker for breast cancer, that have been made possible by the advances in computational methods.

Prof. Sanghamitra Bandyopadhyay received a B.Sc. with honors (Physics) from Presidency College, Kolkata, a B. Tech. (Computer Science and Engineering) from Calcutta University, an M. Tech. (Computer and Information Technology) from IIT-Kharagpur, and a Ph.D. (Computer Science) from the Indian Statistical Institute, Kolkata in 1998. Prof. Bandyopadhyay is the second woman to receive the Shanti Swarup Bhatnagar Prize in Engineering Sciences (2010). She received the Swarnajayanti Fellowship from the Department of Science and Technology in 2006. Her other awards include the Young Scientist Award from the Indian National Science Academy (INSA) (2000); and the Young Engineer Award from the Indian National Academy of Engineers (INAE) (2002).

She is a Fellow of IEEE, INSA, INAE, the National Academy of Sciences India, and the West Bengal Academy of Sciences and Technology.

"Prof. Sanghamitra Bandyopadhyay sets an inspiring example of high-quality original research in computer science done entirely in India that has had a worldwide impact on science and society."

– Pradeep K. Khosla

The science of listening to what life is telling us

Bioinformatics is an interdisciplinary field of study that develops software to make sense of vast amounts of biological data. The software helps in finding patterns in seemingly random sets of data that are generated from biological systems and processes.

The scientist Margaret Belle Oakley Dayhoff is generally considered the pioneer of bioinformatics. In the 1950s and 1960s Dayhoff pioneered the use of mathematics and computational methods to study biological systems. She compiled one of the first protein sequence databases.

Since then, with the growth of computing technology, the field of bioinformatics has grown by leaps and bounds, finding particular use in genomics and genetics. The primary goal of bioinformatics is to gain a deeper understanding of biological processes.
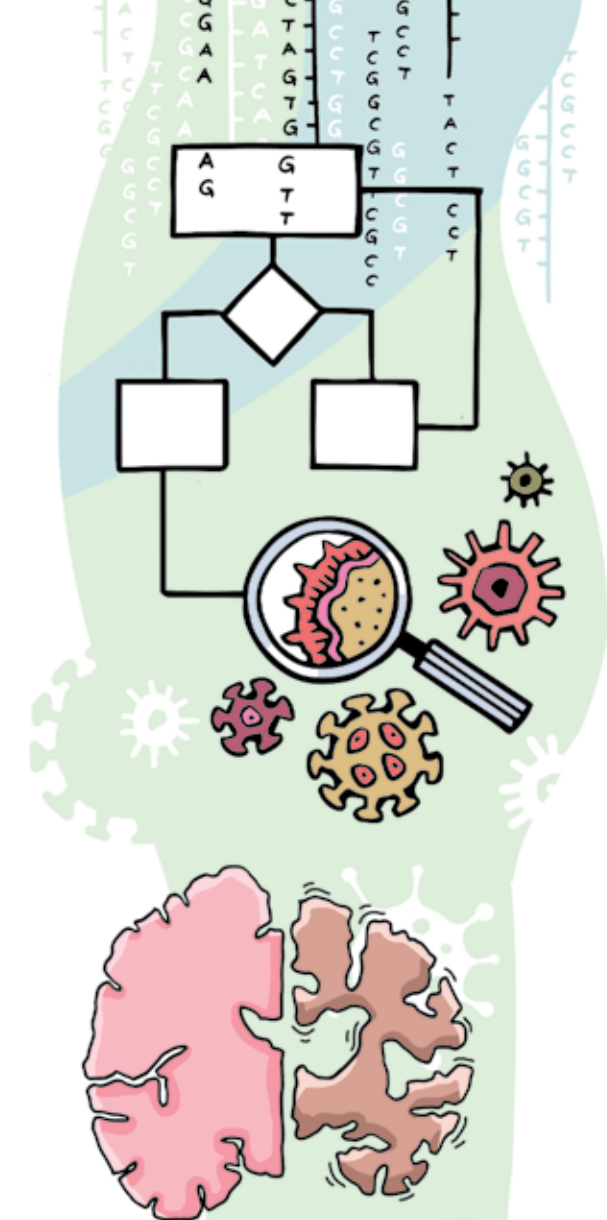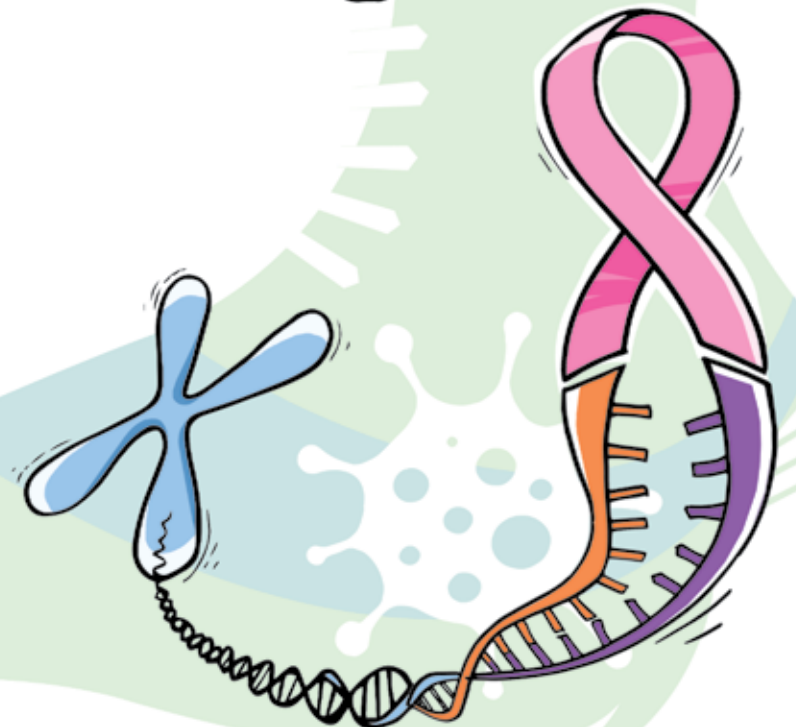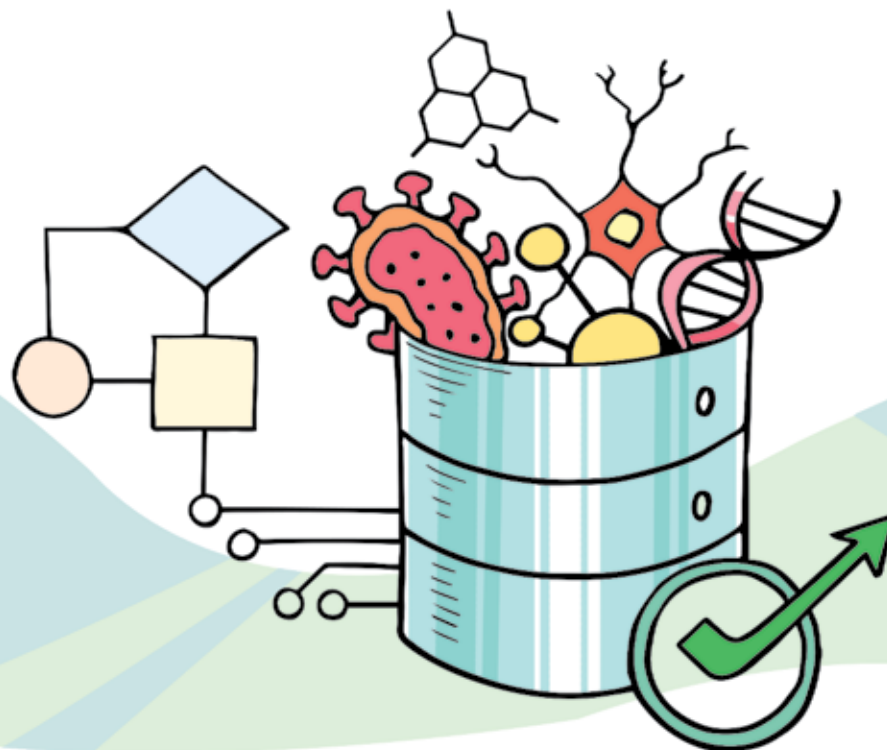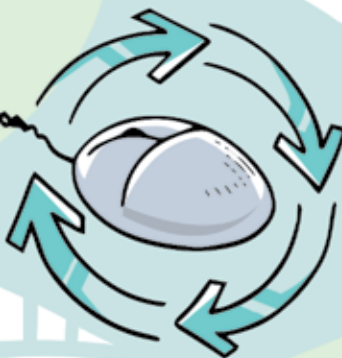
Prof. Sanghamitra Bandyopadhyay's work builds on the advances in bioinformatics. Prof. Bandyopadhyay is a computer scientist who has designed algorithms that can be used to search for patterns and information in large biological data sets. These algorithms are also able to help run computer programs faster and more efficiently in finding an optimal solution while also improving the quality of the solution.

Bandyopadhyay's work has led to the discovery of a new microRNA marker for breast cancer.

The algorithms designed by Bandyopadhyay have also helped to sift through vast amounts of data and detect the mechanisms for diseases such as HIV-1 and the role of the brain's white matter in Alzheimer's disease.

Some of Bandyopadhyay's microRNA target predictions are indexed in miRBase, a biological database for microRNA managed by the Griffiths-Jones Laboratory at the Faculty of Life Sciences, University of Manchester, UK.

HUMANITIES

The Infosys Prize 2017 in Humanities is awarded to the distinguished literary scholar, Prof. Ananya Jahanara Kabir, for her highly original explorations of the long-standing historical elements – conceptual, social and cultural – in colonial modernity, and for her subtle and insightful ethnography of cultural and political life in Kashmir.

SCOPE AND IMPACT OF WORK

Prof. Ananya Jahanara Kabir's superb scholarly writings, ranging from her major book, *Territory of Desire: Representing the Valley of Kashmir* (2009), to her essays on colonial modernity, cover a wide range of fields – history, literature, cultural studies, politics and political economy, and the moral ethnography of the Kashmiri people. They reveal the extent to which the reach of modernity, even if it is relatively comprehensive, is filled with pockets of residual pre-modernity.

Prof. Kabir's writing on the colonial modern explores this through the work of Tacitus and medieval conceptions of sacralized nature and village life and collective organization. She invokes and elaborates on notions of enchantment that suffuse the world and the human subject even at the heart of capitalistic development and control.

An indispensable significance of Kabir's work is that this penetrating account makes us question the pervasive concentration on the criticism of tradition from the point of view of modernity. What she presents is the real possibility that there may be in the interstices of modernity, elements of tradition that can provide critical resources for our understanding of modernity and for putting constraints on it that may be wise and humane.

The originality and sensitivity of Prof. Kabir's mind is equally present in her shrewd understanding of the everyday culture and representational features of the Kashmiri land and its borders. The subtlety and independence of her work and her far-reaching insights that demand recognition and celebration.

CITATION BY THE JURY

Prof. Ananya Jahanara Kabir is a strikingly original and accomplished scholar whose work fundamentally illuminates our thinking about the relationship between modernity and tradition. She has emerged as a leading voice in international comparative literature, which she has increasingly extended to African cultural production and thought. She brings out the contradictions between ruthless colonial exploitation of the natural resources of colonized lands on the one hand and the hold of long-lasting enchantment of village, community, aesthetic expression, and nature.

Prof. Kabir's range of perspectives on these themes is impressively wide, spanning literature and culture, history and anthropology, embodiment and memory, politics and political economy. The remarkable qualities of this work are powerfully present in her ethnographic writings on Kashmir which are widely read and admired.

ANANYA JAHANARA KABIR
Professor of English Literature, Department of English, King's College London, UK

Prof. Ananya Jahanara Kabir has been Professor of English Literature at King's College London since 2013. However, many of her research involvements are moored in Indian literary and cultural subjects.

Kabir spent her graduate and doctoral years at the Universities of Calcutta, Oxford, and Cambridge. In 1997, she won the Prize Fellowship of Trinity 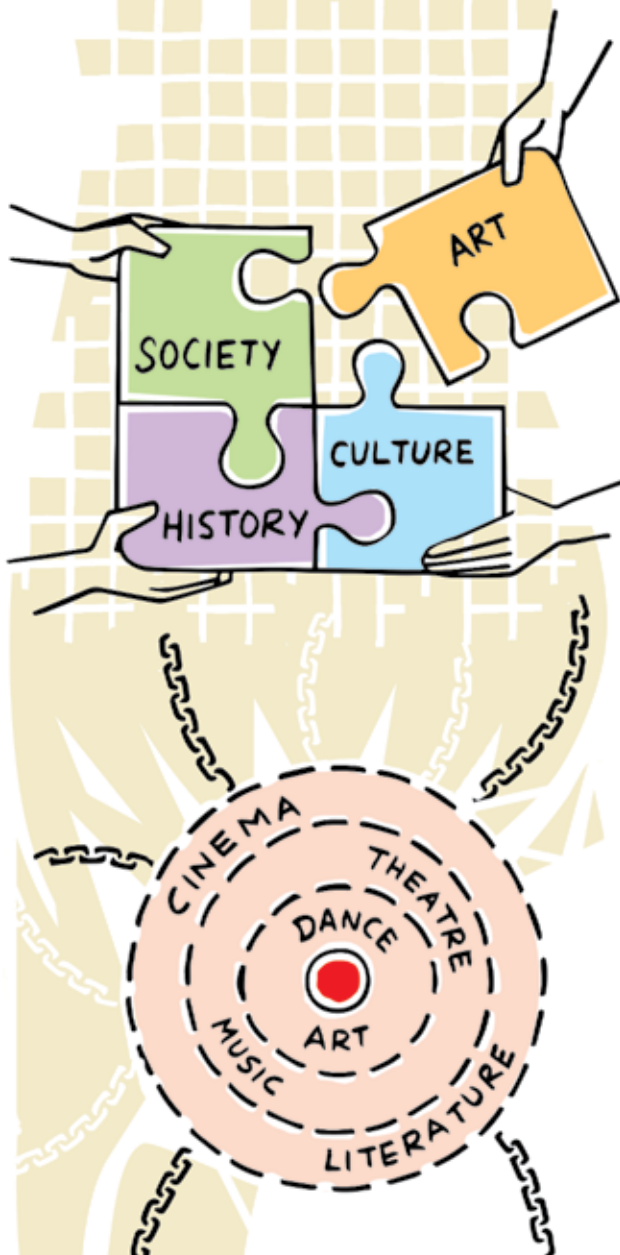College Cambridge for her research on early Anglo-Saxon literature. In 2011, she was appointed Professor of the Humanities at the University of Leeds. As part of an AHRC fellowship program, she co-curated the multi-sited art exhibition, 'Kismet and Karma: South Asian Women Artists Respond to Conflict'.

Kabir's work includes a monograph on the Partition of India. Her current research looks at Afro-diasporic rhythm cultures and modernity.

"Prof. Ananya Kabir is an outstanding literary scholar whose work on the historical elements in the reality of colonial and post-colonial identity is ground-breaking. She has shown how these elements of tradition mix well and must be seen as a part of the modernity of ourselves today. This is extraordinarily important work."

– Amartya Sen

What's past is prologue

The humanities is a set of academic disciplines that study society and culture. These are disciplines that help us understand the values of different cultures, history and how it is made, and how works of art are produced.
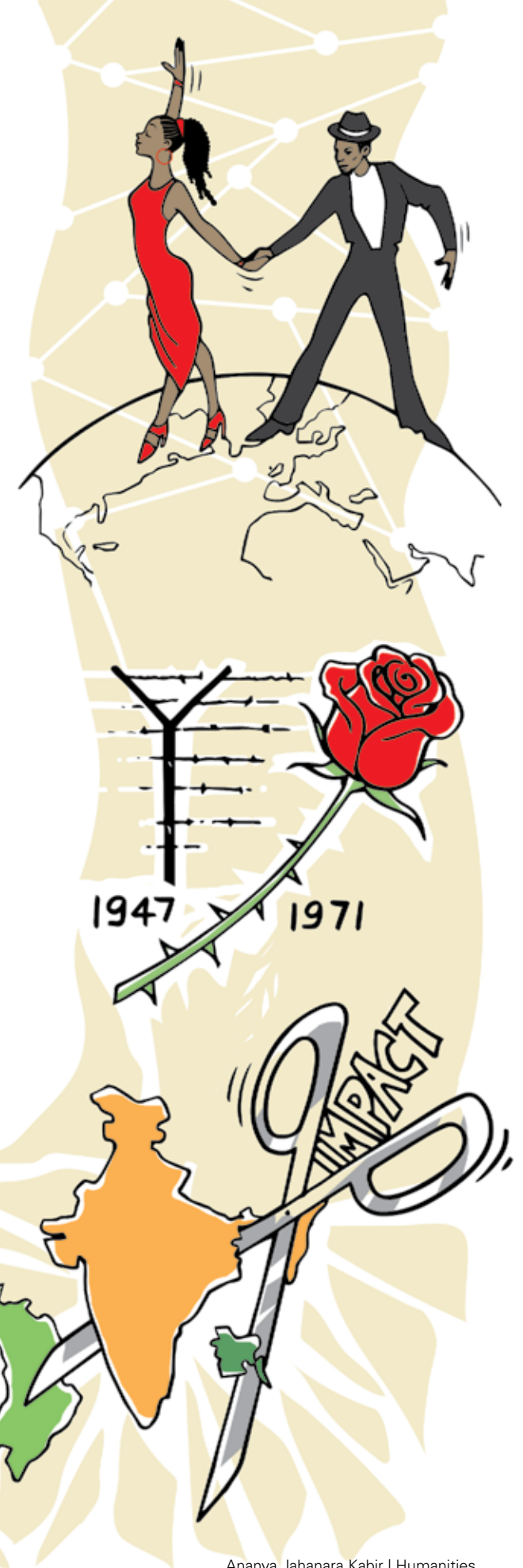
Prof. Ananya Jahanara Kabir is a scholar of the humanities. Her work is primarily concerned with the historical elements in how we define our spaces in the present. She does this through analyzing literature, cinema, dance and other work that have been strongly influenced by conflict or deep traumas that people in particular areas have suffered. These include the influence of colonial rule, disputed territories, and the slave trade.

Prof. Kabir's book, *Territory of Desire: Representing the Valley of Kashmir,* explores how images of the disputed region of Kashmir as a place of beauty, coveted and fought over, have come to dominate the imaginations of postcolonial Indians and are resisted and responded to by Kashmiris. She conducts this investigation through photographs of the landscapes, films and documentaries made about the Kashmir region, stories, poetry, visual art, and other creations of both Kashmiris and non-Kashmiris.

In her book, *Partition's Post-Amnesias*, Kabir examines the impact of Partition on writers, artists, and other creative intellectuals in the subcontinent. Partition in this case encompasses the linked events that led to the formation of the nation-states of Pakistan, India and Bangladesh in 1947 and 1971. She examines how generations of families who have lived through the trauma of Partition create and re-create meaning out of that trauma, including those who didn't directly experience the events of 1947 and 1971. Kabir's work demonstrates that these big political events have lasting effects on subsequent generations of the families that lived through them which generate cross-border networks and affections beyond the nation-state.

Prof. Kabir's current project, *Modern Moves,* studies the music and dance cultures of various African and African-diasporic communities worldwide. She examines how events such as colonial oppression and slave trade have led to the creation of music and dance with African roots in the Atlantic and Indian Ocean worlds, that are then enjoyed globally by people often with no ethnic or racial connection to the African continent. The study aims to find the deep connections between historical experiences of trauma, pleasure as resistance, and modernity and the idea and embodied memory of 'Africa'.

LIFE SCIENCES

The Infosys Prize 2017 in Life Sciences is awarded to Prof. Upinder Bhalla for his pioneering contributions to the understanding of the brain's computational machinery. His investigations have revealed essential neuronal computations that underlie the ability to acquire, integrate and store complex sensory information, and to utilize that information for decision and action.

SCOPE AND IMPACT OF WORK

Prof. Upinder Bhalla is an exceptionally talented neurobiologist who has made transformative discoveries regarding the brain's computational machinery for acquisition, storage and use of sensory information. Utilizing the mammalian olfactory system as a model, Prof. Bhalla has employed richly interwoven theoretical and experimental approaches to understand a range of computational problems extending from sensory signal acquisition, integration and storage to behavioral control and decision-making. The strength of his research program lies in its unprecedented naturalistic treatment of sensory signals as varying continuously in time, intensity and location with respect to the observer.

Through pioneering studies of this complex temporal integration process, Bhalla made the extraordinary discovery that responses of neurons in the olfactory bulb reflect a linear sum of time-varying inputs from individual or mixed odorants. He discovered that this integrative process for identifying individual odorants in mixtures is enhanced by the temporal structure of the natural respiration cycle, a process known as "phase coding."

Bhalla also found that odorant tracking – a fundamentally important skill for survival in a world of spatiotemporally varying food sources, predators and mates – is mediated by a "stereo" odor detection system in which olfactory neurons are delicately tuned to the relative strengths of odorant signals in the two nostrils.

The control of airborne odorant molecules in space and time, as required to accomplish these experiments, is notoriously difficult. Bhalla's success is a testament to his experimental rigor and quantitative sophistication. His discoveries suggest computational principles for neural circuits that have broad relevance for understanding brain function in natural environments.

CITATION BY THE JURY

Prof. Upinder Bhalla works in a relatively uncharted domain of inquiry that joins computational neuroscience, systems neuroscience, and systems biology. His central question is how the brain achieves its function through computation.

Prof. Bhalla's blend of modeling and experimentation has enabled him to tackle the difficult computational problem of sensory processing in a complex naturalistic environment in which multiple stimuli vary in location, intensity and time, and with respect to ongoing behavior.

Using the olfactory system as a model for this analysis, Bhalla has examined the responses of individual neurons and neural circuits. From these neuronal response profiles, he has developed computational and biophysically detailed models that elucidate fundamental mechanisms that underlie sensory identification, memory, and behavioral choice. These models suggest general principles of neuronal computation that pave the way for a fuller understanding of the brain's many sensory and cognitive functions.

UPINDER SINGH BHALLA
Professor, National Centre for Biological Sciences, Tata Institute of Fundamental Research, Bengaluru, India

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Prof. Upinder Bhalla is currently Professor and Dean at the National Centre for Biological Sciences (NCBS), Bengaluru. He did his undergraduate degree in natural sciences at IIT-Kanpur and the University of Cambridge. Bhalla carried out his graduate work at the California Institute of Technology, US, working on information processing in the mammalian olfactory bulb. He received his Ph.D. in 1993. Following post-doctoral training at Mount Sinai School of Medicine, New York, he joined the faculty at NCBS in 1996.

Bhalla won the Shanti Swarup Bhatnagar Prize (2007), and is a fellow of the Indian Academy of Sciences and the Indian National Science Academy. He won the Millennium Medal of the Indian Science Congress (2000). Prof. Bhalla has mentored many graduate students and fostered many international scientific collaborations.

"I congratulate Upinder Bhalla for the excellent work he has been doing for the last two decades which is now not only nationally but internationally recognized as one of the fundamental ways of how we study the role of olfaction in behavior."

– Inder Verma

What's in a smell…?

Prof. Upinder Bhalla is a neurobiologist who set out to study how the human brain takes in information from the environment around us, stores it, and uses that information to make decisions and act accordingly. Prof. Bhalla decided to use the sense of smell in order to study this.
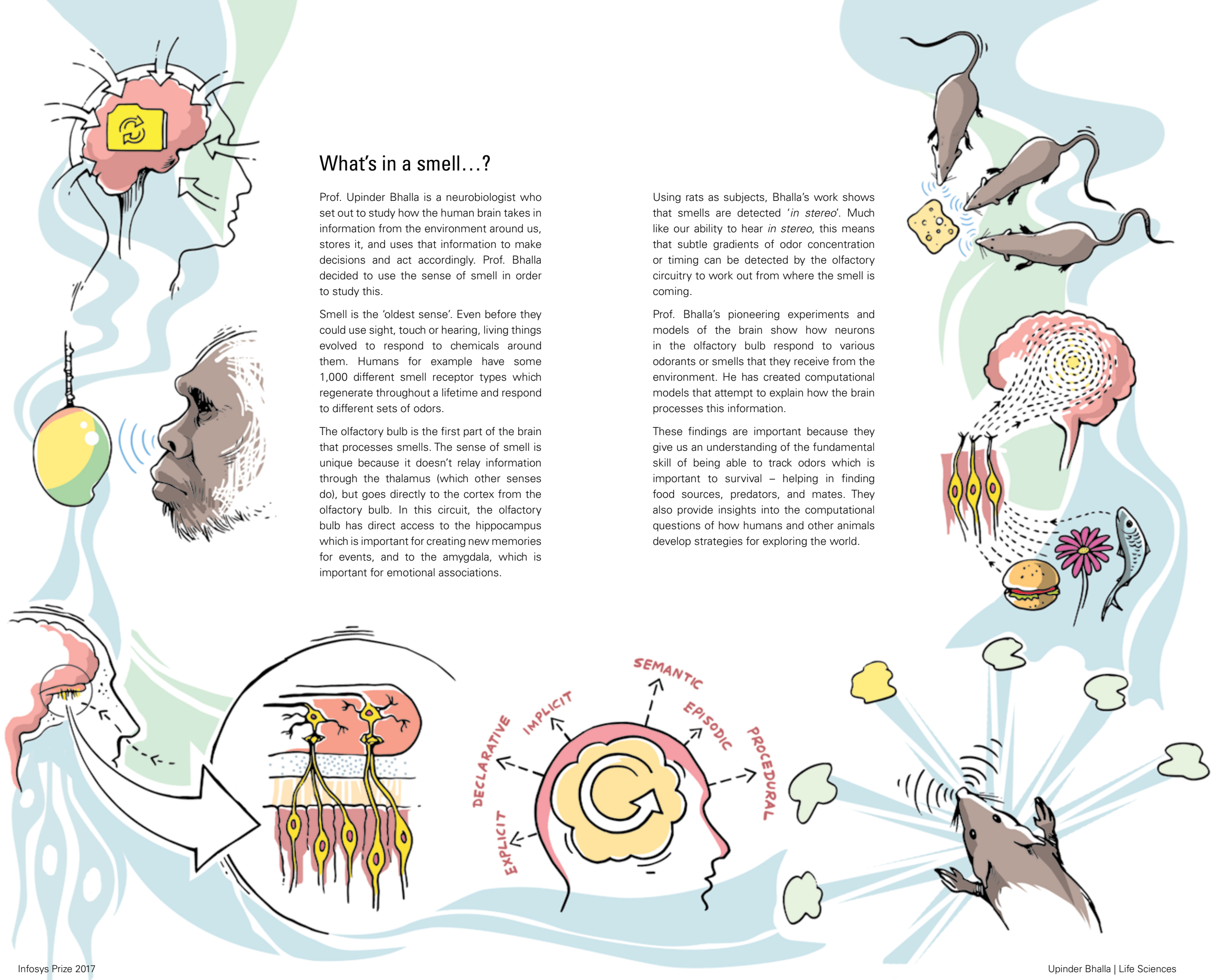
Smell is the 'oldest sense'. Even before they could use sight, touch or hearing, living things evolved to respond to chemicals around them. Humans for example have some 1,000 different smell receptor types which regenerate throughout a lifetime and respond to different sets of odors.
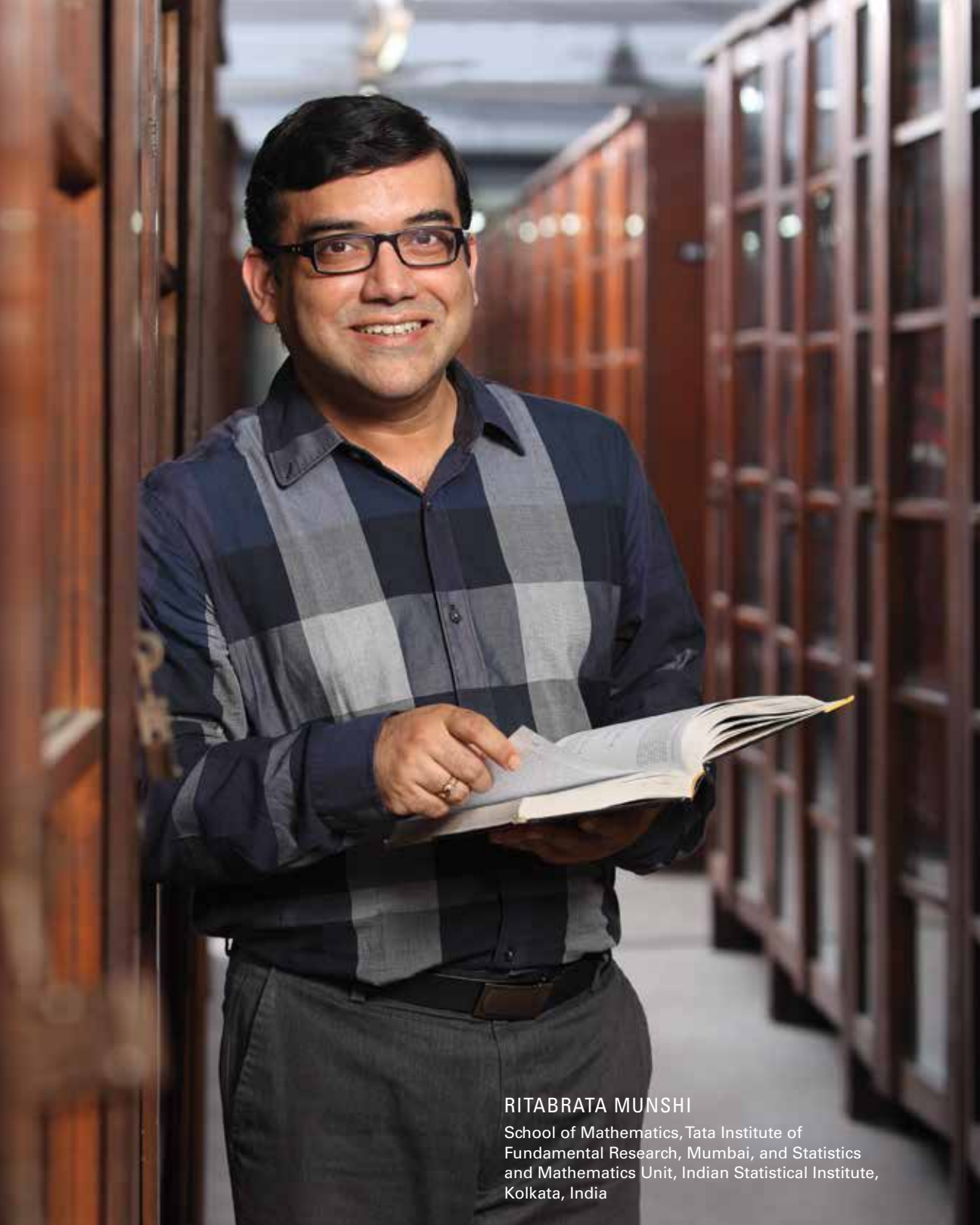
The olfactory bulb is the first part of the brain that processes smells. The sense of smell is unique because it doesn't relay information through the thalamus (which other senses do), but goes directly to the cortex from the olfactory bulb. In this circuit, the olfactory bulb has direct access to the hippocampus which is important for creating new memories for events, and to the amygdala, which is important for emotional associations.

Using rats as subjects, Bhalla's work shows that smells are detected '*in stereo*'. Much like our ability to hear *in stereo*, this means that subtle gradients of odor concentration or timing can be detected by the olfactory circuitry to work out from where the smell is coming.

Prof. Bhalla's pioneering experiments and models of the brain show how neurons in the olfactory bulb respond to various odorants or smells that they receive from the environment. He has created computational models that attempt to explain how the brain processes this information.

These findings are important because they give us an understanding of the fundamental skill of being able to track odors which is important to survival – helping in finding food sources, predators, and mates. They also provide insights into the computational questions of how humans and other animals develop strategies for exploring the world.

MATHEMATICAL SCIENCES

The Infosys Prize 2017 in Mathematical Sciences is awarded to Prof. Ritabrata Munshi for his outstanding contributions to analytic aspects of number theory. Besides ingenious contributions to the Diophantine problem, he has established important estimates known as subconvexity bounds for a large class of L-functions with methods that are powerful and original.

SCOPE AND IMPACT OF WORK

Prof. Ritabrata Munshi's area of work is the analytic side of number theory. He has made very important contributions to the analytic theory of L-functions, in particular to the subconvexity problem for higher rank L-functions. He has also done very ingenious work (notably with Tim Browning) on applying analytic methods in the study of Diophantine problems.

An important problem in number theory is to understand the values of zeta and L-functions on the critical line. There is a general bound for these values that follows from the Phragmen-Lindelof principle and this is known as the trivial or convexity bound. Improving the convexity bound is known as the subconvexity problem, and this has formed the basis of intensive investigation, especially over the last 25 years. The Generalized Riemann hypothesis implies the Lindelof hypothesis, and this may be seen as the optimal result in the subconvexity problem.

In a series of beautiful papers, Prof. Munshi made remarkable progress on this problem going beyond the known cases for Dirichlet L-functions and L-functions arising from cusp forms on GL(2). He developed an ingenious method based on the Hardy-Littlewood circle method (one can see here the influence of his work on Diophantine problems) which produced a breakthrough and decisive results in the subconvexity problem for GL (3).

Munshi has worked across the breadth of analytic number theory, ranging from applying analytic number theory to Diophantine problems, to making remarkable progress in modern analytic number theory related to L-functions arising from automorphic forms.

CITATION BY THE JURY

Prof. Ritabrata Munshi is a very original and powerful mathematician working primarily in the field of analytic number theory. His work is in the tradition of the celebrated work of Riemann which revealed unexpected and deep connections between analysis and prime numbers through his study of the Riemann zeta-function.

Prof. Munshi has developed a very novel method for proving certain subconvex estimates for L-functions on their critical lines, and he has demonstrated the effectiveness of his powerful, new method in many cases of L-functions arising from cusp forms on higher rank groups, by going well beyond what other methods yield. Such estimates are fundamental to many striking applications of the theory of L-functions.

RITABRATA MUNSHI

School of Mathematics, Tata Institute of Fundamental Research, Mumbai, and Statistics and Mathematics Unit, Indian Statistical Institute, Kolkata, India

Prof. Ritabrata Munshi received his undergraduate and early graduate education at the Indian Statistical Institute, Kolkata. He then went to Princeton University to pursue his doctoral studies with Sir Andrew Wiles. After receiving his Ph.D. in 2006, he spent a few post-doctoral years in the US before returning to India to join TIFR. He is currently on lien to ISI, Kolkata.

He is the recipient of many awards including the Shanti Swarup Bhatnagar Prize (2015), Birla Science Prize (2013), and the ISI Alumni gold medal (1999). Prof. Munshi is a Fellow of the Indian Academy of Sciences.

"Prof. Ritabrata Munshi has been recognized for his outstanding contributions to analytic number theory, particularly his work on subconvexity bounds for classes of L-functions. On behalf of the jury I want to congratulate him."

– Srinivasa S. R. Varadhan

They do it with numbers

In 2000, the Clay Mathematics Institute in the United States published a list of seven Millennial Problems. Solving any of the problems could get you a million dollars. Among these is the Riemann Hypothesis. Proposed by Bernhard Riemann in 1859, the hypothesis is a conjecture that the Riemann zeta function has its zeroes only at the negative even integers and complex numbers with real part ½.

Prof. Ritabrata Munshi's work is related to the Riemann Hypothesis. He works on the analytic theory of L-functions. The first application of L-functions goes back to the German mathematician Johann Peter Gustav Lejeune Dirichlet in 1837. He was considering the arithmetic problem of showing many primes in arithmetic progression, such as primes of the form 5n+3.

In order to do this, Dirichlet introduced what is called a 'function' like we use in basic calculus. A function has sometimes been described as the most important concept in mathematics. Dirichlet showed that a solution of the arithmetic problem follows from certain properties of this function. This idea was built upon by Riemann in the 1860s.

The general philosophy of an L-function is to get a 'recipe' to assign a function in calculus from a more intricate mathematical object with the hope that the more difficult problem will get transferred to a more manageable problem about the function.

In terms of representation, the properties of the L-function can be shown as an infinite rectangular strip of unit width lying on a plane. Riemann defined his famous zeta function which is the prototype of L-functions, and showed that to understand primes, one has to study this function inside the strip.

In number theory, sometimes, to solve a problem all you need to know is the size of an L-function inside the strip. In complex analysis (the branch of mathematics that investigates the functions of complex numbers), we can determine the size of a function inside the strip from knowledge we have from outside its edge.

The Riemann Hypothesis says that these functions cannot take very large values. For many applications, mathematicians just need a bound that is slightly better than the trivial or convexity bound which one gets easily from standard calculus. Improving the convexity bound is called the subconvexity problem. Prof. Munshi formulated a new approach to tackle subconvexity bound which has in turn helped tackle several other problems with which mathematicians have been grappling. Munshi's approach is based on the circle method.

The circle method, an analytic tool which resolves arithmetic singularities, originated in work done by G.H. Hardy and Srinivasa Ramanujan in the early 1900s. The circle method is used to count integer solutions of a system of polynomial equations such as Waring's problem. Munshi's contribution to the circle method is an implementation of the level lowering trick. His most important contribution is an application of a trace formula as a form of circle method to establish subconvextiy for degree three L-functions.

$$\zeta(s) = 0 \, ?$$

$$\zeta(s) = \sum_{n=1}^{\infty} \frac{1}{n^s}$$

$$\zeta(s) = \frac{1}{1^s} + \frac{1}{2^s} + \frac{1}{3^s} +$$
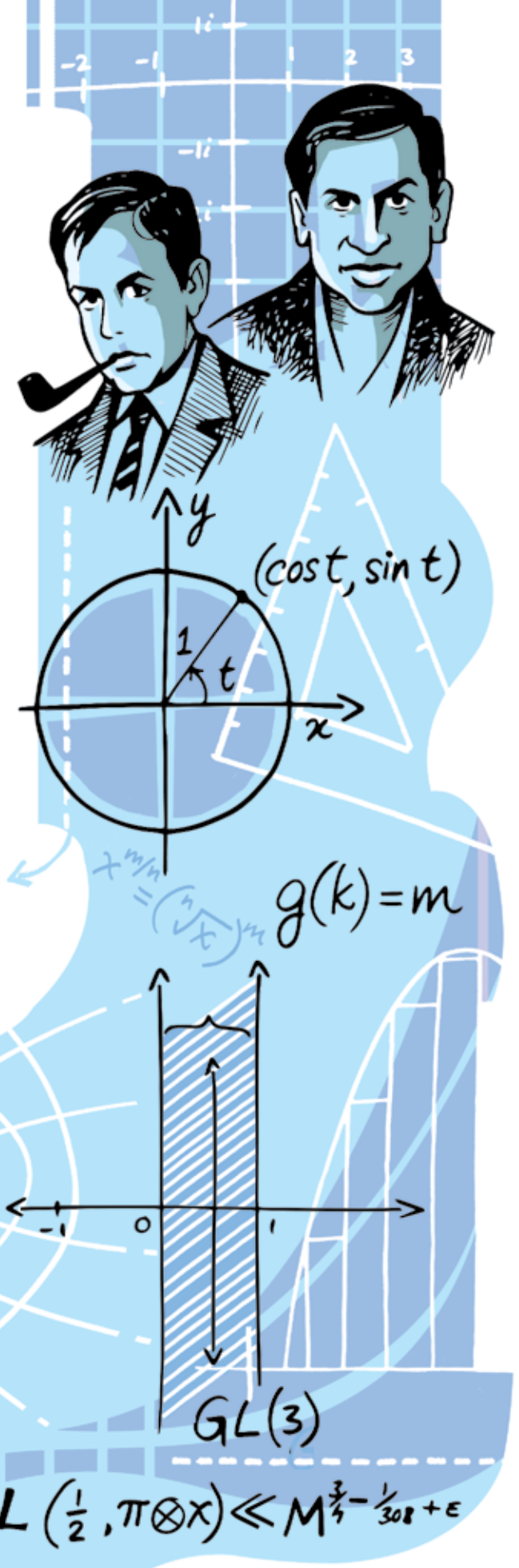
$$5n+3$$

$$\underline{L\text{-functions}}$$

$$L_k(s,\chi) = \sum_{n=1}^{\infty} \chi k(n) n^{-s}$$

$$(\cos t, \sin t)$$

$$x^{m/n} = (\sqrt[n]{x})^m$$

$$g(k) = m$$

$$GL(3)$$

$$f \, \pi \, \Sigma^+ \, \theta_\Omega \quad \boxed{L\text{-function}} \, \infty$$

$$\int \zeta \div \sqrt{}$$

$$L\left(\tfrac{1}{2}, \pi \otimes \chi\right) \ll M^{\frac{3}{4} - \frac{1}{308} + \epsilon}$$

PHYSICAL SCIENCES

The Infosys Prize 2017 in Physical Sciences is awarded to Prof. Yamuna Krishnan for her ground-breaking work in the emerging field of architecture of the DNA. By successfully manipulating DNA to create biocompatible nanomachines, she has created novel ways of interrogating living systems, increasing our knowledge of cell function and is one step closer to answering unresolved biomedical questions.

SCOPE AND IMPACT OF WORK

Prof. Yamuna Krishnan has carried out ground-breaking work in the emerging field of architecture of the building blocks of life – the DNA. She has pioneered the use of synthetic DNA in developing dynamic DNA nanodevices for functional bio-imaging *in vivo* and making rigid DNA nanodevices that can deliver bio-imaging components in a cell-specific manner. Her research encompasses nucleic acid structure and dynamics, nucleic acid nanotechnology, and cellular and subcellular technologies.

Prof. Krishnan's work has helped in discovering a new non-Watson-Crick base-paired DNA motif called i-motif and in showing the microRNA cluster folds into a well-defined structure that can act as transporter of specific cargo held within this rigid structure. These structures can then be taken to test their functional impact on either material or biological system, thus bridging material science and biology.

The impact of Krishnan's work is enormous. It ranges from constructing probes of biological processes in living cells and organisms, use of the functionality of the designer DNA devices in living systems, and development of DNA devices to selectively transport proteins to specific targets. Overall, such technology will improve medicine, biology, and material science.

CITATION BY THE JURY

Prof. Yamuna Krishnan was the first to recognize the functionality of the designer DNA and has exploited this finding in making nanodevices that work in living systems. She designed a dynamic DNA nanodevice that functioned as a pH-triggered molecular switch enabling measurement of the acidity inside a living cell. This work has been expanded to obtain chemical maps of chloride inside the cell.

The impact of her work ranges from constructing probes of biological processes in living cells and organisms, use of the functionality of the designer DNA devices in living systems, and development of DNA devices to transporting proteins to select targets. Prof. Krishnan is a recognized leader in the field of self-assembled nucleic acid nanostructures.

YAMUNA KRISHNAN
Professor, Department of Chemistry,
University of Chicago, US

Prof. Yamuna Krishnan is Professor of Chemistry at the University of Chicago. She received her B.Sc. (University of Madras), M.S. and Ph.D. (Indian Institute of Science, Bengaluru) in India, and gained a postdoctoral research fellowship from the prestigious Royal Commission for the Exhibition of 1851 at the University of Cambridge, UK.

Krishnan joined the National Centre for Biological Sciences, Bengaluru, in 2005 as a Fellow and quickly became a Reader and then an Associate Professor before moving in 2014 to Chicago.

She has won several awards including the Innovative Young Biotechnologist Award (2007), the Wellcome-Trust-DBT Alliance Senior Research Award (2010), the YIM-Boston Young Scientist Award (2012), and the Shanti Swarup Bhatnagar Prize (2013).

"The Infosys Prize recognizes your ground-breaking work in the architecture of the building blocks of life – the DNA. Your development of DNA nanodevices is expected to have a large impact in biology, for instance in constructing probes of processes in living cells. In medicine, your devices will make it possible to transport proteins to selected targets. Congratulations, Professor Yamuna Krishnan."

– Shrinivas Kulkarni

Those amazing technicolor DNA dream machines

Prof. Yamuna Krishnan works on DNA nanotechnology. In order to understand how the basic building block of life, DNA, began to be used as construction material, we need to go back a bit.

The double helix structure of DNA was discovered by James Watson and Francis Crick in 1951, building on the work of Maurice Wilkins and Rosalind Franklin.

In the early 1980s, the scientist Nadrian Seeman, inspired by a woodcut called *Depth* by the artist M.C. Escher, theorized that the strands of DNA could be used for construction on the nanoscale, and laid the foundation for DNA nanotechnology. Then, in 2006 Paul Rothemund at Caltech devised a method to 'fold' DNA strands into two dimensional, 'designer' shapes on the nanoscale. This method of making designer DNA nanoshapes came to be known as DNA origami, after the Japanese art of paper folding. It was now clear that DNA could be used to make any imaginable shape on the nanoscale. But what might we use these shapes for? That was still a question that loomed large.
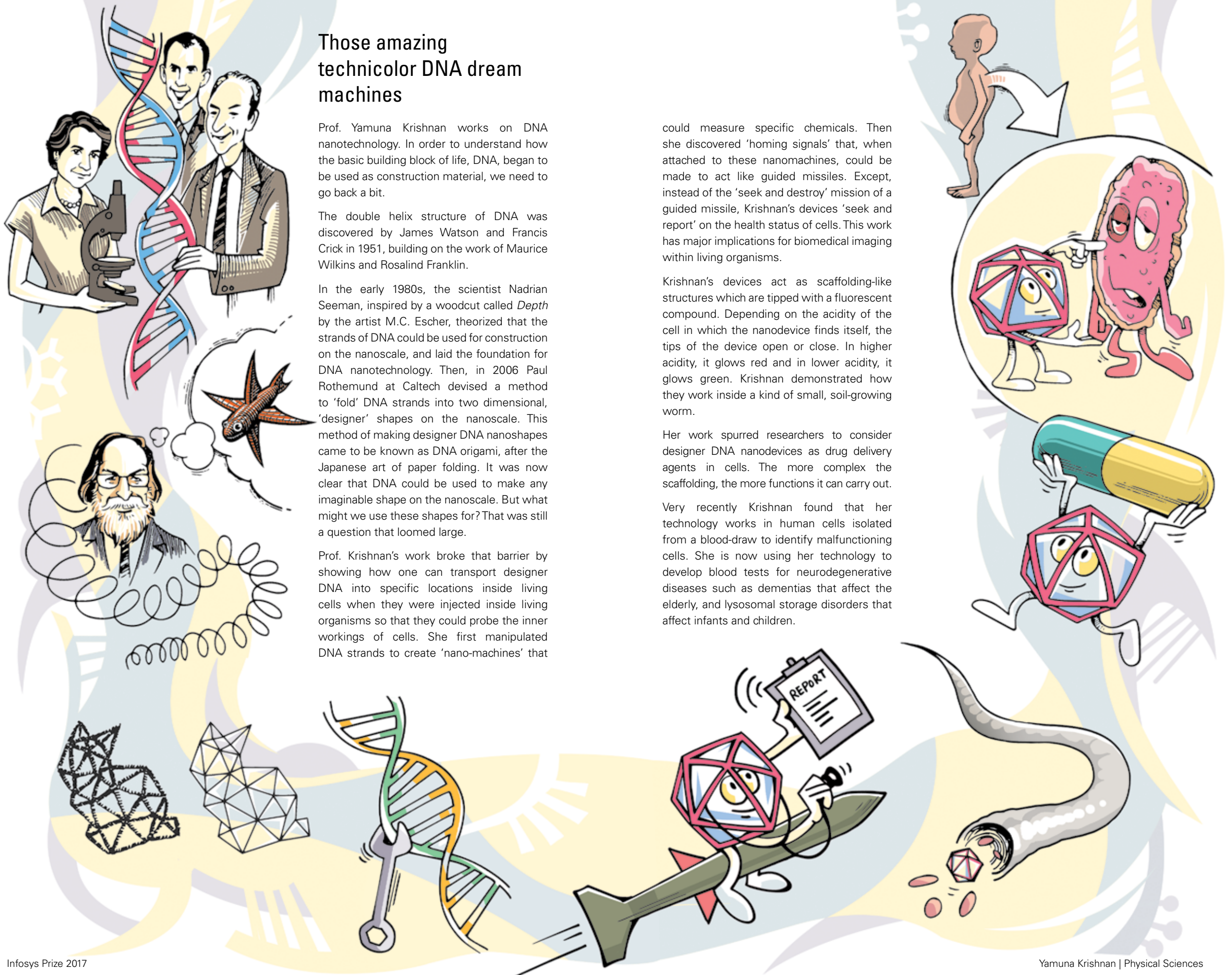
Prof. Krishnan's work broke that barrier by showing how one can transport designer DNA into specific locations inside living cells when they were injected inside living organisms so that they could probe the inner workings of cells. She first m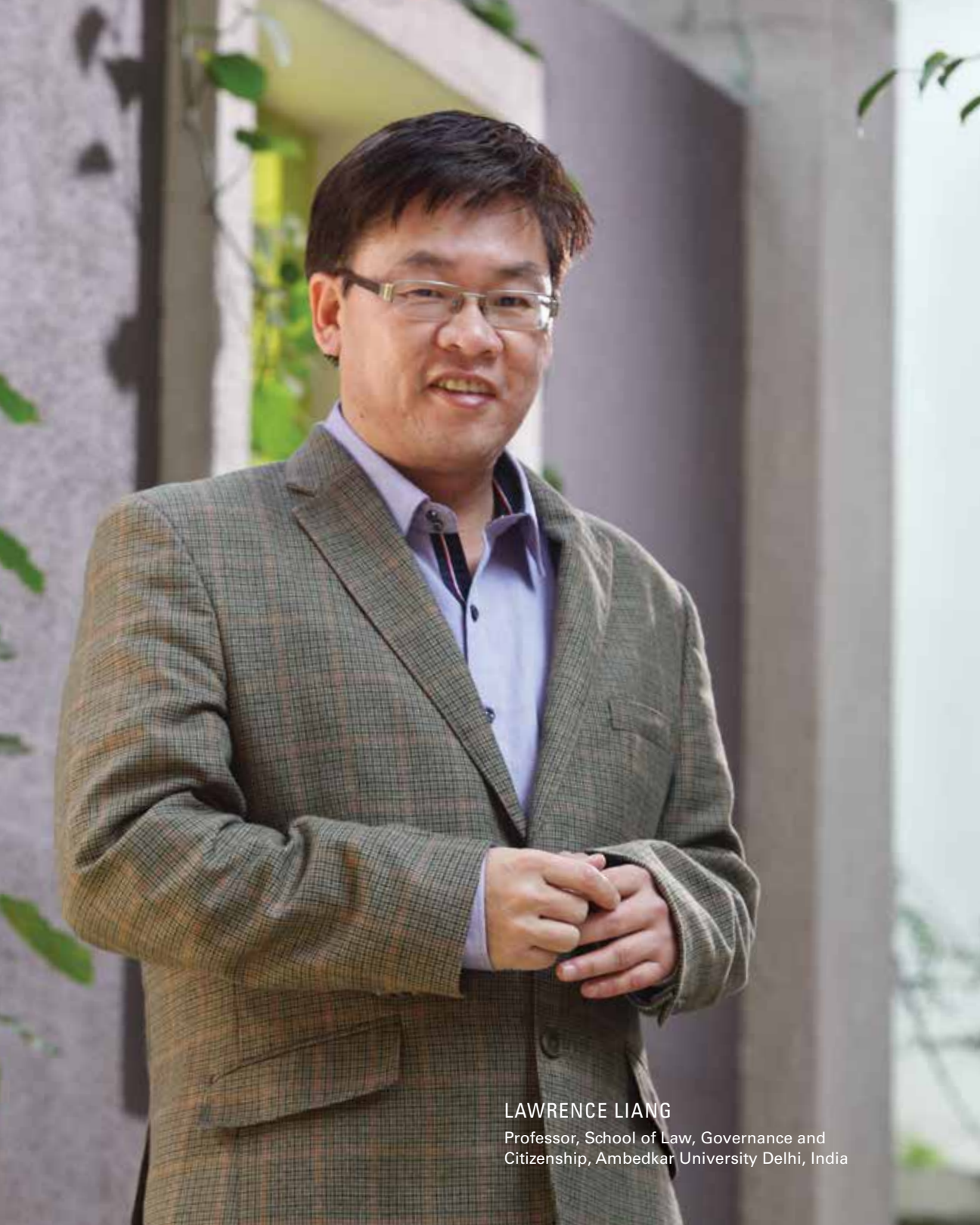anipulated DNA strands to create 'nano-machines' that could measure specific chemicals. Then she discovered 'homing signals' that, when attached to these nanomachines, could be made to act like guided missiles. Except, instead of the 'seek and destroy' mission of a guided missile, Krishnan's devices 'seek and report' on the health status of cells. This work has major implications for biomedical imaging within living organisms.

Krishnan's devices act as scaffolding-like structures which are tipped with a fluorescent compound. Depending on the acidity of the cell in which the nanodevice finds itself, the tips of the device open or close. In higher acidity, it glows red and in lower acidity, it glows green. Krishnan demonstrated how they work inside a kind of small, soil-growing worm.

Her work spurred researchers to consider designer DNA nanodevices as drug delivery agents in cells. The more complex the scaffolding, the more functions it can carry out.

Very recently Krishnan found that her technology works in human cells isolated from a blood-draw to identify malfunctioning cells. She is now using her technology to develop blood tests for neurodegenerative diseases such as dementias that affect the elderly, and lysosomal storage disorders that affect infants and children.

SOCIAL SCIENCES

The Infosys Prize 2017 in Social Sciences is awarded to Prof. Lawrence Liang in recognition of his creative scholarship on law and society. His prodigious output in the fields of copyright law, digital technologies and media, and popular culture consistently raises probing questions about the nature of freedom, rights, and social development.

SCOPE AND IMPACT OF WORK

Prof. Lawrence Liang is a legal scholar and activist who has made notable contributions to the study of free speech, intellectual property and access to digitalized knowledge in India, from a comparative and global perspective. As a co-founder of the Alternative Law Forum, he has shown a remarkable commitment to widening access to legal resources for marginalized groups.

His work demonstrates how issues of intellectual property and piracy play out in the realm of law and media in India. Prof. Liang displays a deep grasp of the history of copyright issues in the West, and demonstrates the dynamics through which the domain of copyright protection, licensing, and commodification has expanded in the era of liberal capitalism. His contributions have the potential of enriching not just our understanding of social progress but the methodological foundation of the social sciences.

Liang has made major theoretical contributions through studying the life experiences of Indians around issues of property, creativity and access. He has helped us rethink how law and ethical practice can address the challenges of exclusion in the emerging digital worlds of India. His conceptualization of 'distributed' cultural commodities provides a nuanced understanding of the different rights at stake in creative products and the processes by which these rights are commoditized.

Liang is also India's leading scholar of free speech jurisprudence. He has expanded the boundaries of law by interpreting law as performance; and he has enriched cultural studies by focusing on the legal infrastructure of culture.

CITATION BY THE JURY

Prof. Lawrence Liang's prodigious output in the fields of copyright law, digital technologies and media, and popular culture consistently raises probing questions about the nature of freedom, rights, and social development. His provocative answers link historical context and ethical practice in unexpected and illuminating ways.

Prof. Liang's writing stands out for its combination of playful sensibility and philosophical depth. His combination of deep legal scholarship, interdisciplinary originality and commitment to social inclusion is exemplary and represents the values enshrined in the best of social science.

LAWRENCE LIANG
Professor, School of Law, Governance and Citizenship, Ambedkar University Delhi, India

Lawrence Liang is Professor of Law at Ambedkar University Delhi. He studied at the National Law School University of India and Warwick University, and has been a Visiting Scholar at Yale, Michigan and several other universities. He co-founded the Alternative Law Forum, Bengaluru, and has played a major role in incorporating Open Source ideas into the cultural domain. He has published widely in scholarly books and journals and is a prominent presence in public debates. His provocative answers link historical context and ethical practice in unexpected and illuminating ways.

"Lawrence Liang has worked on copyright law, digital technologies and media and the implications for individual freedom, rights, and development. It is arguable that we're entering a world where intellectual property will be as important as used to be land rights. The kind of work that Liang has done is likely to gain in importance for India and around the world."

– Kaushik Basu

Negotiating the brave new digital world

Imagine a world where you were not allowed access to the internet. Imagine a world where you were not allowed to say or write your opinions or thoughts. Imagine a world where you had no rights to products you create or things you write. You may have noticed that in recent times, concepts such as 'net neutrality' and 'freedom of speech' have been topics of heated debate – in the media, among policy makers, activists and others.

Prof. Lawrence Liang works in these areas. He is an academic and lawyer who specifically works in the area of law and society. His interests lie at the intersection of law in social, political and cultural life.

Prof. Liang has made major contributions particularly to the study of Indian society's experiences with property law, access to resources and information, and creativity. His work helps to place current issues dealing with law and society in a historical context so that people understand from where their law makers and elected officials are coming.
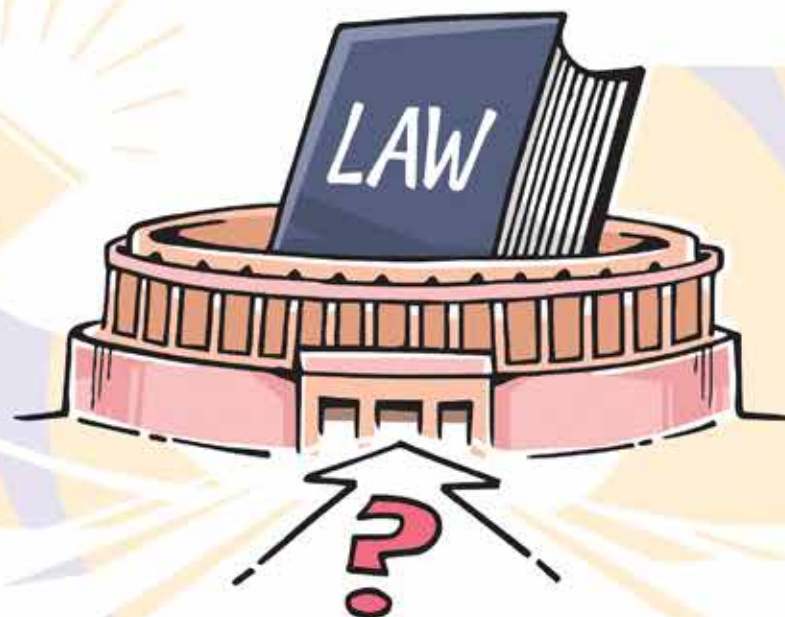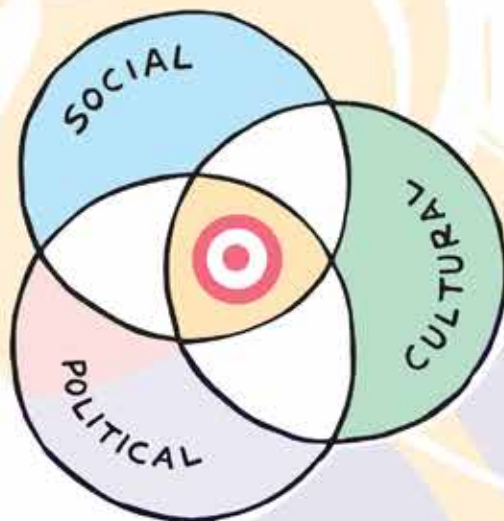
Liang's work in the emerging field of digital technologies has helped shed light on an area where traditional legal measures may no longer apply. The digital world is a new world that requires new rules and regulations. Who has access? Who benefits? How do we determine what must be freely available?

These are the kind of questions with which we grapple. Care must be taken that the ordinary citizens' rights are not infringed upon and that everyone in a democratic society has access to all the information that is rightfully theirs.

As much as it is important to have access to information, it is equally important that created work is protected. Liang's work on free speech jurisprudence (the theory of law) has helped understand law not simply as written text but as a lived reality for the people it seeks to serve.

Among Prof. Liang's published work are *The Public is Watching: Sex, Laws and Videotape* and *A Guide to Open Content Licenses*. He also writes extensively on subjects of intellectual property, and technology and culture.

Liang's current research engages with law and cinema. He shows how cinema shapes the legal and political imaginations of millions of people. He uses landmark Hindi films like *Awara* and *Sholay* to make the case that Hindi cinema presents three simultaneous images of law and justice in India: law as hope, law as limit, and law as violence.

JURY CHAIRS

ENGINEERING AND COMPUTER SCIENCE

Pradeep K. Khosla
Jury Chair

Pradeep K. Khosla is the Chancellor, University of California, San Diego, USA. He has received several awards, including the ASEE George Westinghouse Award for Education (1999), Silicon India Leadership award for Excellence in Academics and Technology (2000), the W. Wallace McDowell award from IEEE Computer Society (2001), Cyber Education Award from the Business Software Alliance (2007), the ASME Computers in Engineering Lifetime Achievement Award (2009), and the inaugural Pan IIT American Leadership Award for Academic Excellence (2009). He was awarded the Philip and Marsha Dowd Professorship in 1998 at the Carnegie Mellon University, Pittsburgh, USA. He has been elected as Member, National Academy of Engineering, Fellow of the Institute of Electrical and Electronics Engineers (IEEE) and Fellow of the American Association of Artificial Intelligence (AAAI).

Jurors

Subhash Mahajan
Distinguished Professor, Department of Materials Science and Engineering, University of California, USA

Bhakta B. Rath
Head – Materials Science and Component Technology Directorate (Retired), USA, and Senior Emeritus Scientist, Naval Research Laboratory, USA

Rajesh K. Gupta
Professor and Qualcomm Endowed Chair, Department of Computer Science and Engineering, University of California, San Diego, USA

Narayanaswamy Balakrishnan
Department of Aerospace Engineering and Supercomputer Education Research, Indian Institute of Science, India

HUMANITIES

Amartya Sen
Jury Chair

Amartya Sen is Thomas W. Lamont University Professor, and Professor of Economics and Philosophy, at Harvard University. Until 2004, he was the Master of Trinity College, Cambridge. He has served as President of the Econometric Society, the American Economic Association, the Indian Economic Association, and the International Economic Association. Amartya Sen's awards include Bharat Ratna (India); Commandeur de la Legion d'Honneur (France); the National Humanities Medal (USA); Ordem do Merito Cientifico (Brazil); Honorary Companion of Honour (UK); Aztec Eagle (Mexico); Edinburgh Medal (UK); the George Marshall Award (USA); the Eisenhower Medal (USA); and the Nobel Prize in Economics.

Jurors

Harriet Ritvo
Arthur J. Conner Professor of History, Massachusetts Institute of Technology, USA

Akeel Bilgrami
Sidney Morgenbesser Professor of Philosophy, Columbia University, USA

Homi K. Bhabha
Anne F. Rothenberg Professor of the Humanities, Director of the Mahindra Humanities Center, and Senior Advisor to the President and Provost, Harvard University, USA

Nayanjot Lahiri
Professor, Ashoka University, India

LIFE SCIENCES

Inder Verma
Jury Chair

Inder Verma is American Cancer Society Professor and the first incumbent of the Irwin and Joan Jacobs Chair in Exemplary Life Science, Laboratory of Genetics, Salk Institute for Biological Studies, USA. He is one of the world's leading authorities on the development of viruses for gene therapy vectors. He is a member of the National Academy of Sciences (USA), Institute of Medicine, American Academy for Arts & Sciences, American Philosophical Society, Third World Academy of Sciences, and a foreign associate of the Indian National Academy of Sciences. He has won the NIH Outstanding Investigator Award (1988), the Vilcek Foundation's prize in biomedical science (2008), the Columbia University's Spector Prize (2010), and the 22nd Annual Cancer Research Award of the Pasarow Foundation.

Jurors

Vamsi K. Mootha
Professor, Systems Biology and Medicine, Harvard Medical School, USA

Thomas Albright
Professor and Conrad T. Prebys Chair, Vision Center Laboratory, Salk Institute for Biological Studies, USA

Ali Shilatifard
Robert Francis Furchgott Professor and Chair, Department of Biochemistry and Molecular Genetics, Northwestern University Feinberg School of Medicine, USA

Christine E. Seidman
Thomas W. Smith Professor of Medicine, Harvard Medical School, USA

Sabeeha Merchant
Professor of Biochemistry, 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 in USA (2016).

Jurors

M.S. Raghunathan
Head, National Centre for Mathematics, Indian Institute of Technology, Mumbai, India

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

Gopal Prasad
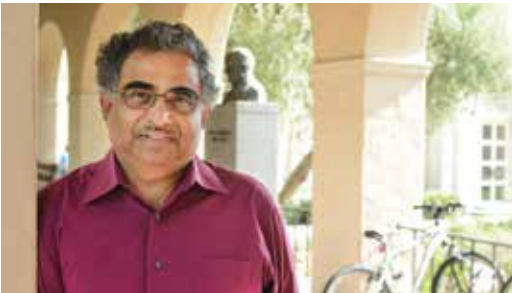*Raoul Bott Professor of Mathematics, University of Michigan, USA*

Claire Voisin
Professor, Collège de France, France

Jennifer Chayes
Distinguished Scientist and Managing Director, Microsoft Research New England, Cambridge, Massachusetts, and Microsoft Research New York City, 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

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

Spenta Wadia
Founding Director and Infosys Foundation Homi Bhabha Chair Professor, International Centre for Theoretical Sciences of TIFR, Professor Emeritus, Tata Institute of Fundamental Research, India

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

Rajaram Nityananda
Professor, Azim Premji University, Bengaluru, India

Jitendra Nath Goswami
Former Director, Physical Research Laboratory, Ahmedabad, India

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, MIT Press), *Prelude to Political Economy: A Study of the Social and Political Foundations of Economics* (2000, Oxford University Press), *Of People, Of Places: Sketches from an Economist's Notebook* (1994, Oxford University Press), and *Beyond the Invisible Hand: Groundwork for a New Economics* (2011, Princeton University Press and Penguin). In May 2008, he was awarded the Padma Bhushan by the Government of India.

Jurors

Arjun Appadurai
Goddard Professor in Media, Culture and Communication, Senior Fellow – Public Knowledge, New York University, USA

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

Pratap Bhanu Mehta
Vice-Chancellor, Ashoka University, India

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

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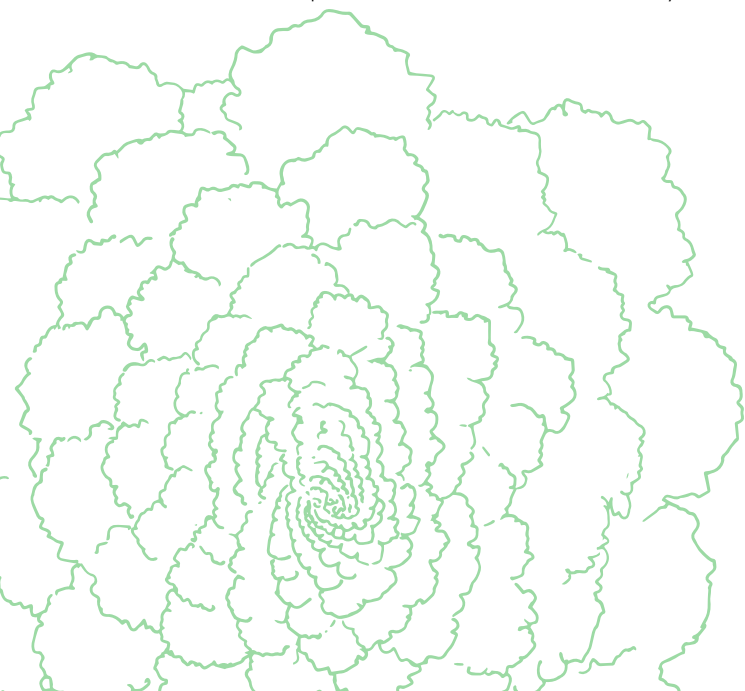General Manager, Infosys Science Foundation

NOTES

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 ₹65 lakh.

In keeping with its mission of spreading the culture of science, the Foundation has instituted the Infosys Prize Lectures – a series of public talks, mostly by jurors and laureates of the Infosys Prize. These talks and interactions aim to inspire young researchers and students by igniting their curiosity and opening up a world of possibilities. In 2014, the Foundation piloted *Gnanadeepa*, a training program for educators mostly in Karnataka, to improve the delivery of concepts in science and mathematics. The Foundation nurtures an interest in science directly at the student level through its support of scholarships, quizzes, and a Summer School in Physics for college students.