Infosys Science Foundation

Infosys Prize 2020

Our entangled world

All life on earth is so beautifully meshed together that to consider humans apart from the rest would be quite impertinent. In fact, humans as a species can hardly survive without their fellow living beings. There are a zillion reasons to believe this, and science has regularly unearthed more — microorganisms in our gut aid digestion; pollinators help seed the food we eat; green plants and phytoplankton produce oxygen that we breathe. And then there are the forward and backward chains of dependencies that make all this possible. And we have not yet explored even a fraction of the intricate relationships we have with all the inhabitants of earth.

Some researchers question the assumption that all life is equally valuable. The idea being that we can do without many life forms that are just taking up space. So the coral ecosystem is of great value to human beings but what does a parrot fish do for us? Oh and those sordid roaches and dispensable rodents! A delightful ditty sums up this reservation,

God in his wisdom
Made the fly
And then forgot
To tell us, why?
- Ogden Nash

Is biodiversity indeed an indulgence? Is bringing visible advantage to us human beings the sole purpose of existence? Or are there finer equations we are missing? Michael Soule, the remarkable biologist held that 'nature has intrinsic value beyond what it can afford humans.' Researchers have discovered so many unique and fragile ecosystems of the world that hinge on a cautious chemistry between species. If one goes extinct, ripples will be felt across the environment. The mysterious workings of nature may not be all apparent to us but everything we know so far tells us that we are just a tiny strand in the vast and tangled weave of life. Unravel one stitch and it may all come apart!

Engineering and Computer Science

The Infosys Prize 2020 in Engineering and Computer Science is awarded to Prof. Hari Balakrishnan for his broad contributions to computer networking, his seminal work on mobile and wireless systems, and for commercial use of mobile telematics to improve driver behavior and make roads safer around the world.

Hari Balakrishnan

Fujitsu Professor of Computer Science,
Massachusetts Institute of Technology,
Cambridge, USA

BIO

Prof. Hari Balakrishnan is the Fujitsu Professor of Computer Science at Massachusetts Institute of Technology. He obtained a B.Tech. from IIT-Madras in 1993 before completing his Ph.D. at University of California, Berkeley in 1998.

Prof. Balakrishnan leads the Networks and Mobile Systems group at CSAIL.

Balakrishnan has received numerous academic honors, including Sloan Fellow (2002), ACM Fellow (2008), IIT-Madras Distinguished Alumnus (2013), the US National Academy of Engineering (2015), membership in the American Academy of Arts and Sciences (2017), IEEE Fellow (2020), and the IEEE Koji Kobayashi Computers and Communications Award (2021).

Hari Balakrishnan's publications have received numerous Test of Time or Hall of Fame Awards, such as SIGCOMM (2011), SIGOPS (2015), SIGMOD (2017), SIGMOBILE (2018, 2017), and SenSys (2019).

Scope and impact of work

Prof. Hari Balakrishnan has repeatedly blazed the trail in mobile and wireless systems for others to follow. He was the first to develop a deep understanding and improve the performance of TCP on wireless networks; this work won the ACM Doctoral Thesis Award. In addition, he developed several novel mechanisms to seamlessly handle mobility.

Prof. Balakrishnan's Cricket system was the first accurate indoor location system. The CarTel system was one of the first "participatory sensing" applications, creating the field of mobile sensing. His work includes Spinal codes, the first rateless codes to nearly achieve Shannon capacity over both Gaussian and binary-symmetric channels with an efficient encoder and decoder, thereby providing a new way to combat time-varying wireless channels.

Two noteworthy results from the CarTel project include Pothole Patrol, which used the opportunistic mobility of sensor-equipped vehicles to detect the surface conditions of roads, and algorithms for accurate path and delay inference from noisy position streams.

Balakrishnan's SoftPHY work systematically exploited demodulation confidence to improve bit rate adaptation, contention management, and parsimonious re-transmission, and his work on sensornets was the first to consider overall system longevity as an important design goal.

In each of these areas in wireless and mobility, Hari Balakrishnan's groundbreaking work was followed by a flood of follow-on papers, for example, the aforementioned sensornet work has been cited over 16,000 times according to Google Scholar.

Citation by the jury

Prof. Hari Balakrishnan has made seminal contributions in a number of areas in computer systems and networking. For example, he helped co-invent Distributed Hash Tables for peer-to-peer systems through his pioneering work on Chord. He has made contributions to Internet architecture for better naming, routing, and Distributed-Denial-of-Service prevention, including pioneering work on Resilient Overlay Networks. Prof. Balakrishnan has also made many contributions to the Internet congestion control, stream data processing, and practical privacy-preserving computations.

The CarTel project of Hari Balakrishnan and Sam Madden introduced the idea of using sensors attached to mobile assets such as vehicles and users' phones to measure the environment in a scalable way. These ideas have had significant academic and commercial success. The company they founded, Cambridge Mobile Telematics (CMT), is today the world's largest mobile telematics provider supporting many leading insurance and rideshare companies in 25 countries, helping to reduce the millions of road crashes that occur annually.

Hari Balakrishnan, you are an ideal candidate from our point of view because engineering is about doing things, and you're doing both the theory side and the practical side of things. You have done work which is already being discussed in classrooms as well as having had a practical impact. Congratulations from me and everyone on the jury!

Arvind

A smartphone to keep the speed demon away

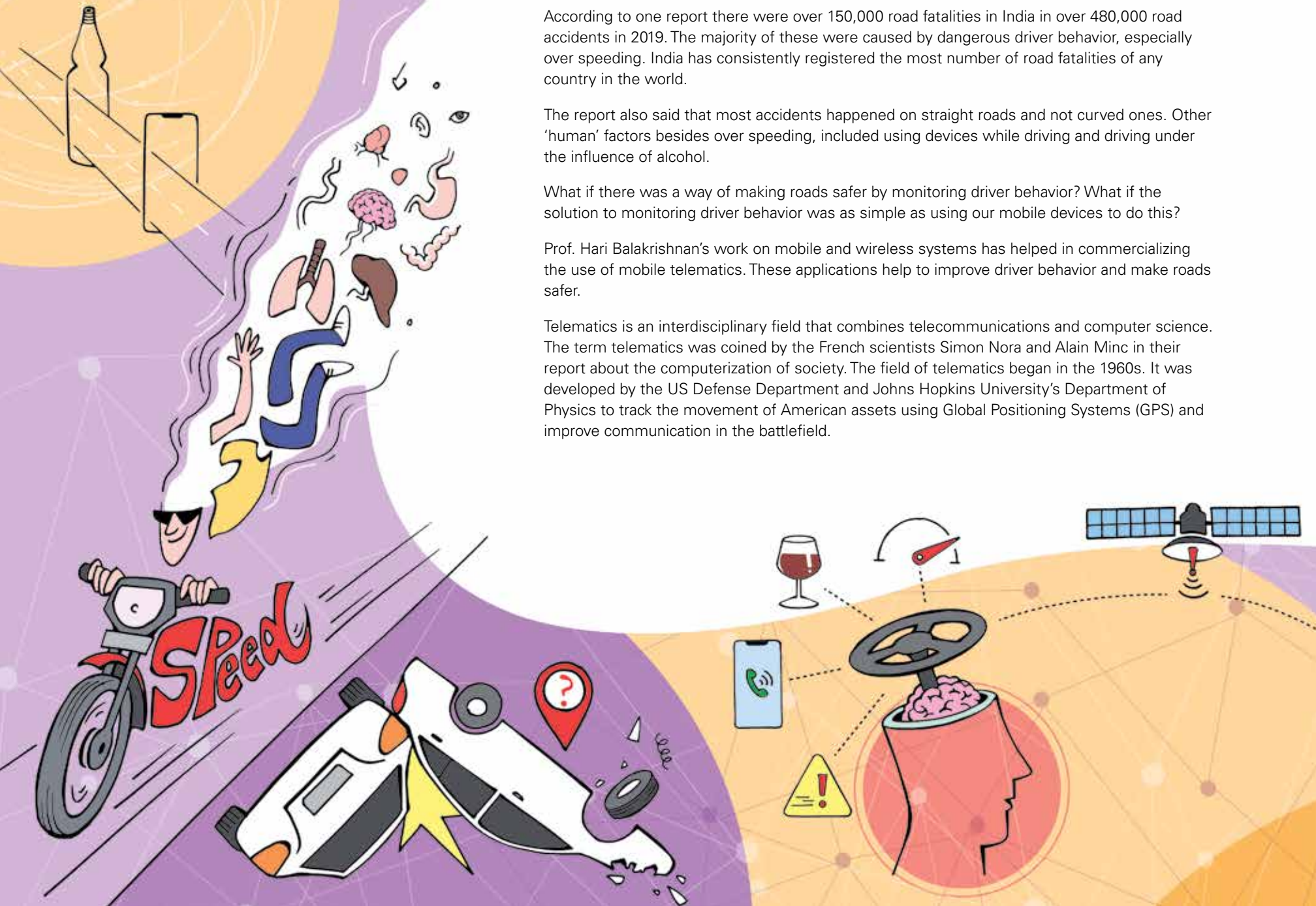
According to one report there were over 150,000 road fatalities in India in over 480,000 road accidents in 2019. The majority of these were caused by dangerous driver behavior, especially over speeding. India has consistently registered the most number of road fatalities of any country in the world.

The report also said that most accidents happened on straight roads and not curved ones. Other 'human' factors besides over speeding, included using devices while driving and driving under the influence of alcohol.

What if there was a way of making roads safer by monitoring driver behavior? What if the solution to monitoring driver behavior was as simple as using our mobile devices to do this?

Prof. Hari Balakrishnan's work on mobile and wireless systems has helped in commercializing the use of mobile telematics. These applications help to improve driver behavior and make roads safer.

Telematics is an interdisciplinary field that combines telecommunications and computer science. The term telematics was coined by the French scientists Simon Nora and Alain Minc in their report about the computerization of society. The field of telematics began in the 1960s. It was developed by the US Defense Department and Johns Hopkins University's Department of Physics to track the movement of American assets using Global Positioning Systems (GPS) and improve communication in the battlefield.



Prof. Hari Balakrishnan and his collaborator Prof. Sam Madden started the CarTel project at MIT in 2004. CarTel pioneered mobile sensing technologies with embedded devices and smartphones, and they equipped Boston taxis with sensors to measure traffic surface conditions and traffic. The CarTel system was the first of its kind to use participatory sensing applications. Participatory sensing is the process by which individuals and communities use mobile phones and cloud services to collect and analyze sensor data.

This research led to the founding of Cambridge Mobile Telematics (CMT) in 2010. CMT's DriveWell platform uses data from mobile sensors to extract insights and analytics about driver behavior such as phone distraction, risky speeding, hard braking, and more.

The platform then provides personalized scoring and insights to help the driver improve. The system engages drivers through competition and rewards. Within 30 days of using the system, drivers have seen 35% reduction in phone distraction, 20% reduction in hard braking, and 20% reduction in risky speeding.

CMT is today the world's largest mobile telematics provider. It currently has 65 enterprise programs in over 25 countries, working with leading insurers, rideshares, cellular carriers, car makers, and municipalities to make roads safer by making drivers better.

Humanities

The Infosys Prize 2020 in Humanities is awarded to the historian Dr. Prachi Deshpande for her extraordinarily nuanced and highly sophisticated treatment of South Asian historiography. Her book *Creative Pasts* and her many articles examine with fine insight the evolution of modern history writing in Maharashtra from the Maratha period onwards and offer an illuminating and novel perspective on the history of Western India with implications going well beyond that region.

Prachi Deshpande

Associate Professor of History,
Centre for Studies in Social Sciences,
Kolkata, India

BIO

Dr. Prachi Deshpande trained in history at Fergusson College, Pune, and at Jawaharlal Nehru University in New Delhi, before completing her Ph.D. at Tufts University in 2002. She then taught at several institutions in the US and received tenure at the University of California, Berkeley, before returning to India to take up her current position at the Centre for Studies in Social Sciences in Kolkata, in 2010.

Deshpande has published scholarly works in English and Marathi. Her book *Creative Pasts: Historical Memory and Identity in Western India, 1700-1960* (2007) examined the emergence of modern history-writing practices in the Marathi-speaking areas of Western India, and the importance of historical memory in shaping an enduring Maharashtrian regional identity.

Dr. Deshpande's essays and book chapters include "The Writerly Self: Discourses of Literate Practice in Early Modern Western India," in *Indian Economic and Social History Review* (2016), "Scripting the Cultural History of Language: Modi in the Colonial Archive," in Partha Chatterjee, Tapati Guha-Thakurta and Bodhisattva Kar, eds. *New Cultural Histories of India* (2014), "Pasts in the Plural: A Review Essay on Bhalchandra Nemade's Hindu: Jaganyaachi Samruddha Adagal", in *Studies in Humanities and Social Sciences* (2010).

Scope and impact of work

Dr.Prachi Deshpande's contributions to the history of Western India are seminal. Her pathbreaking book *Creative Pasts: Historical Memory and Identity in Western India, 1700-1960* is widely applauded, admired, and cited. It has enormously enhanced our historical understanding of Western India, and has had a substantial impact on the fields of cultural, social and political history. It contributes to a better understanding, not only of the Maratha polity and its culture in the 18th century, but also of how this political culture has been understood and reinterpreted by scholars of very different persuasions in the 19th and 20th centuries. The book is an important intervention in debates on nationalism and history-writing, the place of caste and gender, autobiography and introspection, as well as the interface between history and memory. Dr. Deshpande has brought a fresh and knowledgeable angle on these issues that revitalizes their enduring intellectual interest, while also going beyond the familiar dichotomies of "traditional" kinds of historical memory and those that developed in modernity.

Deshpande has also published a number of significant papers in journals and anthologies, in both English and Marathi. Two of her essays that are deservedly famous are "The Making of a Nationalist Archive: Lakshmibai, Jhansi and 1857" in *Journal of Asian Studies* (2008), focused on Lakshmibai, the female ruler of Jhansi in 1857, and "The Writerly Self: Discourses of Literate Practice in Early Modern Western India" in *Indian Economic and Social History Review* (2016), focused on scribal and literate culture in Western India. These open up exciting new possibilities for research for her own generation and the next.

Deshpande has also commented brilliantly on current literary and cultural debates, especially in regard to Marathi language and literature, and is a widely sought-after speaker of national and international repute.

Citation by the jury

Dr. Prachi Deshpande is recognized as one of the most accomplished historians of her generation working on South Asia today. Her remarkably innovative work cuts across the early modern and modern periods. She is peerless in her deep knowledge of sources in Marathi, and her 2007 book *Creative Pasts: Historical Memory and Identity in Western India, 1700–1960* is an outstanding product of that knowledge as well as of a very imaginative theoretical mind that explores the most fundamental historiographical issues.

Dr. Deshpande has also written with great insight and depth of scholarship on scribal groups and their role, the social history of scripts, and the history of pedagogy and education. She has been a central participant in some of the most fruitful debates on education and history, in both Marathi and English.

My warmest congratulations to Dr. Prachi Deshpande on being awarded the Infosys Prize for Humanities for 2020. I want to express my great admiration and respect for your work, which I have read with much instruction and pleasure over the past few years. Your work has made significant contributions to a wide range of historical themes and has deepened our understanding of the history of Western India and of large and longstanding historiographical issues such as the relations between history and memory, and of the literary and other non-standard sources of historical learning.

Akeel Bilgrami

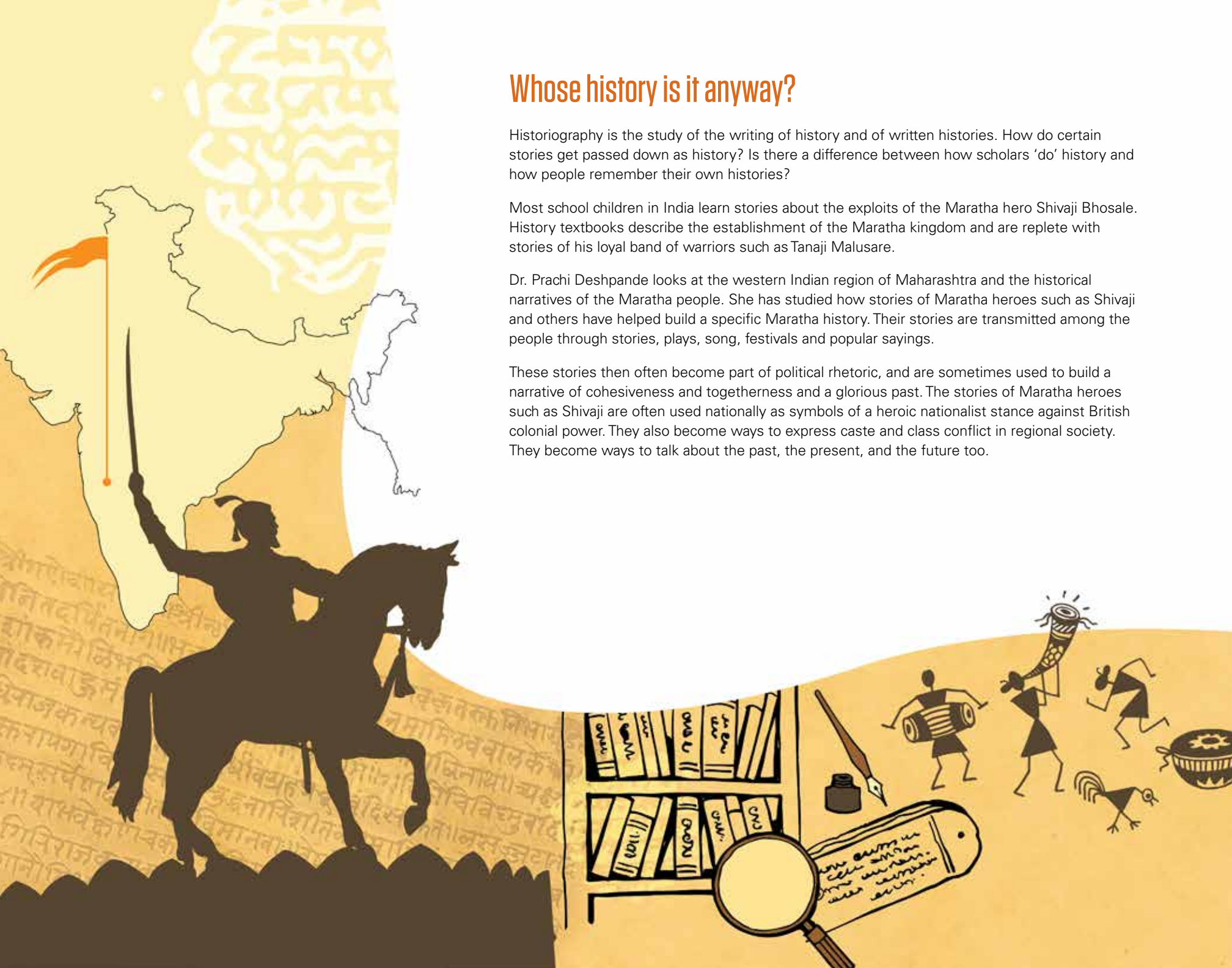
Whose history is it anyway?

Historiography is the study of the writing of history and of written histories. How do certain stories get passed down as history? Is there a difference between how scholars 'do' history and how people remember their own histories?

Most school children in India learn stories about the exploits of the Maratha hero Shivaji Bhosale. History textbooks describe the establishment of the Maratha kingdom and are replete with stories of his loyal band of warriors such as Tanaji Malusare.

Dr. Prachi Deshpande looks at the western Indian region of Maharashtra and the historical narratives of the Maratha people. She has studied how stories of Maratha heroes such as Shivaji and others have helped build a specific Maratha history. Their stories are transmitted among the people through stories, plays, song, festivals and popular sayings.

These stories then often become part of political rhetoric, and are sometimes used to build a narrative of cohesiveness and togetherness and a glorious past. The stories of Maratha heroes such as Shivaji are often used nationally as symbols of a heroic nationalist stance against British colonial power. They also become ways to express caste and class conflict in regional society. They become ways to talk about the past, the present, and the future too.



Dr. Deshpande examines how historiography or the writing of history was practiced especially in the century immediately before the coming of colonialism. Her book explores how historical narratives of the Maratha period contribute to modern understanding of terms such as Maratha and Marathi to describe a group of people. Her research looks at how historical memory is created, the difference between traditional kinds of historical memory, and how modernity changed this. Historical memory describes stories about the past that have taken hold in popular imagination through stories that are repeated over generations. These are then passed on through poetry, stories, film and other channels.

In her recent work, Deshpande looks at how we think of language histories. She uses an old cursive script called moḍī, which was used for record-keeping and correspondence, to explore how people have thought about and used the Marathi language over several hundred years. Marathi was used in many regions with other languages and scripts before it became the official language of Maharashtra. Deshpande focuses on such everyday language practices to understand how ideas about script, literacy, spelling, letter-writing, clerkship, language identity and multi-linguality have changed over time.

With her work, Deshpande not only provides a better understanding of 18th century Maharashtra but also provides tools to understand how the past lives on in the present through political culture, language practices, and historical memory.

Life Sciences

The Infosys Prize 2020 in Life Sciences is awarded to Prof. Rajan Sankaranarayanan for fundamental contributions towards understanding one of the most basic mechanisms in biology. The error-free translation of the genetic code to make protein molecules is of utmost importance to life. Prof. Sankaranarayanan has made seminal contributions towards understanding a critical checkpoint in the production of proteins from messenger RNA. His work has potential applications to the design of drugs such as antibiotics and immunosuppressants.

Rajan Sankaranarayanan

Group leader, Structural Biology Laboratory, Centre for Cellular and Molecular Biology, Hyderabad, India

BIO

Prof. Rajan Sankaranarayanan is Chief Scientist at the Center for Cellular and Molecular Biology (CCMB) in Hyderabad. He received his Ph.D. from the Molecular Biophysics Unit at the Indian Institute of Science, in the field of Structural Biology.

After postdoctoral work with Dino Moras in Strasbourg, Prof. Sankaranarayanan began his independent research position at CCMB in 2002, where he has continued until the present time.

Sankaranarayanan's work has been recognized by several awards, notably the Shanti Swarup Bhatnagar Prize (2011), the G.N. Ramachandran Gold Medal (2015), and the G.D. Birla Award (2018). He has been elected to all three national academies of science in India.

Scope and impact of work

Prof. Rajan Sankaranarayanan has made major advances in understanding the problem of discrimination against D-amino acids in the production of genetically-encoded proteins, which are constructed only of L-amino acids. Enantiomeric fidelity is key to proper cellular and organismal function. Indeed, the tragedy of thalidomide can be traced to the fact that it exists as an enantiomeric mixture with one form being a sedative and the other causing birth defects.
Given the enormously deleterious effects of incorporating D-amino acids into polypeptide chains their exclusion is not left to chance. Components of the translational machinery function in concert to exclude D-amino acids from the translation process.

Prof. Sankaranarayanan's group has made ground-breaking contributions to delineating the mechanism for the most important proof-reading component—the enzyme D-aminoacyl-tRNA deacylase (DTD), which cleaves off D-amino acids that are mischarged on tRNAs. They determined that the structure of a complex of the enzyme with a small molecule mimic that of a D-amino acid attached to a tRNA. The structure showed how the protein backbone of the enzyme formed a pocket that preferentially recognized the D-aminoacyl substrate for cleavage.

This discovery provides a beautiful illustration of function-specific molecular recognition, because it reveals how the enzyme embraces the substrate backbone, leaving the sidechain free. This enables the enzyme to faithfully cleave off D-amino acids from all D-aminoacyl-tRNAs, without regard to the nature of the amino acid.

Subsequent work from Prof. Sankaranarayanan's group has continued to shed light on other mysteries in translational quality control.

Citation by the jury

Prof. Rajan Sankaranarayanan's work has addressed a fundamental question in how proteins are made. Proteins are basic building blocks of life that carry out a large number of functions. They consist of linear polymers or polypeptide chains built from up to 20 amino acids, all of the L form. What is the mechanism by which nature selects L - and not D-amino acids — hence amino acids of the proper chirality or mirror-image symmetry—to make proteins? This fidelity is a key to proper cellular and organismal function. By analyzing the atomic level structures of the enzymes responsible for maintaining the proper chirality Prof. Sankaranarayanan has established how they work. The structural portraits he has generated "speak a thousand words" and reveal selection mechanisms that are conserved across life. Sankaranarayanan's work on fundamental problems in molecular recognition has potential applications in drug design through protein engineering, by designing chemical keys to open the locks on chiral fidelity discovered by him.

On behalf of the jury for the Infosys Prize in Life Sciences, I am delighted to congratulate you on being the winner of the 2020 Infosys Prize. Your work has addressed a fundamental question in understanding one of the most basic mechanisms in biology. The error-free translation of the genetic code to make protein molecules is of utmost importance to life. The structural portraits you have generated "speak a thousand words" and reveal selection mechanisms that are conserved across life. Your work on fundamental problems in molecular recognition has potential applications in drug design through protein engineering.

Mriganka Sur

The stuff of life

In the recent race for a vaccine against the COVID-19 virus, proteins have been in the news. The mRNA Covid vaccine essentially functions by teaching cells how to make a protein, which in turn triggers an immune response that produces antibodies that would then 'arm' the body for any future attacks by the virus.

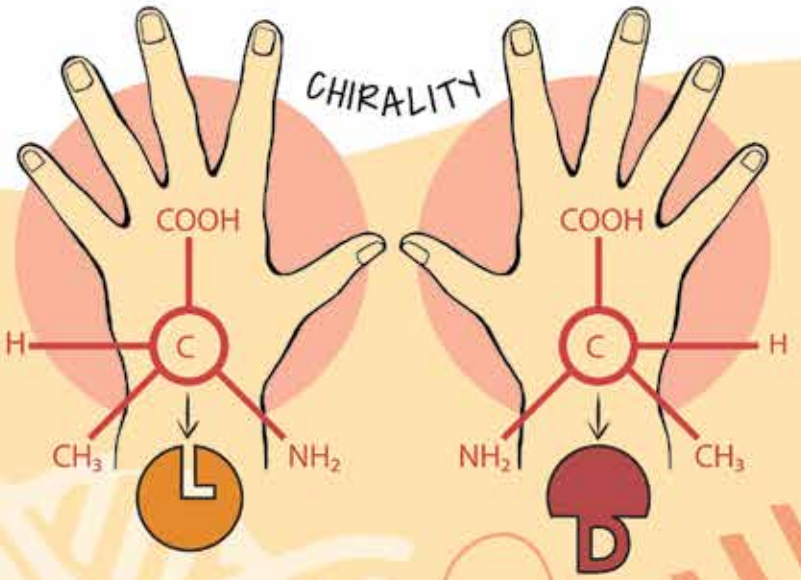
Proteins are the most important component of life forms. They power the immune system, digest food, and fire neurons. The Swedish chemist Jons Jacob Berzelius first coined the term protein in 1838. The term was derived from the Greek word proteios, meaning, "holding first place". Without proteins, life as we know it would not exist.

Structurally proteins consist of linear polymers or polypeptide chains, and each of these chains is made up of 20 amino acids.

All amino acids except glycine are of two types—L- (levo-rotatory) and D- (dextro-rotatory) amino acids i.e. left-handed and right-handed amino acids.

This spatial property of handedness or chirality (from the Greek word chiral meaning hand) is an important one that determines function and is present all around us. For example, our hands are mirror images of each other. Objects such as screws are either left or right. Certain types of light also exhibit chirality and are used for optically rotating molecules.

Similarly, amino acid molecules also exhibit chirality. The molecules are chemically and physically similar in every way but are mirror images of each other like our hands and cannot be super imposed on one another—a phenomenon called enantiomerism. This has important implications for how they react when mixed with different components.



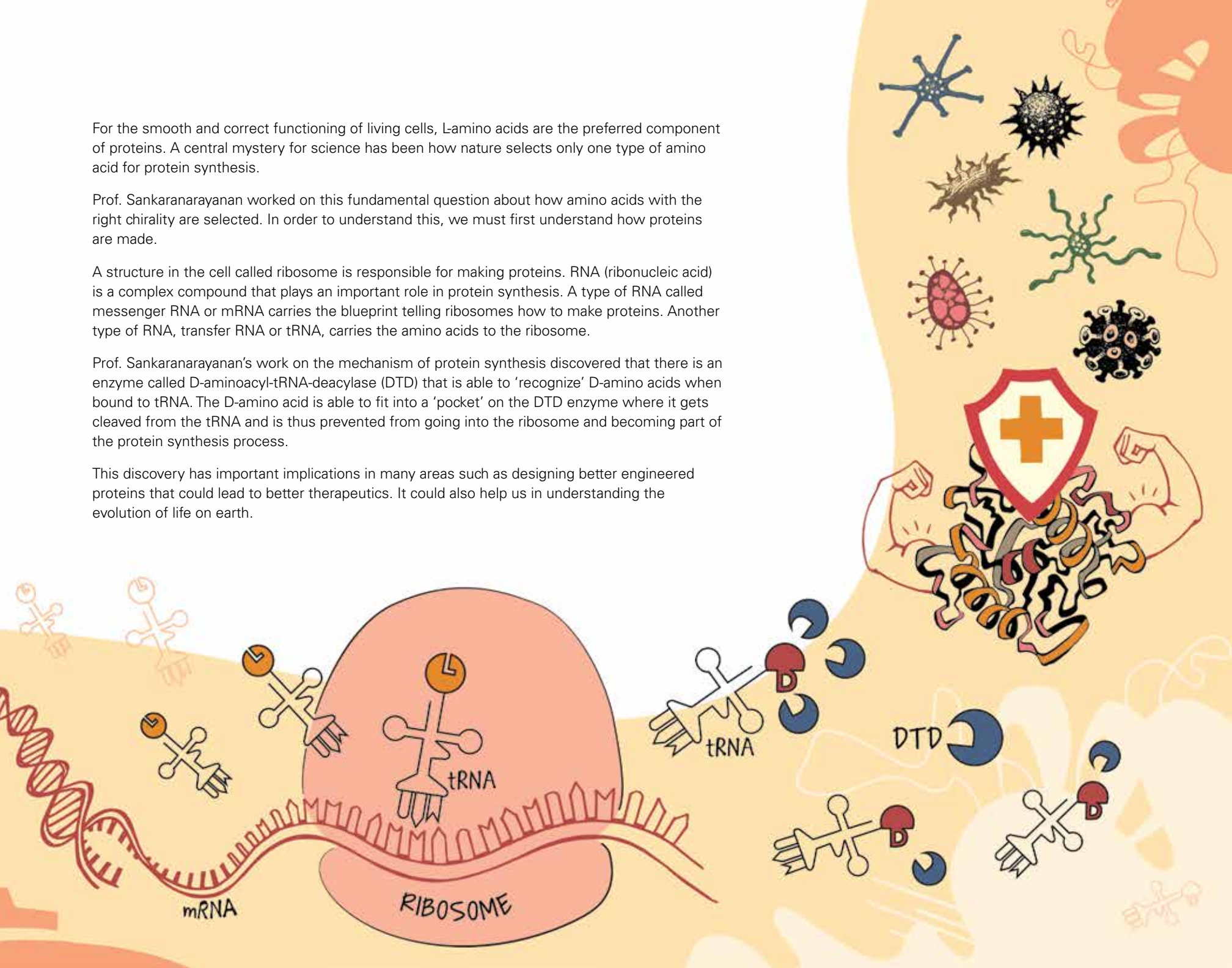
For the smooth and correct functioning of living cells, L-amino acids are the preferred component of proteins. A central mystery for science has been how nature selects only one type of amino acid for protein synthesis.

Prof. Sankaranarayanan worked on this fundamental question about how amino acids with the right chirality are selected. In order to understand this, we must first understand how proteins are made.

A structure in the cell called ribosome is responsible for making proteins. RNA (ribonucleic acid) is a complex compound that plays an important role in protein synthesis. A type of RNA called messenger RNA or mRNA carries the blueprint telling ribosomes how to make proteins. Another type of RNA, transfer RNA or tRNA, carries the amino acids to the ribosome.

Prof. Sankaranarayanan's work on the mechanism of protein synthesis discovered that there is an enzyme called D-aminoacyl-tRNA-deacylase (DTD) that is able to 'recognize' D-amino acids when bound to tRNA. The D-amino acid is able to fit into a 'pocket' on the DTD enzyme where it gets cleaved from the tRNA and is thus prevented from going into the ribosome and becoming part of the protein synthesis process.

This discovery has important implications in many areas such as designing better engineered proteins that could lead to better therapeutics. It could also help us in understanding the evolution of life on earth.



Mathematical Sciences

The Infosys Prize 2020 in Mathematical Sciences is awarded to Prof. Sourav Chatterjee for his groundbreaking work in probability and statistical physics. He is recognized in particular for his contributions to areas such as fluctuations in random structures, concentration and super-concentration inequalities, spin glasses, Poisson and other non-normal limits, and first-passage percolation.

Prof. Chatterjee is one of the most versatile probabilists of his generation, and is known for his formidable problem-solving powers.

Sourav Chatterjee

Professor of Mathematics and Statistics,
Department of Statistics,
Stanford University, USA

BIO

Prof. Sourav Chatterjee obtained his bachelor's and master's degrees in statistics from the Indian Statistical Institute in Kolkata (in 2000 and 2002) and thereafter went on to earn his Ph.D. from Stanford University with Persi Diaconis. After stints on the faculty at University of California, Berkeley and the Courant Institute, he has been Professor of Mathematics and Statistics at Stanford University since 2013.

Prof. Chatterjee's work has been recognized with a number of awards including the Rollo Davidson Prize (2010), the Doeblin Prize (2012) in Probability (he was its first recipient), and the Line and Michel Lo`eve International Prize in Probability (2013). He gave an invited address at the International Congress of Mathematicians in 2014, and was elected as Fellow of the Institute of Mathematical Statistics in 2018.

Scope and impact of work

The work of Prof. Sourav Chatterjee over the last fifteen years has had significant influence on the progress made in probability and statistics during this period. There are several broad areas in which his work has had considerable impact. In 1972, Charles Stein introduced a method that offered a completely novel way of proving the classical central limit theorem that allowed at the same time a method for evaluating the quality of the approximation.

In several pathbreaking publications Prof. Chatterjee has demonstrated that Stein's method can be modified and extended to solve several problems in areas such as fluctuations in random structures, concentration and super-concentration inequalities, spin glasses etc. Chatterjee's work (done jointly with S.R.S. Varadhan) has played a critical role in the emerging body of work on large deviations for random graphs.

Stochastic block models appear as candidates for realistic networks with high connectivity within individual communities and sparse connections between different ones. They occur in computing networks, social networks as well as business networks. Prof. Chatterjee's seminal contribution in this area has been extensively cited.

Sourav Chatterjee has also made major contributions to several areas in Statistical Physics. His work has had impact on Yang-Mills Theory, Gravitational Allocation, directed polymers, Lattice Gauge Theory, Random Growth Models, Gaussian Random Fields, Random Field Ising Model, and Quantum Unique Ergodicity, to name just a few.

Prof. Chatterjee takes up difficult problems and succeeds in solving them by generating new methods or improving an old one. His publications have been cited extensively by more than a thousand authors.

Citation by the jury

Probability theory is a branch of mathematics which plays an essential role in many theoretical and applied fields. Prof. Sourav Chatterjee has made contributions that have had significant impact in diverse areas. In statistics, they include determining the sample size needed in importance sampling and estimating the entries of a large matrix when only a noisy version of a fraction of the entries is observed.

Prof. Chatterjee has contributed to the study of Gauge-String duality in Lattice Gauge Theory, Quark Confinement, Solitons and Spin Glass in Statistical Physics. In addition, he has made contributions in probability theory to Large Deviation Theory of random graphs, scaling exponents in First Passage Percolation and studying the interrelationships between chaos, super concentration and multiple valleys for Gaussian Random Fields.

Congratulations! The jury was very impressed with the breadth and range of your work across probability, statistics, and mathematical physics. You are one of the most powerful problem-solvers in the field of your generation. Your recent work on quark confinement and use of probabilistic methods to make quantum field theory rigorous is impressive. Congratulations again!

Chandrashekhar Khare

What are the chances?

Every time someone tries to answer that question, they are unconsciously making probability calculations.

From checking your weather app for chances of rain to the vital life-saving margins of error that come out of the laboratories testing the effectiveness of a possible vaccine against COVID-19, the success of your picnic plans or your very life may depend on the number crunching statisticians and mathematicians doing those calculations. Probability calculations even determine what your insurance premium should be based on your age or driving behavior.

The field of probability is a young one in mathematics. It has its origins in an exchange of letters between French mathematicians Blaise Pascal and Pierre Fermat in 1654. Another contemporary mathematician, Antoine Gombaud who was fond of gambling, was contemplating "the problem of points". The problem was proposed by an Italian monk Luca Pacioli (a collaborator of Da Vinci) in 1494 in the form of a question about how to divide the winnings if for example a game that requires six goals to win is interrupted when one player has five goals and the other has three goals. The player with five goals should have a larger share but how much larger?

Gombaud presented the problem to Pascal who then began a correspondence with Fermat. This set of letters laid the foundation of what is today known as Probability Theory.

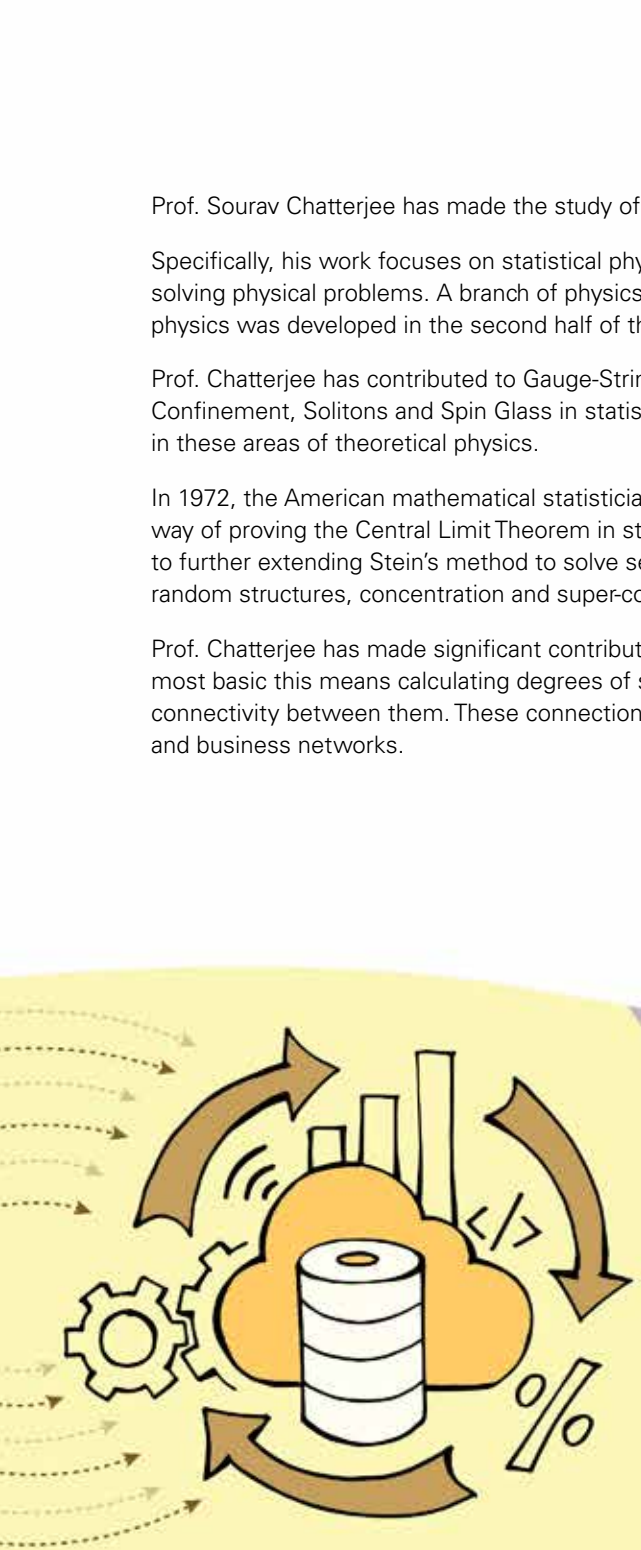
Prof. Sourav Chatterjee has made the study of statistics and probability his life's work.

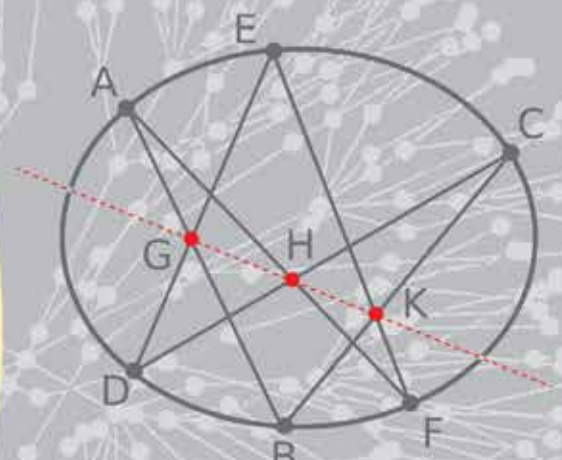
Specifically, his work focuses on statistical physics that uses probability theory and statistics in solving physical problems. A branch of physics that deals entirely in pure mathematics, statistical physics was developed in the second half of the 19th century.

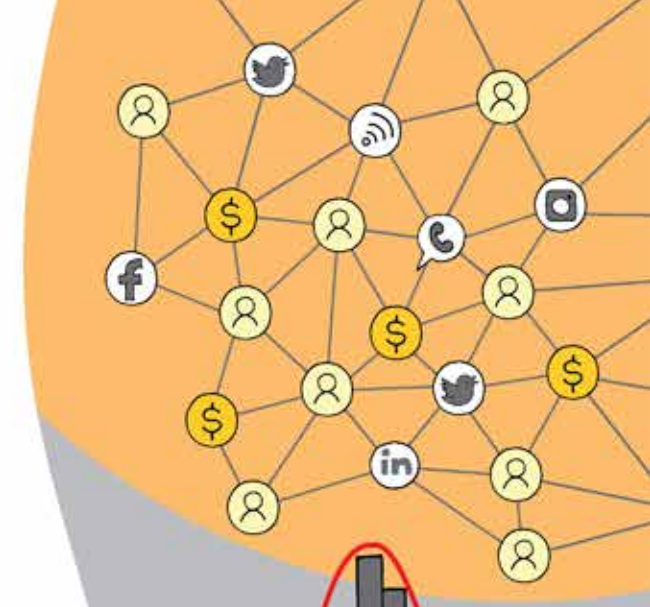
Prof. Chatterjee has contributed to Gauge-String duality in Lattice Gauge Theory, Quark Confinement, Solitons and Spin Glass in statistical physics. His work has enormous implications in these areas of theoretical physics.

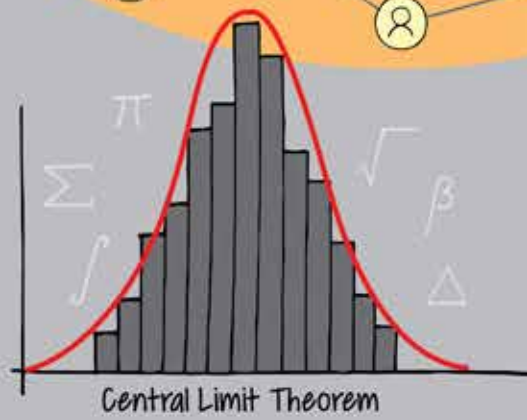
In 1972, the American mathematical statistician Charles Stein wrote a paper that provided a way of proving the Central Limit Theorem in statistics. Prof. Chatterjee's work has contributed to further extending Stein's method to solve several problems in areas such as fluctuations in random structures, concentration and super-concentration inequalities, spin glasses etc.

Prof. Chatterjee has made significant contributions to modern communications theory. At its most basic this means calculating degrees of separation between people and how to improve connectivity between them. These connections occur in computing networks, social networks, and business networks.









Physical Sciences

The Infosys Prize 2020 in Physical Sciences is awarded to Prof. Arindam Ghosh for his development of atomically thin two-dimensional semiconductors to build a new generation of functional electronic, thermoelectric and optoelectronic devices. He has probed new quantum phenomena in graphene with conductivity noise and created a new platform for light-matter interaction that impacts quantum technologies and sensing in a fundamental way.

Arindam Ghosh

Professor, Department of Physics,
Indian Institute of Science,
Bengaluru, India

BIO

Prof. Arindam Ghosh is Professor of Physics at the Indian Institute of Science, Bengaluru. He obtained his Ph.D. from IISc in 1999 and was a Postdoctoral Research Associate at the University of Cambridge, UK till 2005 before joining IISc as Assistant Professor in 2005.

Prof. Ghosh won the Swaranjayanthi Fellowship in 2008. He was elected fellow of the Indian Academy of Sciences (2015) and Indian National Science Academy (2017). Ghosh's other awards include the Shanti Swarup Bhatnagar Prize (2012), the Materials Research Society of India Medal (2012), the Oxford Instruments Young Nanoscience Award (2016), the P.K. Iyengar Memorial Award for Excellence in Experimental Physics (2016), and the DAE Raja Ramanna Prize Lecture in Physics (2017). He most recently won the J.C. Bose Fellowship of DST in 2018.

Scope and impact of work

Prof. Arindam Ghosh is one of the key contributors to the global development of the field of two-dimensional materials and has made several discoveries that have advanced both fundamental concepts and domains of application. Prof. Ghosh's work on light-matter interaction with layered materials has placed his group among the leading global researchers in this topic. His discovery of a new physical mechanism to convert light into electricity using hybrid structures of graphene and molybdenum disulphide kick-started the new field of two-dimensional optoelectronics. These heterostructures can achieve conversion of light into electricity that is nearly ten billion times more efficient than bulk semiconductors, such as silicon.

Ghosh's work represents, a paradigm shift in optoelectronics, where unique properties of graphene and other layered semiconductors could be synergistically combined to achieve massive optical gains. The ability to detect very small intensity of radiation is of paramount importance because of its applications in photography, low power communication, optical sensing as well as in defence and security. Prof. Ghosh's many recent works on this topic cover new materials, and extend to infrared light as well as aim to achieve single photon detection.

Graphene, and its multilayer descendants, also have novel properties that are of great interest to our fundamental understanding of the role of quantum mechanics and quantum entanglement in many-particle systems. One of these is the prediction that there should be electrons that can flow on the edge of a graphene flake without any resistance. Arindam Ghosh's development of the technology of ultra-sensitive detection of electromechanical response and electrical noise at very low temperatures has allowed the first direct detection of such electrical currents on a zigzag edge of graphene.

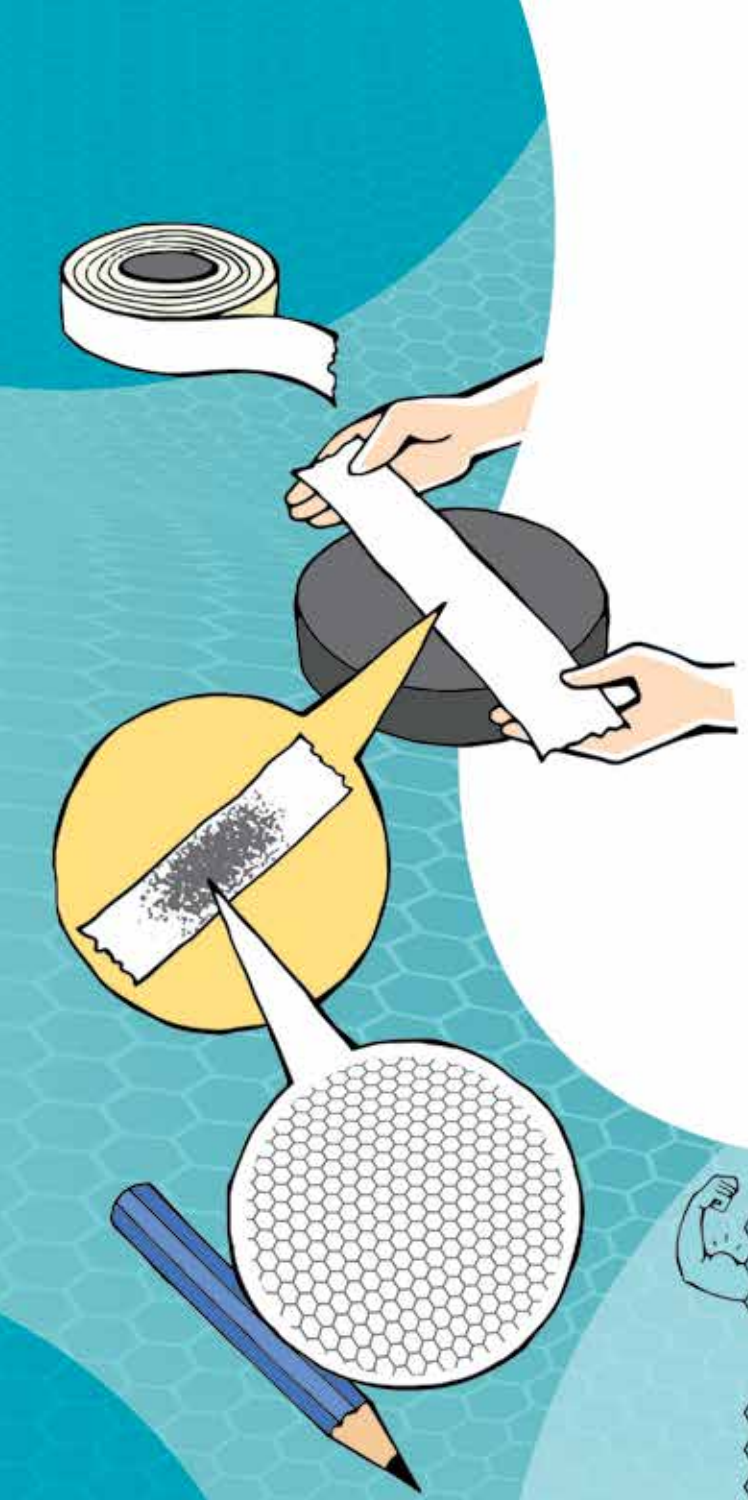
Citation by the jury

Prof. Arindam Ghosh has realized an atomically thin composite of graphene and molybdenum disulphide (MoS2), which displays unprecedented sensitivity in converting optical radiation into electric current, with a sensitivity of about ten orders of magnitude higher than the extensively used silicon photodetectors. His group has unravelled the mechanism of this photodetector, and shown that it is conceptually distinct from the conventional technology of p-n junction diodes in silicon.

Prof. Ghosh has also developed the technology of the measurement of very weak electrical signals down to millikelvin temperatures. This has allowed direct detection of electrical currents flowing along the zigzag edge of a single layer of carbon atoms known as graphene. Ghosh has developed new technologies for detecting thermoelectricity in atomically thin van der Waals heterostructures, promising new insights into the electronic structure of the many new heterostructures now being discovered.

Prof. Ghosh congratulations! We were very impressed with your work in a new way of converting particle radiation into an electrical current. This magnificent jump in sensitivity that you have achieved compared to silicon photo detectors is not only interesting from the basic physics point of view but may also have some applications in the future. You are the first winner in experimental condensed matter of the Infosys Prize in Physical Sciences. We hope your win will inspire more young people to take up experimental physics.

Shrinivas Kulkarni



Living in a material world

In 2004, two scientists at the University of Manchester Andre Geim and Kostya Novoselov, isolated a one-atom thick, two-dimensional material called graphene from a lump of graphite using a bit of sticky tape. A form of carbon, graphene is a better absorber of heat and electricity than materials such as copper. And it is not only one of the thinnest materials but also one of the strongest and most flexible.

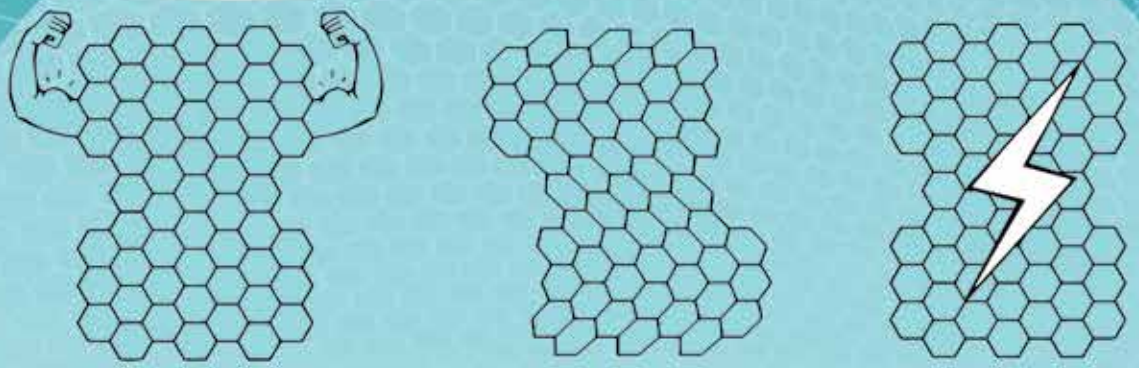
The discovery of graphene heralded a whole new era—the future in the trace of a pencil as some dubbed it.

Throughout history, the discovery of new materials has marked the beginning of scientific and societal revolutions. Various epochs are named for the materials that played prominent roles during those times—the Stone Age, Iron Age, Bronze Age and so on. We do indeed live in a material world.

In an age when our devices have become extensions of ourselves, we are always looking for new materials that could make them faster, more efficient, smaller and lighter, almost magical.

In 1965, Gordon Moore predicted that the number of transistors on a microchip doubles every two years and that the speed and capacity of computers will increase every couple of years.

The journey to Moore's statement started in 1904 when John Ambrose Fleming invented the two-electrode vacuum tube rectifier which would play an important role in electrical circuits.



By 1946, the world's first general-purpose computer, ENIAC, was unveiled to the world. It was equipped with 18,000 vacuum tubes, weighed 30 tons, occupied a 160-square-meter room and consisted of a total of about 110,000 electronic circuit devices.

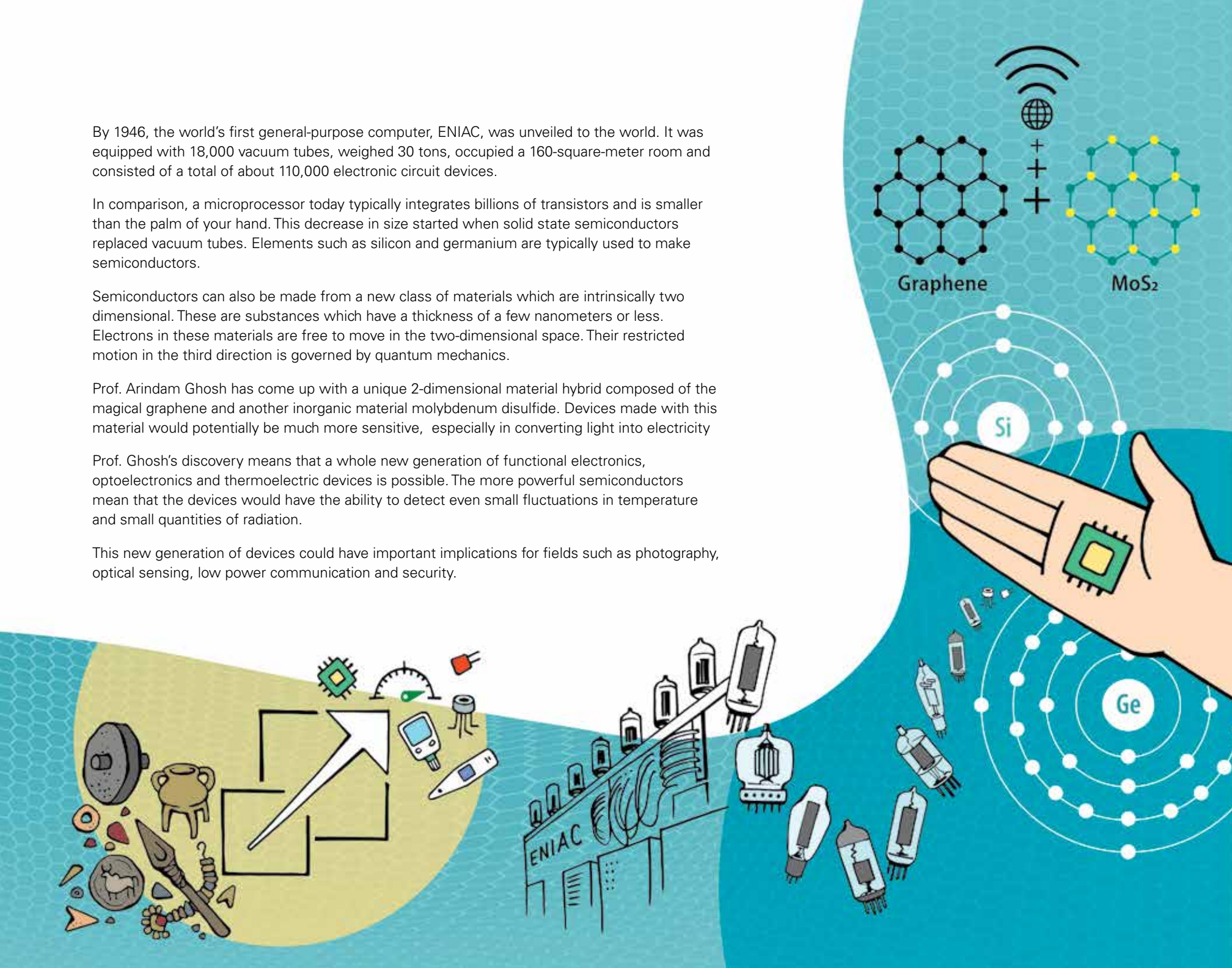
In comparison, a microprocessor today typically integrates billions of transistors and is smaller than the palm of your hand. This decrease in size started when solid state semiconductors replaced vacuum tubes. Elements such as silicon and germanium are typically used to make semiconductors.

Semiconductors can also be made from a new class of materials which are intrinsically two dimensional. These are substances which have a thickness of a few nanometers or less. Electrons in these materials are free to move in the two-dimensional space. Their restricted motion in the third direction is governed by quantum mechanics.

Prof. Arindam Ghosh has come up with a unique 2-dimensional material hybrid composed of the magical graphene and another inorganic material molybdenum disulfide. Devices made with this material would potentially be much more sensitive, especially in converting light into electricity

Prof. Ghosh's discovery means that a whole new generation of functional electronics, optoelectronics and thermoelectric devices is possible. The more powerful semiconductors mean that the devices would have the ability to detect even small fluctuations in temperature and small quantities of radiation.

This new generation of devices could have important implications for fields such as photography, optical sensing, low power communication and security.



Social Sciences

The Infosys Prize 2020 in Social Sciences is awarded to Prof. Raj Chetty for his pioneering research on identifying barriers to economic opportunity and for developing solutions to help people escape from poverty towards better life outcomes. His research and extraordinary ability to discern patterns in large data have the potential to induce major shifts in the discipline of Economics.

Raj Chetty

William A. Ackman Professor of Economics, Harvard University and Director of Opportunity Insights, Cambridge, USA

BIO

Prof. Raj Chetty is one of the youngest tenured professors in Harvard University's history. Born in India, he moved to the US as a young boy, still in elementary school, with his immigrant parents. He completed his Ph.D. at the age of 23 from Harvard, and joined the faculty of University of California, Berkeley before returning to his alma mater as professor.

Prof. Chetty, along with collaborators John Friedman and Nathaniel Hendren, set up Opportunity Insights (a not-for-profit organization at Harvard University) which has developed an Opportunity Atlas, based on anonymous data following 20 million Americans. The Atlas offers answers to questions such as "which neighbourhoods in America provide the best chance to climb out of poverty?".

Chetty's prodigal scholarship has been widely recognized through various awards, such as the MacArthur Genius Fellowship (2012) and the John Bates Clark Medal (2013).

Scope and impact of work

Prof. Raj Chetty has a magical ability to use large data in conjunction with theories — traditional and behavioral – to draw implications for vital issues and policies concerning poverty, inequality, education, intergenerational mobility, insurance, and tax policy. His research is extraordinary in scope, spanning fields that may appear unrelated. He examines these issues across the usual sub-disciplinary silos, which exemplifies the uniqueness of his work.

Prof. Chetty's pioneering scholarly work and teaching methods have begun to reshape teaching and research in Economics. Using big data on micro-units to analyze macro questions about inequality, employment and education is critical. These issues are fundamental to human lives, and they represent the potential that the discipline of Economics, when used in combination with big data, has to shape actual economies. Bridging theory and empirics, Chetty's approach harnesses the largely untapped power of big data to allow scholars to join the dots between the various elements that constitute development.

This is particularly important at a time when big data has become contentious for sometimes being surreptitiously utilized for nefarious purposes. Raj Chetty's work demonstrates how to use big data responsibly, showing its tremendous positive power as an instrument for increasing human welfare whilst simultaneously protecting individual privacy. His work is focused on the US, but has potential for developing countries, including India, where millions grapple with debilitating poverty and crippling effects of inequality.

The value of Chetty's big data based analysis has become even more apparent in the COVID-19 pandemic. Opportunity Insights has set up an Economic Tracker, using millions of data points, which shows us how existing faultlines in the US are deepening due to the COVID crisis.

Citation by the jury

Prof. Raj Chetty's pioneering and imaginative research on identifying barriers to economic opportunity is unique, deep and brilliant. He is committed to finding solutions to help people rise out of poverty towards better life outcomes.

Prof. Chetty's work demonstrates how to use big data responsibly in addition to showing the positive power of big data as an instrument for understanding economic development and increasing human welfare. His work is focused on the US, but has clear relevance for developing countries, including India, where millions grapple with debilitating poverty and the crippling effects of inequality.

Raj Chetty's contributions both to knowledge and to methods of research and pedagogy have the potential to induce major shifts in the discipline of Economics.

Raj Chetty's research has been widely hailed for the light it sheds on a range of important topics, from inter-generational mobility and education, to tax policy and social insurance. What makes his work outstanding is its methodological originality. Raj has a magical ability to discern patterns in large data. His work has the potential to induce methodological shifts in economics and expand the reach of the discipline. I congratulate Raj for his remarkable contributions.

Kaushik Basu

Whither opportunity?

How does growing up in a low income neighborhood affect chances of success later in life? Does where you go to school in third grade determine where you will be at 30? Does your environment have a significant effect on your chances for success in later life?

These are some of the questions that the economist Prof. Raj Chetty is exploring. Along with these larger questions, Chetty and his team at Opportunity Insights are also examining the more complex aspects of these questions, such as why do low income families stick to areas where there are fewer opportunities?

Are such families motivated by concerns about family, or social groupings? Are these more human and complex issues stopping them from moving into what could be considered upwardly mobile areas with better opportunities.

How does Opportunity Insights go about examining these questions? In order to find answers to questions as complex as these, the most important thing is data. Large quantities of raw data about as many people as possible.

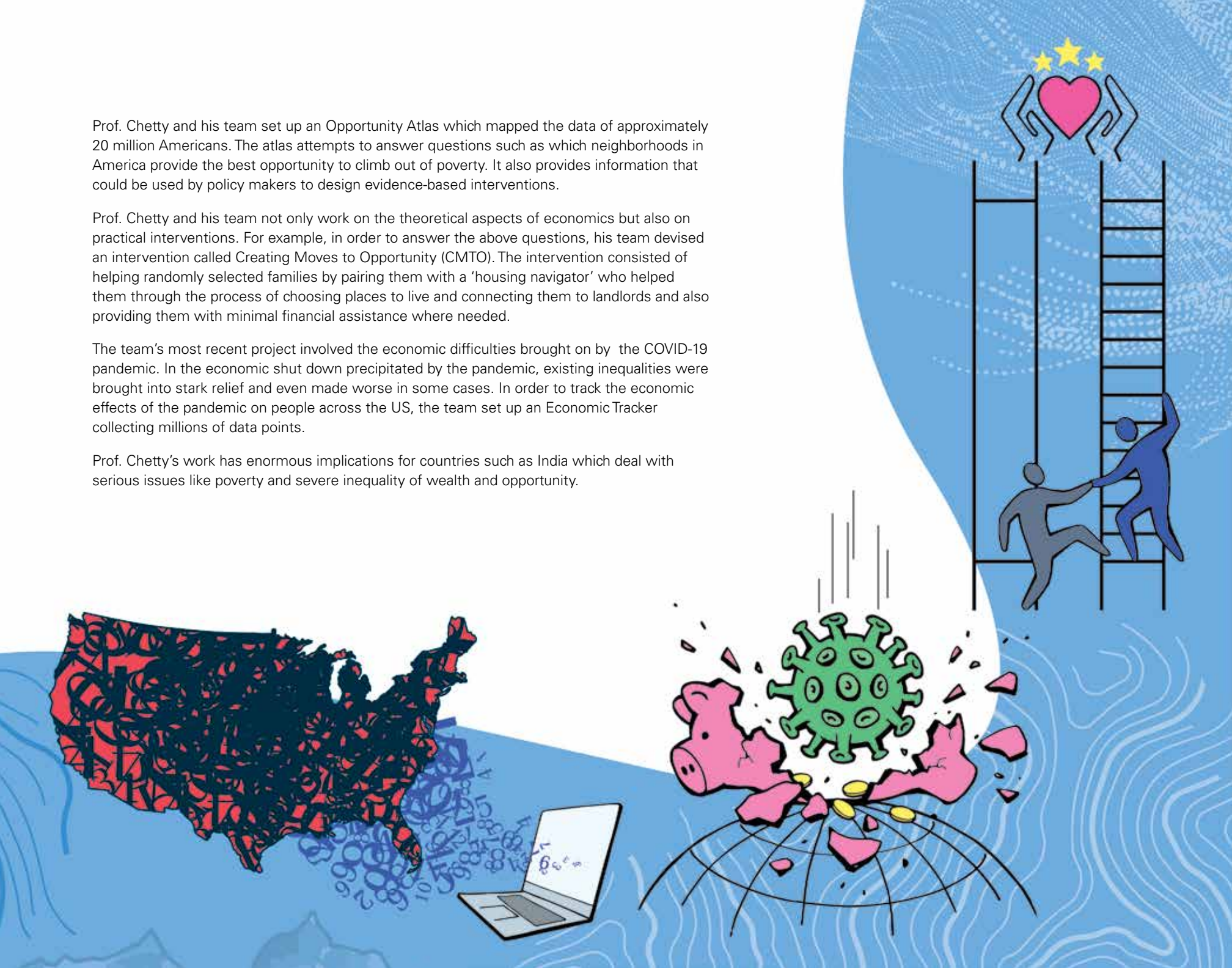
Big data has got a bad rap in recent years, raising the specter of invasion of privacy and other issues. But what if big data can be used to our advantage? What if the knowledge garnered from such data could be used to right systemic wrongs? Can big data help us identify and find solutions to problems such as inequality of opportunity?

Prof. Chetty and his team set up an Opportunity Atlas which mapped the data of approximately 20 million Americans. The atlas attempts to answer questions such as which neighborhoods in America provide the best opportunity to climb out of poverty. It also provides information that could be used by policy makers to design evidence-based interventions.

Prof. Chetty and his team not only work on the theoretical aspects of economics but also on practical interventions. For example, in order to answer the above questions, his team devised an intervention called Creating Moves to Opportunity (CMTO). The intervention consisted of helping randomly selected families by pairing them with a 'housing navigator' who helped them through the process of choosing places to live and connecting them to landlords and also providing them with minimal financial assistance where needed.

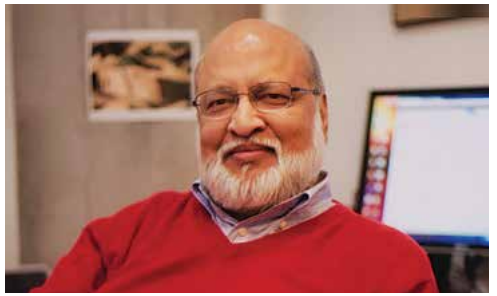
The team's most recent project involved the economic difficulties brought on by the COVID-19 pandemic. In the economic shut down precipitated by the pandemic, existing inequalities were brought into stark relief and even made worse in some cases. In order to track the economic effects of the pandemic on people across the US, the team set up an Economic Tracker collecting millions of data points.

Prof. Chetty's work has enormous implications for countries such as India which deal with serious issues like poverty and severe inequality of wealth and opportunity.



Jury Chairs

Engineering and Computer Science



Arvind

Jury Chair

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 - IEEE Charles Babbage Outstanding Scientist Award (1994); Distinguished Alumnus Award, I.I.T. Kanpur (1999); Outstanding Achievement Award, University of Minnesota (2008); and IEEE Computer Society Harry H. Goode Memorial Award (2012).

Jurors

Dhananjaya Dendukuri

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

Jayathi Y. Murthy

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

Sudhir Jain

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

Jitendra Malik

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

Kaushik Bhattacharya

Howell N. Tyson, Sr., Professor of Mechanics and Materials Science; Vice Provost Department of Mechanical and Civil Engineering, California Institute of Technology, 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.* 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

Sanjay Subrahmanyam

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

David Shulman

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

Janet Gyatso

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

Christopher Shackle

Professor emeritus, Modern Languages of South Asia, School of Oriental and African Studies (SOAS), University of London, UK

Clare Harris

Professor of Visual Anthropology, School of Anthropology and Museum Ethnography; Curator for Asian Collections, Pitt Rivers Museum, University of Oxford; Fellow of Magdalen College, Oxford, UK

Jury Chairs

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

John Kuriyan

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

Vishva M. Dixit

Vice-President, Discovery Research, Genentech, San Francisco, USA

Gagandeep Kang

Professor, Department of Gastrointestinal Sciences, Christian Medical College, Vellore, India

Mary Beckerle

Jon M. Huntsman Presidential Endowed Chair; CEO - Huntsman Cancer Institute at the University of Utah; Associate Vice President of Cancer Affairs, University of Utah Health, USA

Mathematical Sciences

Chandrashekhar Khare

Jury Chair

Chandrashekhar Khare is Professor in the Department of Mathematics at University of California, Los Angeles. After obtaining his Ph.D. from Caltech, Prof. Khare was at the Tata Institute of Fundamental Research in Mumbai for a decade. He then moved to the University of Utah. From 2007 he has been at UCLA.

Khare's work with Jean-Pierre Wintenberger gave a proof of a celebrated conjecture of J.-P. Serre in the subject. The conjecture had remained unresolved for more than three decades after it was first formulated. Prof. Khare has received a number of honors and awards in recognition of his work.He received the Humboldt Research Award in 2011, Cole Prize in 2011, Infosys Prize in 2010, Guggenheim fellowship in 2008, Fermat Prize in 2007, and the INSA Young Scientist Award in 1999. He was an invited speaker at the International Congress of Mathematicians in Hyderabad in August 2010. In 2012, he was elected as a Fellow of the Royal Society.

Jurors

Akshay Venkatesh

Professor, School of Mathematics, Institute for Advanced Study, USA

Parimala Raman

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

Srinivasa S. R. Varadhan

Professor of Mathematics and Frank J. Gould Professor of Science at the Courant Institute of Mathematical Sciences, New York University, USA

Shafi Goldwasser

Director, Simons Institute and C. Lester Hogan Professor, Electrical Engineering and Computer Sciences, University of California, Berkeley, USA

M.S. Raghunathan

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

Jury Chairs

Physical Sciences

Shrinivas Kulkarni

Jury Chair

Shrinivas Kulkarni is the George Ellery Hale Professor of Astronomy and Planetary Science at Caltech, USA. His interests include the study of compact objects (neutron stars and gamma-ray bursts) and the search for extra-solar planets through interferometric and adaptive techniques. He is the Interdisciplinary Scientist for the Space Interferometry Mission (SIM) and co-Principal Investigator of the Planet Search Key Project (at SIM). His awards include the Alan T. Waterman Prize of the NSF, Packard Fellowship, Presidential Young Investigator from the NSF and the Helen B. Warner Award of the American Astronomical Society and the Jansky Prize of Associated Universities, Inc. He was elected 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

Tejinder Singh Virdee

Professor of Physics, Imperial College, London, UK

Milind Purohit

Dean of Faculty Affairs, Okinawa Institute of Science and Technology Graduate University, Japan

Subir Sachdev

Herchel Smith Professor of Physics, Harvard University, USA

Ajay K. Sood

DST Year of Science Professor, Department of Physics, Indian Institute of Science, Bengaluru, India

Rana Adhikari

Professor of Physics, California Institute of Technology, 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

Haroon Bhorat

Professor of Economics and Director of the Development Policy Research Unit, University of Cape Town, South Africa

Eliana La Ferrara

Professor of Economics and Invernizzi Chair in Development Economics; Scientific Director, Laboratory for Effective Anti-Poverty Programs (LEAP), Bocconi University, Milan, Italy

Ashwini Deshpande

Professor of Economics, Ashoka University, India

Avinash Dixit

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

Jorgen Weibull

Professor, Stockholm School of Economics and Affiliated Professor of Mathematical Statistics, KTH Royal Institute of Technology, Sweden

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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.

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.

While we have not been able to conduct physical programs during the corona virus pandemic, this difficult time has served to emphasize the importance of scientific output on societal and economic progress. We remain committed to seeking and highlighting stellar research through the Infosys Prize.

Log on to www.infosys-science-foundation.com to know more.

Infosys Science Foundation

Infosys Prize 2020

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