CONNECT

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Mars Rover
Students on a mission

Vox Pop
Thoughts on climate change

Gagandeep Kang
Promoting public health

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Editorial

Last year, a global team of scientists, including those from CAOS, IISc, sounded the alarm that humans may be pushing Earth systems out of control. In this issue of *CONNECT*, we feature the story behind the planetary boundaries framework that they proposed to quantify the effects of human activities on the planet.

On campus, a team of budding scientists is busy building a rover that can work on Mars, for an international competition. Another group of students is using the ancient artform of Kalari to train their body and mind, between classes and lab work.

In a freewheeling chat, vaccine expert Gagandeep Kang talks about her childhood, public health, women in science, and more. We also feature highlights from a STEM training programme in which 20 female school students from remote areas of the country visited the Institute for two weeks of hands-on science.

This issue also features the stories of some staff members who provide dedicated support for research work. T Chandrashekar finds his work as a lab assistant for two decades highly rewarding, while Savitha P shares a day in her life of managing the National Nanofabrication Facility.

In other stories, the grandson of former IISc director JC Ghosh helps us piece together his grandfather's legacy. Science historians share the importance of their work and the challenges they face. We also introduce a new column in this issue, *CONNECT ASKS*, in which students share their thoughts on an important topic – this time, on how they would help mitigate climate change.

Happy reading!

Team Connect

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Red Rover

- Shloak Vatsal

Photo: KG Haridasan

Some members of Team Vicharika with the rover prototype

IISc's UG students are designing a prototype that could help scientists explore Mars, as part of an international competition

In the Old Physics Building, tensions are running high. Tucked away in a corner of the first floor, the workspace is crammed with batteries, pipes and boxes. Amidst the disorganised and dusty shelves, a group of students packs into the meeting room, disregarding the lack of chairs. Their attention is all on the object in the centre of the room: A printer-sized rover that they are in the process of building.

Among the students, a debate rages about how they are going to procure wheels for the rover. Why not get it 3D printed to save on cost, suggests one student, pointing to the 3D printer lying in a corner. Another one dismisses the idea, saying that they haven't tested the reliability of the product. As they debate the pros and cons, the clock is ticking. Their deadline to finish making the rover is inching closer.

The competition that the team is shooting for is called the University Rover Challenge (URC), organised by the Mars Society, an international non-profit organisation that seeks to encourage student teams to build rovers that could potentially work on Mars. The IISc team, who call themselves "Vicharika" (one who thinks), are participating in the competition for the first time.

Powering forward

"Vicharika was initially conceived as a robotics club. However, it didn't materialise since the idea lacked support," explains team member Sahil Chaudhary, a second year BTech student in Mathematics and Computing. When they approached Shishir Kolathaya, Assistant Professor at the Robert Bosch Centre for Cyber-Physical Systems (RBCCPS), he advised them to look for competitions to start with so that people would feel incentivised to participate in such a club. That was when they came across the University Rover Challenge (URC).

Photo: KG Haridasan

Testing the rover on undulating terrain

Started in 2007, URC is held annually at the Mars Desert Research Station, outside Hanksville, Utah, in the USA. The site is a large barren desert, with soil composition similar to Mars. Over a hundred college teams compete in this robotics challenge to design and build the next generation of Mars rovers that will one day work alongside astronauts exploring the red planet.

"Not just robotics, the rover needs expertise in communication, mechanical and electrical engineering, and even capabilities in biology to detect life in the Martian soil," explains Sidak Grewal, team leader and second year Bachelor of Science (Research) student. The rover that the IISc team is developing is fitted with an arm capable of performing a wide range of complex mechanical tasks, such as pressing keyboard keys, flipping buttons, lifting objects, and tightening screws. These tools then need to be packed into a compact machine and tested in the harsh sandy terrain of the desert. The rover has to be developed in stages within specified deadlines, and the team needs to submit various progress reports and plans at different times. The final competition takes place in the first week of June.

Sidak adds, "The scoring depends entirely on the performance on the field, and there's no scope for mistakes there. Even if you have good plans and a great vision, it doesn't matter if the rover fails."

> ***'Not just robotics, the rover needs expertise in communication, mechanical and electrical engineering and even capabilities in biology to detect life in the Martian soil'***

Vicharika comprises about 25 people with varied backgrounds and experiences. The team membership isn't limited by experience or field, but by the willingness to contribute and learn. The core team is made up completely of undergraduate students, with PhD students joining in as mentors and advisors. "We didn't advertise it initially since we were unsure about going ahead. So, the first few people learnt [about it] through word-of-mouth. But this helped us create a strong core of highly enthusiastic and dedicated people," explains Sahil.

"I have worked on robotics projects since the sixth grade and wanted to start a robotics club here. I told Sahil about my experience and joined URC to work on the robotic arm," says Pratham Gupta, a first year BTech in Mathematics and Computing student. "I have a hard time saying no to problems. The bioscience module of the rover was one such problem due to the novelty and challenges involved. Hence, I joined the team," says Dhruv Gupta, a third year Bachelor of Science (Research) student.

"It's great to have professors who are so readily available and excited to help us. For example, we approached Kaushik Basu [Electrical Engineering] for help with the electronics, and he offered us help with the power distribution board too," Sidak explains. "Similarly, Koushik Viswanathan [Mechanical Engineering] helped us source our components and gave us access to many of the tools and materials in his lab."

"The interdisciplinary nature of research at IISc lets you explore these varied applications in every field. I am a biology major and want to explore biological

applications in space and engineering. URC provided the perfect platform to explore such frontiers," says Swaraj Nandi, a second year Bachelor of Science (Research) student.

Sahil adds that another advantage has been the ease of funding. "When we corresponded with older teams from other places, we realised that the lack of funds was a great hurdle for them." Fortunately, Vicharika received funds from RBCCPS, which proved to be a morale booster for the new team. "Bharadwaj Amrutur [the Chair] immediately agreed to our budget and offered more if the need arises. It was the greatest privilege for a group of students planning to start something new, and it motivated us a lot."

Mission-mode

The challenge involves completing four missions expected from the rover in future space explorations. For the science mission, the rover has to collect and analyse soil samples using onboard instruments. The analysis includes searching for signs of life and geological data such as water flow, minerals and soil structure. Under the delivery mission, the rover is required to find and deliver objects over various rugged terrains. For the equipment servicing mission, the rover has to perform complex tasks such as tightening screws, typing on a keyboard, inserting a USB drive, and operating a joystick. The competition also involves an autonomous navigation mission, in which the rover has to travel to different coordinates specified by the Global Navigation Satellite System, which is similar to the Global Positioning System (GPS). This has to be done autonomously, without any input from the control room, and requires complex codes and programs to function correctly.

The team has designed the rover with six modules to undertake these missions successfully. The communication module enables contact with the rover over long distances. The navigation and control stack uses software programs. The electronics module handles the power board and circuits. The mechanical module includes the body, wheels and chassis. The robotic arm has to undertake tasks like equipment repair. Finally, a life sensing module looks for signs of life on the planet.

> ***It is the life-sensing module of the rover that is the most unique and challenging***

It is this life-sensing module of the rover that is the most unique and challenging. Not only should it look for living organisms, but also find evidence of extinct life. Molecular assays, which are used to confirm the presence of biomolecules – like proteins that are generally found in living organisms – do not work very well for extinct life, because they would have degraded over thousands of years. "Testing for extinct life is very complicated. We can do size sequencing with the molecules, where the smaller-sized pieces are more likely to be from fossils. On the other hand, intact biomolecules are likely to come from a living organism," Dhruv explains. To identify the biomolecule, they use a nanopore – a tiny hole of nanometre size with electric current flowing in it. Collected sample is passed through the pore using very narrow pipes. When a biomolecule passes through, resistance spikes and the electric current changes, indicating the presence of the biomolecule.

Photo: KG Haridasan

The team's workspace with the first (left) and second (right) prototypes

Photo: KG Haridasan

Demonstrating the rover's capability to carry heavy weights

However, challenges remain as creating the nanopore and testing it within the schedule might not be possible. With the deadline approaching in March, they are looking at other techniques like colorimetry – where a light beam is passed through the sample – to identify different compounds.

The team plans to build three prototypes for the competition. The first one focuses mainly on manual control, which they tested successfully in September 2023. The second prototype will see the addition and testing of other components such as communication and navigation, which they plan to build, fulfilling all competition requirements. They want the third prototype to be a refined version of the second, with changes based on test results. The communication module has already achieved a speed of 100 Mbps over 10 km, and they are currently working on the navigation for the second prototype.

"Navigation includes planning, mapping and localisation. It's very important to process the sensor's data to estimate the position of the rover and navigate in the desert with sloping hills. But we got the planner program working very fast with help from Pushpak Jagtap [RBCCPS], who gave us the idea of using his Control Barrier Certificate as the local planner. We are trying to finish the rest very soon," Sahil explains.

"Such competitions motivate all of us to explore more in the field and help the domain itself to expand further," says Sahil. Crucially, such projects help gather critical data on the working of these machines and bring forward innovative solutions for problems in space exploration. Swaraj says, "It is not so much about sending the rover to space as it is about testing various modules and concepts in conditions similar to that of Mars."

With the current cycle of URC coming to an end in June, the team finally wants to make the idea of a robotics club a reality. "During the project, we identified many difficulties that create a hurdle for people interested in robotics. After conceiving an idea, you have to order stuff, get permissions, adjust your schedule. This dampens the motivation of people," explains Sidak. They envision the robotics club to bring down these barriers of entry. "We have set up a 3D printer, a mini lathe [a machine used for shaping metal], a vice [to hold the workpiece during hand operations], a big Bosch cutter, and hand grinder, and plan to get more tools." They have already started working on plans to build a drone with flaps and cheaper telescope mounts used to automatically position telescopes in the night sky.

Sidak continues, "All of us here at Vicharika share this belief that the club should be open and responsive to the community's needs. We think it resonates with our founder JN Tata's ideology. It should act as an enabler for people to explore the exciting and promising field of robotics."

Shloak Vatsal is a second year Bachelor of Science (Research) student at IISc and a science writing intern at the Office of Communications

Out of Bounds

- Abinaya Kalyanasundaram

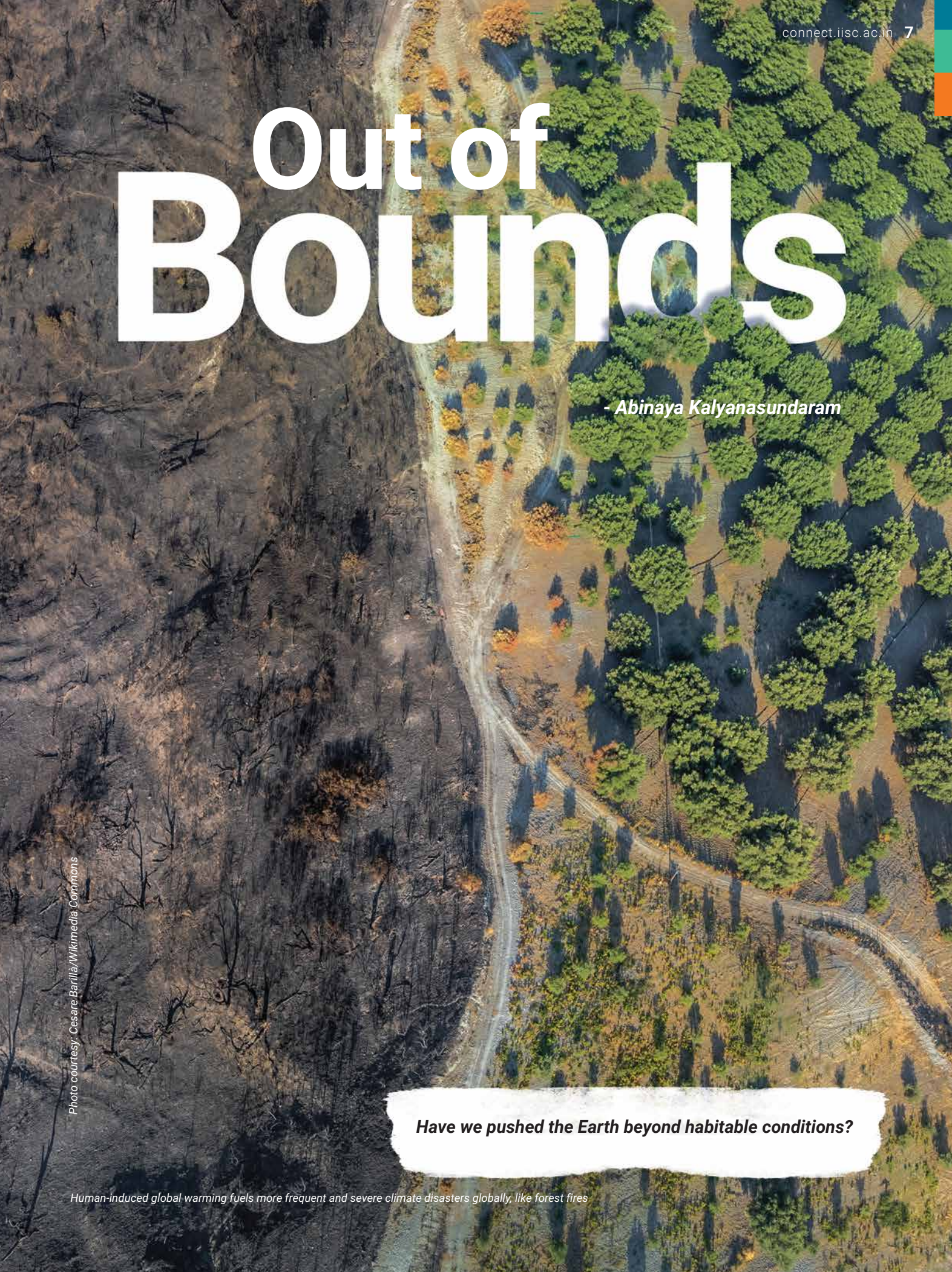


Photo courtesy: Cesare Barilà/Wikimedia Commons

Have we pushed the Earth beyond habitable conditions?

Human-induced global warming fuels more frequent and severe climate disasters globally, like forest fires

Twenty four years ago, Govindasamy Bala was a young physicist at the Lawrence Livermore National Laboratory in the USA. He and his colleague, Ken Caldeira, were carrying out research using a comprehensive climate model. For the first time, they wanted to test an improbable and controversial idea: Reducing the amount of sunlight that reaches the Earth's surface, presumably by using reflectors in space. This could theoretically counteract the warming effects of rising CO_2 levels.

This reduction could, in principle, be achieved by injecting reflective aerosols into the stratosphere, or by painting the roof of buildings white in cities or even by brightening the clouds over oceans, thus increasing the reflectivity of the planet. Such "intentional" large-scale approaches are now known as solar geoengineering or solar radiation modification.

Scientists had already proposed this idea as a quick-fix, but it was considered controversial because there could be several side effects on climate, and could also cause international conflict. It was also not known if it would be successful. "We thought this may not work because the characteristics of sunlight and CO_2 are different," explains Bala, currently Professor at the Centre for Atmospheric and Oceanic Sciences (CAOS), IISc. CO_2 warms the planet uniformly from the equator to the poles year-round, day and night, and is evenly mixed in the atmosphere, while sunlight warms the planet mainly at lower latitudes, with stronger effects during the summer and in the daytime. Scientists worried that blocking the sunlight might end up cooling the planet unevenly, and may perhaps not work at all.

The predictions from Bala's and Caldeira's climate model, however, were surprising. They showed that if the incoming sunlight is diminished by about 2%, the warming effects caused by a doubling of atmospheric CO_2 concentrations from pre-industrial levels (1950s) could be counterbalanced. "We were able to offset the effects of a doubled CO_2 level way better than we expected," explains Bala. They published their findings in 2000, but were prudent enough to mention: "... geoengineering schemes could markedly diminish regional and seasonal climate change from increased atmospheric CO_2. Nevertheless, geoengineering schemes could prove environmentally risky."

"That's how it started," says Bala. He had no idea then that his research on solar geoengineering and aerosols would one day lead him to work on a landmark effort to quantify human impact on Earth systems.

Setting the guardrails

Around the same time that Bala and team were working on this climate model, across the Atlantic Ocean, biological oceanographer Katherine Richardson had just joined a scientific steering committee at the International Geosphere Biosphere Program (IGBP) in Stockholm, Sweden. Until then, she had primarily focused on carbon cycling only in the ocean via phytoplankton and fish. "And then whatever happened to [the carbon] after that, I really didn't care," Katherine says, laughing.

"But when I got into this scientific steering committee, I realised, whoa, wait a minute. There is so much more to carbon cycling, and the whole Earth is an ecosystem." She began to work with Will Steffen, who was the director of the IGBP then.

Will, a chemical engineer from the USA, was a leading proponent of Earth System Science, which recognises that the "Earth operates as a single, complex, adaptive system, driven by the diverse interactions between energy, matter and organisms." It connects traditional disciplines such as ecology, biology, oceanography and climate science to build a "unified understanding of the Earth." Keen on investigating humanity's effects on the planet, Will led a humongous data analysis project to plot charts for 12 socio-economic trends (such as global population, use of motor vehicles, energy consumption, and so on) and 12 earth system trends (such as atmospheric CO_2 levels, surface temperature, species extinction, and so on) from the 1750s till 2004 (this was later updated in 2010).

Will and his team expected to see major changes in Earth system trends in response to increased socio-economic trends. But what they did not expect was an exponential rise in all the graphs at the same time, around the 1950s. These findings came to be known as the 'great acceleration curves', and were published in 2004 in the book *Global Change and the Earth System: A Planet Under Pressure*, co-authored by Will, Katherine and others.

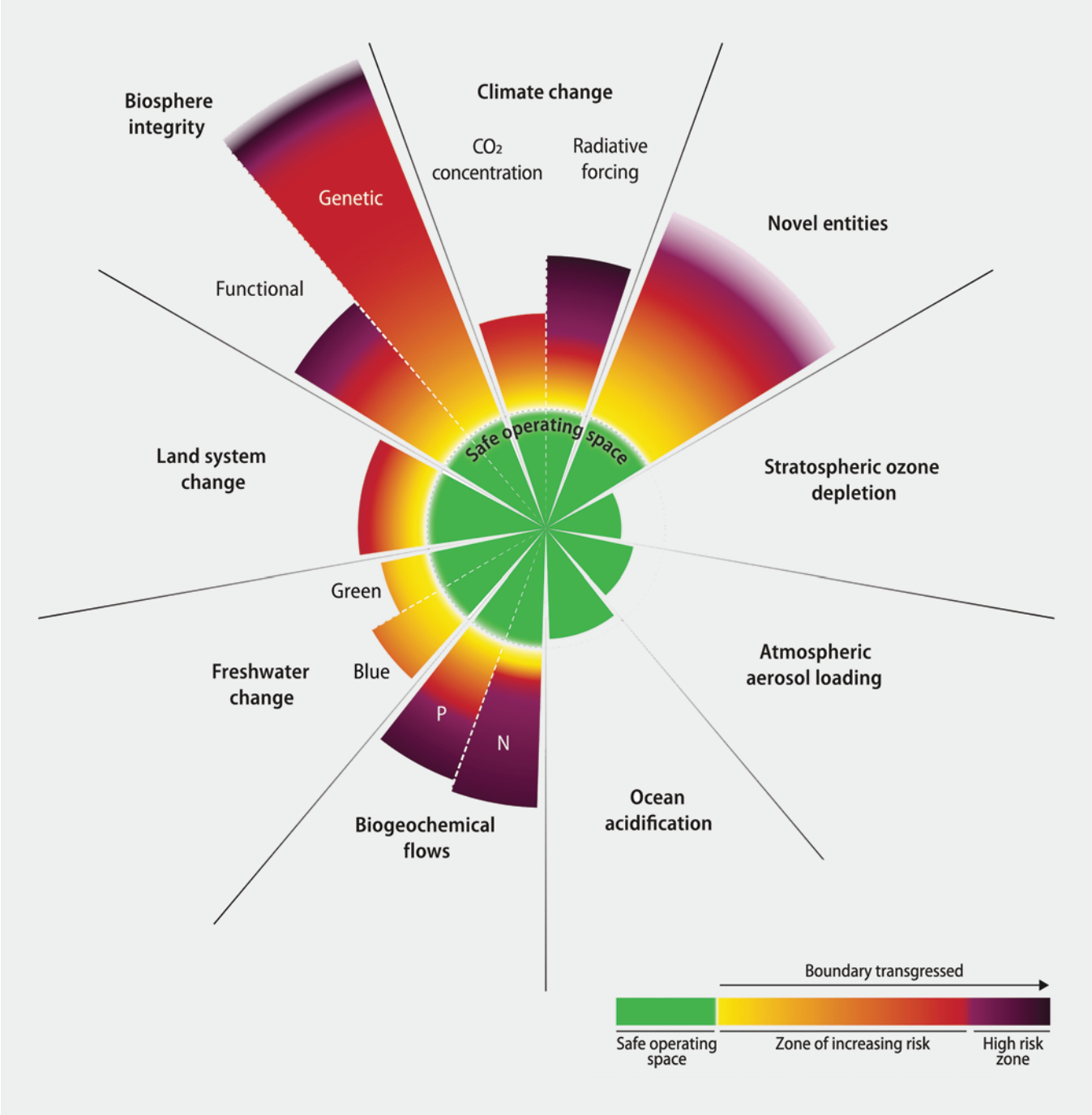
> ***Planetary boundaries are nine processes that regulate the Earth's stability and resilience, which have been greatly impacted by human activity***

"With this background, we started looking at what's important for the Earth [to function] and the human activities that could totally change the system," explains Katherine.

Along with Swedish scientist Johan Rockström, Director of the Stockholm Resilience Centre (SRC) at the time, Katherine and Will set out to find a scientific way to ask: "how much is too much?"

After a turbulent first meeting of 28 global scientists in Sweden in 2008, several follow-up meetings were set up which finally led to a framework that came to be called the planetary boundaries. They are, essentially, nine processes that regulate the Earth's stability and resilience, which have been greatly impacted by human activity. These include climate change, ocean acidification, stratospheric ozone depletion, biogeochemical flows in the nitrogen and phosphorous cycles, freshwater change, land system change, biosphere integrity, novel entities, and atmospheric aerosol loading.

Each boundary is linked to a control variable with specific safe values. For example, for climate change, the control variable is CO_2 concentration, with a safe boundary at 350 ppm. If these values are exceeded, there's a higher risk of causing irreversible changes (the current level is 417 ppm).



Current status of the nine planetary boundaries (September 2023) (Reprinted with permission of AAAS. From Katherine Richardson et al., Earth beyond six of nine planetary boundaries. Sci. Adv. 9,eadh2458(2023). DOI:10.1126/sciadv.adh2458. © The Authors, some rights reserved; exclusive licensee AAAS. Distributed under a CC BY-NC 4.0 Licence)

In 2009, the scientists quantified seven of the nine planetary boundaries, revealing that three (climate change, biospheric integrity, nitrogen cycle) were already breached. In September 2023, six boundaries were reported as crossed, sparking global concern.

Why does the Earth need to stay within these boundaries? To answer this question, we need to travel back to an ambitious polar research project in the early 1990s.

Paradise on Earth

In the summer of 1989, a team of European scientists set up camp at 3,200 m above sea level, right in the middle of the world's second largest body of ice – the Greenland ice sheet. Braving biting winds, they wanted to extract an ice core about 3,000 m deep, at its thickest point.

Ice cores act like Earth's time capsules. Tiny air bubbles trapped within these cores can reveal past atmospheric gas concentrations. Additionally, isotopic ratios of oxygen and hydrogen in the ice can tell us about historical temperature variations.

Over the next three years, using a steel cable and an electromechanical drill, they extracted these ice cores. Finally, on 12 July 1992, the drill hit bedrock. At this depth, the ice is more than 250,000 years old.

Analysis of the ice cores from this Greenland Ice Core Project (GRIP) revealed several insights. The most fascinating was a graph that showed how, over the past 100,000 years, the Earth seemed to have had a highly unstable climate, with periods of colder glacial periods interspersed by warmer interglacial periods. The scientists noted dramatic temperature oscillations within relatively short periods, sometimes variations of about 10°C within one decade.

But about 11,700 years ago, the graph presented a stark anomaly. The Earth's climate relatively flatlined to a remarkably warm and steady interglacial period. It turns out that this epoch – geologists call it the Holocene – was the evolutionary Eden for *Homo sapiens*.

As the Earth warmed, glaciers began to retreat. Tundra gave way to forests and grasslands. Large mammals that had adapted to the ice age, like the mammoth, vanished, leaving space for smaller mammals to evolve and proliferate. Humans, too, found it easy to spread around the world. As populations increased, we began inventing processes that would change the planet forever.

> ***'The Holocene … is the only type of environmental condition we know for certain our societies can thrive in'***

"It is only in this [Holocene] period that everything we associate with modern humanity was developed – agriculture, written language, the big civilisations – everything. This is the *only* type of climate and environmental condition we know for certain our societies can thrive in," noted Katherine at the 2016

Photo courtesy: The Ocean Agency/XL Catlin Seaview Survey/Richard Vevers

Rising CO_2 emissions intensify ocean acidification posing threats to marine ecosystems and causing coral bleaching globally

Breaking Walls conference in Berlin. "We shouldn't do anything that would risk putting it out of this state."

But we may have already done just that. We are now living in what many scientists are unofficially calling the Anthropocene, a new epoch defined by humanity's colossal impact on Earth systems.

Environmental conditions change on Earth over long periods – meteors can crash into it, solar flares or volcanic eruptions can drastically change the climate, and tectonic plates can shift, changing the flow of continents and oceans. Such changes have shaped the planet over its 4.6 billion-year history.

Now, however, all scientific evidence points to humans as the primary drivers of change on the Earth.

About half of the Earth's habitable land has been converted to rear livestock and agriculture. We move sediment, rock and sand at will to build our cities, so much so that sand is the second most exploited natural resource in the world after freshwater. More than half of ocean water is actively fished. Nine out of 10 of us breathe unhealthy air. Man-made microplastics have been found in everything from the salt we eat to human blood and breastmilk. In just 50 years, we have managed to push the Earth out of a state it had been in for 10,000 years.

> ***In just 50 years, humans have managed to push the Earth out of a state it had been in for 10,000 years***

An Evolving Science

After the publication of the first planetary boundaries paper in 2009, Johan, Katherine and Will continued refining the science of quantifying a "safe operating space for humanity." They needed more people in the core team. Steffen suggested global sustainability scientist Sarah Cornell, who jumped at the chance. Her work in the 1990s had contributed to worldwide efforts to quantify and understand the global nitrogen cycle. "My primary role was to connect domain expert

Photo courtesy: Govindasamy Bala

Govindasamy Bala (third from left) with his current research group at CAOS, IISc

scientists and Earth system scientists to refine the framework's message," says Sarah, who is now a Principal Researcher at the Stockholm Resilience Centre (SRC).

The SRC became a hub for the planetary boundaries work to continue. After laying out the basic framework for nine boundaries and quantifying seven in the first paper, the focus now was to dive deeper and take critical feedback from peers as well as social scientists into account. An update was published in 2015, redefining some of the boundaries, and recognising two of them – climate change and biosphere integrity – as the "core" boundaries. There was also greater emphasis on how the nine planetary boundaries interact with each other, clarifying misunderstandings that they are static and independent.

At that time, however, two of the nine boundaries were yet to be quantified – novel entities and atmospheric aerosol loading. These were the focus of the next phase of research. "We still couldn't have question marks. We had to have metrics for all of them," Katherine says.

Novel entities are human-introduced elements in Earth systems, like microplastics or genetically modified organisms. A working group was formed which noted that assessing the sheer quantity of such entities was a challenge, as the increasing production and release of diverse, potentially risky substances surpass our ability to monitor their safety. It was then established that the only truly safe operating space for novel entities is when they are entirely absent "unless their potential impacts with respect to the Earth system have been thoroughly evaluated." This planetary boundary is set at zero release of untested synthetic chemical compounds. The report states this is "clearly currently overstepped."

> ***'We were trying to identify a single number for the global aerosol boundary, and that was very challenging'***

The atmospheric aerosol loading boundary, on the other hand, presented a peculiar dilemma. Unlike CO_2, which lasts in the atmosphere for hundreds to thousands of years and is uniform across the globe, aerosols have a lifespan of only 10 days. This means that they are highly concentrated only near their sources, such as in the

northern hemisphere where there is greater human activity, making it difficult to set a global limit. So, the team roped in some climate change and aerosol experts, like Bala.

"At that point [in 2015], only a regional aerosol boundary had been identified and quantified," says Bala. "At the planetary scale, the mechanism by which aerosol could affect the global climate was not identified. We were trying to identify a single number for the entire world, and that was very challenging."

Bala's extensive research over the years on aerosols and their complex interactions with climate and monsoons provided a vital clue to set the planetary boundary value.

Aerosols are a suspension of fine solid particles or liquid droplets in air, and can be natural (like dust) or anthropogenic (man-made, like particulate air pollutants such as sulphates, nitrates and soot). Different aerosols influence climate in complex ways. Some aerosols form the nuclei for water vapour to condense as clouds, some like black carbon absorb solar radiation and warm the climate, while others like sulphates reflect the radiation back into space and cause cooling. Aerosols are also a major source of air pollution with huge implications for human health.

> ***Setting the numbers for boundaries is not an absolute science, and keeps evolving***

Aerosol Optical Depth (AOD) is a measure of the aerosol mass in the atmosphere and is a metric for sunlight extinction (loss). For example, an AOD increase of 0.1 in a column of air causes approximately 10% extinction of light. If the AOD value is large, more sunlight is extinguished and less sunlight falls on the Earth's surface. "That also means the energy available for evaporation is reduced, and since evaporation is what ultimately falls as rainfall, the hydrological cycle is affected," explains Bala.

Bala's research group found that the differences in AOD between the northern and southern hemispheres can greatly impact monsoon rainfall in the tropics by altering the energy balance between the two hemispheres. "If you inject reflective aerosols into the northern hemisphere, the rainfall in the northern hemisphere monsoon regions will decrease, and rainfall in the southern hemisphere monsoon regions will increase. And vice versa," he explains.

Their modelling studies revealed a significant impact on Indian rainfall when the AOD difference between the two hemispheres changed by 0.25 – the rainfall decreased by more than 20%, a very high number (even a 4-5% change can shift a monsoon classification from normal to excess or deficit). The AOD imbalance between the hemispheres also means uneven energy balance between them. A recent paper from Bala's lab, which quantifies the sensitivity of tropical regional monsoon systems, shows that the Indian monsoon rainfall could decrease by about 8% for every 0.1 increase in interhemispheric difference in AOD.

The aerosol boundary was thus set at 0.1, with increasing risks from 0.1 to 0.25, using the mean annual interhemispheric AOD difference as a control variable. Presently, the interhemispheric difference is around 0.076, indicating that the aerosol loading from human activities has not surpassed the set boundary. Yet.

"But these numbers are approximate ... even a 0.1 AOD difference is probably pretty bad in itself," says Bala. "Going forward, reduction in aerosol emissions and cleaning our air will have both climate and health benefits."

Setting the numbers for boundaries is not an absolute science, Katherine says. "We can't absolutely prove that where we set the boundary is the right place. Our understanding of [the] science evolves and as we understand better, we can be more specific."

Planet, People and Policy

The planetary boundaries approach has been widely appreciated but also called out for neglecting global inequality and social justice concerns.

"We argued that the planetary boundaries are abstract numbers and

Photo courtesy: Pixabay/SD pictures

According to the IPCC, burning of fossil fuels is the dominant cause of global CO2 emissions (89%)

mostly quantitative. Very few of them are qualitative, applicable at local scales or take into account significant harm to humans," says Joyeeta Gupta, a professor of environment and development in the Global South at the University of Amsterdam. Co-chairing the Earth Commission with Johan Rockström, Gupta, along with 40 other natural and social scientists (including Bala), built on the planetary boundaries framework and added layers of social equality and quality of life to the analysis. They published their version – the Safe and Just Earth System boundaries – in May 2023.

By including social justice and equality considerations, some of the 'just' boundaries are set at tighter values than the 'safe' boundaries. When it comes to climate, for example, while the planetary boundaries framework considers 1.5°C of global warming as relatively 'safe' for humankind, the "just" boundary is set at 1°C to avoid "significant harm such as loss of lives, livelihoods or incomes, displacement, loss of food, water or nutritional security, chronic disease, injury or malnutrition."

For its part, the planetary boundaries framework makes it explicit that it "does not dictate how societies should develop."

"The planetary boundaries are not goals, targets, budgets or tolerable limits. Exploring these needs much more than science! Earth is a complex living system, not a machine," Cornell adds. "The framework provides a way to *diagnose* a world that is being changed, to motivate societies to act in more 'joined up' ways rather than treat each global change process separately – as global policymaking has tended to do."

> ***'The planetary boundaries are not goals, targets, budgets or tolerable limits. Exploring these needs much more than science'***

The numbers are meant more like guidelines, Katherine adds. "For example, your blood pressure can be over 120/80 mmHg without you having a heart attack, but the risk of having one increases."

90 seconds to midnight

When scientists told the world in 1974 that chlorofluorocarbons (CFCs) could destroy the Earth's protective ozone layer, few took them seriously. Until 10 years later, when a thinning in the ozone layer was detected above Antarctica. Countries around the world swiftly pooled resources to rectify the situation. In just three years, the Montreal Protocol was ratified in 1987, setting a mandatory timetable to phase out ozone-depleting substances. Developing countries were funded to aid in this transition, and the companies that made these chemicals came up with alternatives. Consequently, the ozone layer slowly recovered and is now comfortably within the 'safe operating space.' This is widely regarded as one of the swiftest environmental corrective actions in human history. It also highlighted something crucial – science alone cannot save the world without backing from global policy and cooperation.

But despite global treaties to combat human-induced climate change, such as the Kyoto Protocol (1997), and the Paris Agreement (2016), there has been insufficient progress, as many nations are not willing to sacrifice economic development for the sake of the environment. Katherine suggests redefining economic system concepts, particularly around the emission of waste. "It should *cost* [corporations] to release greenhouse gases, to put waste into the environment. Six of the nine planetary boundaries are related to our accumulating waste. I dream that in 2050 children won't know what waste is," she says.

With six planetary boundaries already breached, the consequences described by the authors seem to be unfolding in real time across the world. 2023 was reported to be the hottest year on record. Extreme weather events are becoming more and more common. Last year, the Doomsday Clock, a symbolic countdown to presumed human extinction established in 1947, was set at 90 seconds to midnight, the closest it has ever been, pointing to a possibly dystopian future.

"This dystopian [future] will be a realistic conclusion of [our species], unless we stop functioning as 'business as usual,'" remarks Katherine. "It's never going to be 'business as usual' again."

Staying in STEM

- Mohit Nikalje

Photo: Bindu Patel

A training programme seeks to inculcate scientific curiosity in women students from far-flung areas

Explaining how to visualise DNA bands after extracting DNA

I was running late. I hurried to the seminar hall in the Department of Developmental Biology and Genetics (DBG). The orientation session, which was scheduled for 10 am, had already started when I reached, so I sneaked in silently, hoping not to attract the attention of the audience. I saw a few young students, fully dressed in properly ironed school uniforms, turning to look at me, as I scrambled to find a seat.

It was the first day of the IBM STEM for Girls programme being organised at the Division of Biological Sciences. Under this initiative, about 20 female students from far-flung regions of the country spend about two weeks at IISc, listening to lectures and spending time in research labs.

As I sat down, Maria Thaker, Associate Professor at the Centre for Ecological Sciences (CES), was addressing the students. They had come from rural areas of Gujarat, Nagaland, and Odisha. The students, who were in class 11, were accompanied by their teachers and representatives of some NGOs like Youthnet Nagaland and Quest Alliance, which helped select these bright students interested in science from government-run schools and bring them to IISc.

For the past three years, IBM has been working with IISc to implement this programme aimed at boosting the involvement of women in STEM (Science, Technology, Engineering and Mathematics). Statistics show that only 14% of scientists, technologists, and engineers in research institutions in India are women. Despite promising career opportunities in these fields, the participation of women remains low in our country.

The event in which I participated as a volunteer was held from 11 to 22 December 2023.

After the orientation concluded, excitement and anticipation filled the air. In high spirits, we all stepped out for a snacks break.

A gentle tap from behind

As I was gulping down hot coffee, I started talking to some of the participants to find out more about where they were from and what their interests were. Suddenly, I felt a gentle tap on my shoulder. It was a teacher from the Gujarat group, who expressed his concern that students from Odisha and Gujarat were struggling to understand what was being said in English, as they study in vernacular languages back home.

The organisers then decided that they should have translators for each session. This is where students like me from the MSc in Life Sciences programme stepped in. Throughout the programme, we worked with the faculty members at IISc, translating their English talks to Hindi. It made us feel like we were making a difference.

> ***Throughout the programme, we worked with the faculty members at IISc, translating their English talks to Hindi***

For the two weeks, the students were given accommodation at the Hoysala guest house, and the MSc teaching lab assistant, Nagraj R, was assigned to escort them to the Biological Sciences building every morning. On the first day, Nagraj claimed to them that the walk would only take five minutes, but the actual walk ended up taking nearly 15 minutes, leaving both the students and their teachers slightly exhausted.

The students soon got used to the daily walks, and expressed their admiration of the greenery, monkeys, and birds on campus – even if some of the baby monkeys kept stealing stuff from their hostel rooms. Some students from Nagaland rued how, due to poaching, animal numbers are dwindling in their state. After reaching the Biological Sciences building, their schedule remained nearly the same every day, with morning lectures followed by lunch, practical sessions and lab visits in the afternoons, and then back to the guest house.

‘Professor speaks very fast’

Mornings in the CES classroom would be filled with murmurs before faculty members arrived and delivered their talks. They spoke about a range of topics and recent advancements in science. Words like animals, bacteria,

Photo: Drishtant Kawale

Students, volunteers and teachers hanging out on the last day

and cancer started becoming common in classes. Although many didn't necessarily need introduction, the speakers made it a point to simplify the terms so that the school-goers could understand them clearly.

Nikhil Gandasi, Assistant Professor at DBG, was particularly popular among students for his ability to simplify complex concepts related to diabetes using illustrations. He explained to them about different factors that can lead to diabetes, with lifestyle being the major factor, apart from genetics and pollution.

During the first few lectures, some of the students were very quiet. Zuchobeni Patton, a student from the Nagaland group, later told me, "When people say 'Professor' as my cousin is, I imagine someone who speaks very fast." She was worried that she would not be able to understand what they were saying. To address such fears, the faculty members started making the sessions more interactive and encouraged the students to ask questions.

I attended a session where I was translating for P Kondaiah, a retired professor from DBG, who was talking about cancer. Translation would sometimes mean translating the words from English to Hindi, and sometimes also simplifying complex words. We were ourselves surprised to learn that the Hindi word for a cell is "kosh" and that the digestive system is called "pachankriya kendra."

We had no choice but to learn Hindi scientific vocabulary, so we created a small dictionary of commonly used words. I remember I was asked to translate "cancer can be caused by different factors" and the Hindi word for cancer – "karkroga" – invoked vivid memories of watching advertisements issued in public interest in theatres before the movie started.

> ***Over the course of several lectures, the students learned about numerous fascinating concepts***

Over the course of several lectures, the students learned about numerous fascinating concepts. They learned about quorum sensing – how cells communicate with each other – and about how viruses can kill their hosts. They were also intrigued to discover that crocodiles and birds are direct descendants of the once mighty dinosaurs, which sparked their curiosity about the process of species evolution.

Lunch was always the highlight, as it gave us the opportunity to gather feedback from students and make improvements. Chitchat at lunch also became fun discussions on cultures, traditions, food habits and daily routines. The students from Nagaland were used to a very different schedule: They would wake up around 8 in the morning, have lunch around 12 and dinner as early as 5 pm. So, it took a few days for them to adjust to a different lifestyle and cuisine. But soon, dosa became their favourite.

'I like to work in the lab'

After lunch, it was time for practical sessions, which many students called "fun time" as they enjoyed working in the lab. The experiments were designed in a way that they could carry them out by themselves.

The practical sessions would begin with IISc volunteers explaining the principles of the experiment first, followed by its significance, using everyday examples. During one session, we described gel electrophoresis as a "running competition" for molecules, in which larger molecules run slowly compared to smaller molecules, which run faster.

To explain to them the importance of using gloves in microbiology experiments, we demonstrated the handling of Luria Bertani (LB) media plates – typically used to grow microbial cultures – with and without gloves. We showed them how a colony of microbes would grow on a plate when handled without wearing gloves. In a similar demonstration, we asked them to expose media plates in the air for a while and observe a myriad of colonies making the media their home.

DNA extractions also gained enough limelight, as the students got a chance to break open a bacterial cell and look closely at DNA in the form of bands using gel electrophoresis, which they had only learned about in their textbooks. One question from Drushti, a student from the Gujarat group made us think a lot; she asked, "Can we see the double helix structure of DNA under the microscope?" It gave us a chance to explain to her how DNA is too small to be seen under the microscope, and how its structure was pieced together using X-ray crystallography.

Photo: Ravi Chawda

Meetali Singh, Assistant Professor in DBG, speaking to students about RNA

'How can I get into your company?'

A substantial part of STEM research also takes place in industries, so exposure to such opportunities was also part of the plan for the programme.

On 16 December, a Saturday, we visited the office of Danaher India Development Center (IDC) in Bellandur, around lunchtime.

The students were divided into groups and each group was assigned a translator for their visits to the laboratories at IDC.

Research at IDC focuses on software development for the machines used in diagnostics. Machines used for cancer diagnosis and blood analytics are their top products. Their room-sized surgical microscopes left the students in awe.

Mesmerised by the work environment, one of the students asked, "How can I get into this company?" It was heartening to see them get exposure to diverse opportunities available to them, apart from just 'doctor' and 'engineer.'

Another session that had a similar impact on them was by Prabhdeep Kaur, Assistant Professor at the new Isaac Centre for Public Health at IISc.

"*Sarvajanik swastha ka matlab kya hota hai* [What does public health mean]?" she asked them at the beginning.

A doctor herself, she went on to explain how public health involves safeguarding and improving the health of individuals and communities. She was quick to clarify that healthcare does not only involve doctors and nurses. "A teacher can also serve as a public health servant by educating [people] about hygiene," she explained.

Such discussions and the IDC visit gave the students an opportunity to think of broader career options.

'She's planning to continue in science'

On the final day at the MSc teaching lab where the practical was conducted, the atmosphere turned into a stage for showcasing talents. The Gujarat group performed their traditional Garbha, making other students and volunteers dance with them.

At the end of two weeks, it became clear to the faculty members and volunteers that the students had indeed undergone a transformation – they were speaking more confidently and buzzed with questions about STEM careers. Their teachers were amazed to see many of their students who were quiet in class, being interactive in the sessions. Then the singing started. I chose to sing "*Jab deep jale aana, Jab sanj dhale aana,*" an old Hindi song from the movie *Chitchor*, marking an emotional farewell.

On the last day, we held a certificate distribution programme to wind up. Usha Vijayraghavan, Dean of Biological Sciences, and IBM representatives were also present at the ceremony. As volunteers, we felt a sense of sadness that it was time to say goodbye, but we were also pleased to have played a part in making a positive impact on the lives of these students.

As the students began to leave, the atmosphere was filled with energy and excitement, which we hoped they would take with them when they went back. Liniu H, a teacher from the Nagaland group later told me, "I am happy to tell you that one of my students was planning to shift to arts after her 12th, but after this programme, she's planning to continue [in science]."

Mohit Nikalje is a second year MSc in Life Sciences student at IISc and a science writing intern at the Office of Communications

Photo: Madhusudhan Menon

Certificate distribution and wrapping up on the last day

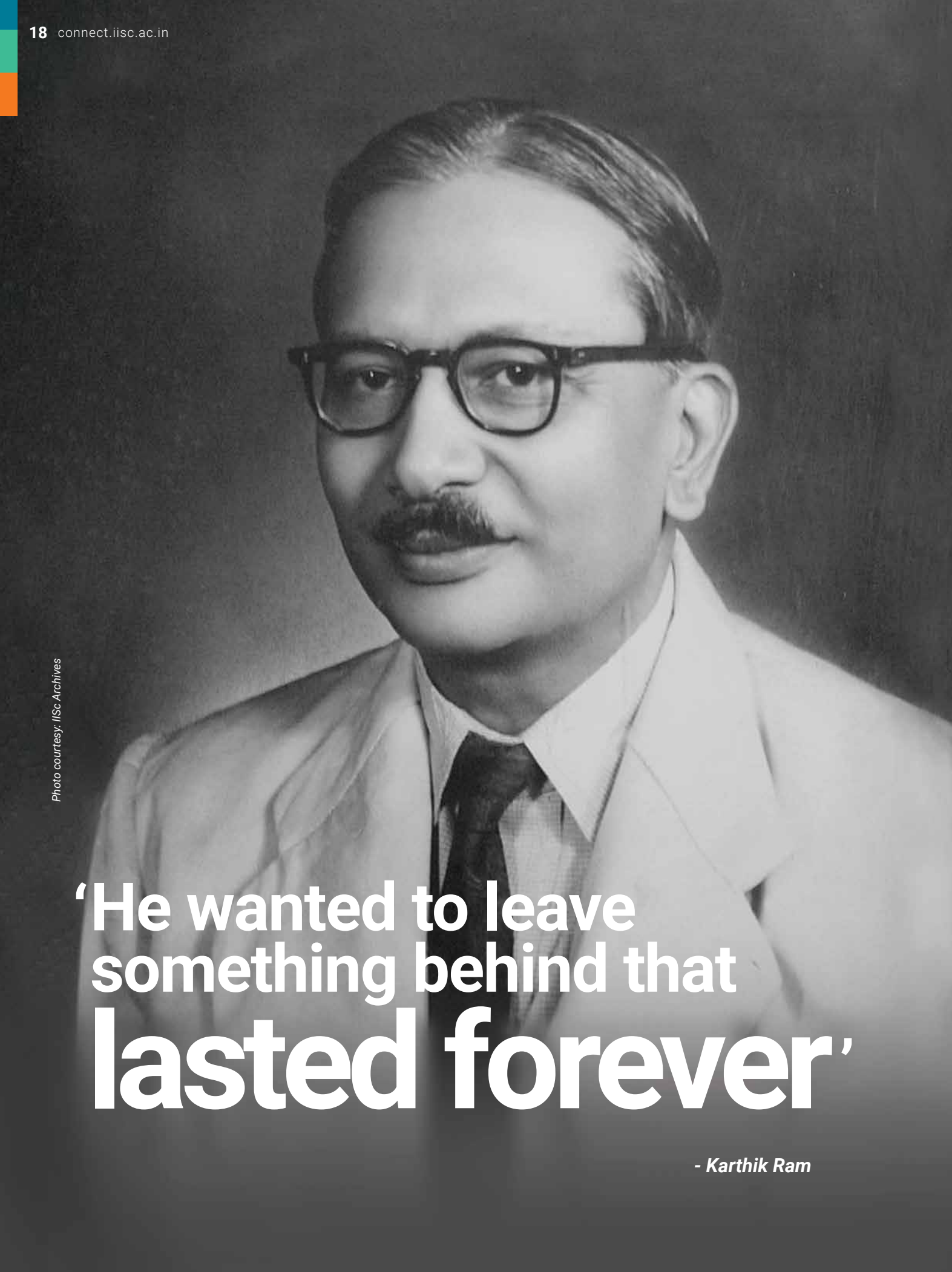


Photo courtesy: IISc Archives

‘He wanted to leave something behind that lasted forever’

- Karthik Ram

JC Ghosh, an eminent chemist, was IISc's Director during World War II and the founding Director of IIT Kharagpur. His grandson, Dipankar Ghosh, spoke to* CONNECT *about his grandfather's personal and professional life.

In the late 1980s, E Arunan was looking for a place to stay in the midwestern town of Manhattan in the heart of the United States – he had just joined the Kansas State University to pursue his PhD. He eventually found a large house where three other Indian students were already staying. One of his housemates was Dipankar Ghosh. "I was doing my Master's in Statistics while Arunan was doing his PhD in chemistry," recalls Dipankar.

The two of them lost contact with each other once Dipankar graduated and left for New York. He became an IT professional and an entrepreneur based in the United States, while Arunan pursued a career in research and eventually joined the Department of Inorganic and Physical Chemistry at IISc as a faculty member (he is now the Chair of the Department).

A few years ago, however, thanks to Facebook, Dipankar and Arunan were able to renew their friendship. In 2014, during an email exchange between them, Arunan found out that his former housemate was the grandson of Jnan Chandra Ghosh, better known as JC Ghosh, IISc's former Director, one of India's most eminent chemists and a consequential institution builder in modern science.

Dipankar, who eventually moved back to India, met with Arunan and even visited IISc in late 2014. He also gave Arunan a few photographs of his grandfather.

The photographs, however, had not always been with Dipankar. He had found them rather fortuitously. In the mid-1990s, the family's ancestral house in New Alipore in Kolkata – where JC Ghosh grew up and spent his last years – was sold. "But the new owners could not do anything much to the house because it was declared a heritage building," he says. "I was in the USA at that time." Dipankar was aware that a few things that belonged to his grandfather were still in the house. "After a year or two, I went back to the house and asked the new owners about the things that belonged to Dr JC Ghosh." Their response disappointed him. "They said that it was all packed away in some trunks somewhere and they could not look for it then."

> ***'I went all over Calcutta [now Kolkata] looking for someone to restore at least a few of these photographs'***

A few years later, Dipankar's aunt, one of Ghosh's daughters, called to tell him that she found a trunk at the ancestral house with some photographs. When Dipankar came to Kolkata the next time, he opened the trunk to find a few photographs of his grandfather, but they were in poor shape. "The glass was broken and there was pigeon poop all over it," he recalls. But he felt that he might be able to save a few. "I went all over Calcutta [now Kolkata] looking for someone to restore at least a few of these photographs. Back then, people would have to restore photographs by

hand. Then I found two old people in a dilapidated studio who agreed to do it." Once the photographs were restored, Dipankar handed them to Arunan when they finally had an opportunity to meet in person. Arunan promptly passed the photographs on to the IISc Archives for safekeeping.

Ghosh was born in 1894 in Purulia District in the Bengal Presidency. He was a product of what came to be known as the Bengal Renaissance – a cultural, social, intellectual, artistic, and scientific movement that took root in the region in the late 18th century and continued until the early 20th century. Among the many scientists who emerged from Bengal during this period include Satyendranath Bose, Meghnad Saha, JC Bose, Upendranath Brahmachari, and Ghosh himself.

"He [Ghosh] lived in a joint family. My grandfather was the third of four brothers. But they moved to Calcutta and they were all inspired to get educated," says Dipankar. Ghosh obtained his BSc in 1913 and MSc in 1915 from Presidency College in Calcutta. "During his BSc, which he did in Chemistry, his batch mates were Meghnad Saha who was in Physics and SN Bose who was in Mathematics."

Even before his Master's results were out, Ghosh was invited to join the Chemistry Department of Rajabazar Science College, which had just been founded by the noted educationist and Vice Chancellor of Calcutta University, Ashutosh Mukherjee.

The next momentous year in Ghosh's life was 1919. He won a scholarship that year to pursue a doctoral degree in photochemistry at the University College, London. The year was significant for another reason. "He got married to my grandmother, Neelima, in 1919 – I have a table in my house [from that year] that came to my grandfather as dowry. The story is that they met when my grandfather was still at Presidency."

While in London, Ghosh studied electrolytes and came up with what is known as the theory of strong electrolytes. His work initially attracted controversy but eventually won him acclaim when it was buttressed by experimental evidence. News of his work reached India and not long after, in 1921, Ghosh was invited to join as Professor and Head of the Chemistry Department of the recently established Dacca (now Dhaka) University.

> ***'He got married to my grandmother, Neelima, in 1919 – I have a table in my house [from that year] that came to my grandfather as dowry'***

Ghosh accepted the offer and moved to Dacca with Neelima. His time here was easily his most productive phase in terms of research. He went on to establish an important school of research in photochemistry, well before it became a fashionable area of investigation. While they were in Dacca, the family grew, says Dipankar – they had two girls and three boys, including Dipankar's father.

Photo courtesy: Dipankar Ghosh

JC Ghosh (seated; third from left) with other scientists at Calcutta University, including JC Bose (seated; second from left), Meghnad Saha (seated; first from left) and SN Bose (standing; second from left)

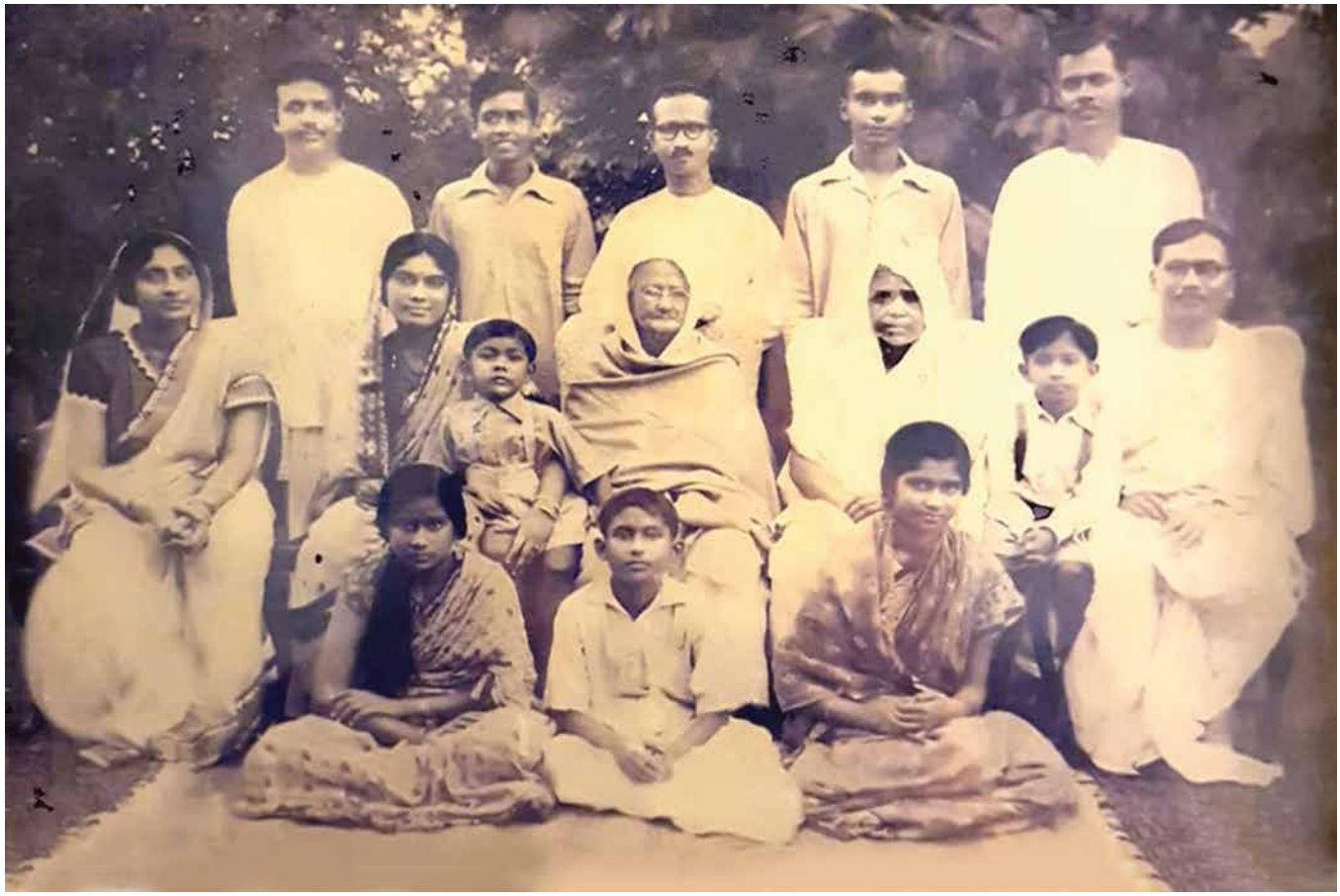


Photo courtesy: Dipankar Ghosh

Ghosh (sitting on chair; extreme right) and Neelima (sitting on chair; extreme left) with their large family just before he left Dacca. The entire family moved to the Director's bungalow at IISc a few days after this photograph was taken

When Ghosh was blazing trails in his research at Dacca University, IISc in Bangalore was looking for a new Director in the late 1930s. During this time, the Institute had an Acting Director (CV Raman had been forced to resign as the Director in 1937). The search committee homed in on Ghosh – who was still only 45 – in 1939.

By then, Ghosh was counted among India's best scientists. He was also favoured for the job because of the leadership qualities and administrative skills he displayed when he led the Chemistry Department at Dacca. Dipankar thinks that there was yet another reason why Ghosh was chosen to become IISc's Director.

"There are letters which I have seen that show that when he was at Dacca, he travelled all over India to universities that were being set up, like the Andhra University in Visakhapatnam. They would invite him and get his guidance and inputs as they were founding these institutes, especially in South India. He was quite amenable and ready to help."

According to Dipankar, Ghosh "gained prominence" in South India in the 1920s and 1930s. He became known to the royal families of princely states and to the British who were involved in setting up these institutions. "So, he built a reputation that he was somebody who could get things done." There were other qualities in Ghosh that might have made a frontrunner for the job, says Dipankar. "He was diplomatic. He was very polished and dressed like an English gentleman."

Once Ghosh got the job offer from IISc, he moved to Bangalore with the rest of his now somewhat large family. "They belonged to that part of society who knew what was going to happen [partition of India]. So, they all, including one of my grandfather's research assistants, moved to Bangalore together," says Dipankar. He adds that the research assistant eventually became family and even a trustee of his grandfather's estate when he died.

Ghosh served nearly two terms as the Director of IISc. As his second term was coming to end, Ghosh was appointed by India's first Prime Minister, Pandit Jawaharlal Nehru, as the Director-General of Industry and Supply, a position he held from 1947 to 1950 (he was given a leave of absence from IISc and an Acting Director was appointed in his place when he left for Delhi). He was also made a member of the All India Council of Technical Education when he was in Delhi.

> ***'It is believed that when students at IIT Kharagpur heard that Ghosh was leaving, they went on a mass strike'***

In 1951, Ghosh was chosen for yet another challenging task: to become the founding Director of India's first Indian Institute of Technology (IIT) at Kharagpur. Once he helped set it up – it was the only IIT among the earlier ones set up without help from other countries – and nurtured it through the birth pangs, he was asked to take over as the Vice Chancellor of

Photo courtesy: Dipankar Ghosh

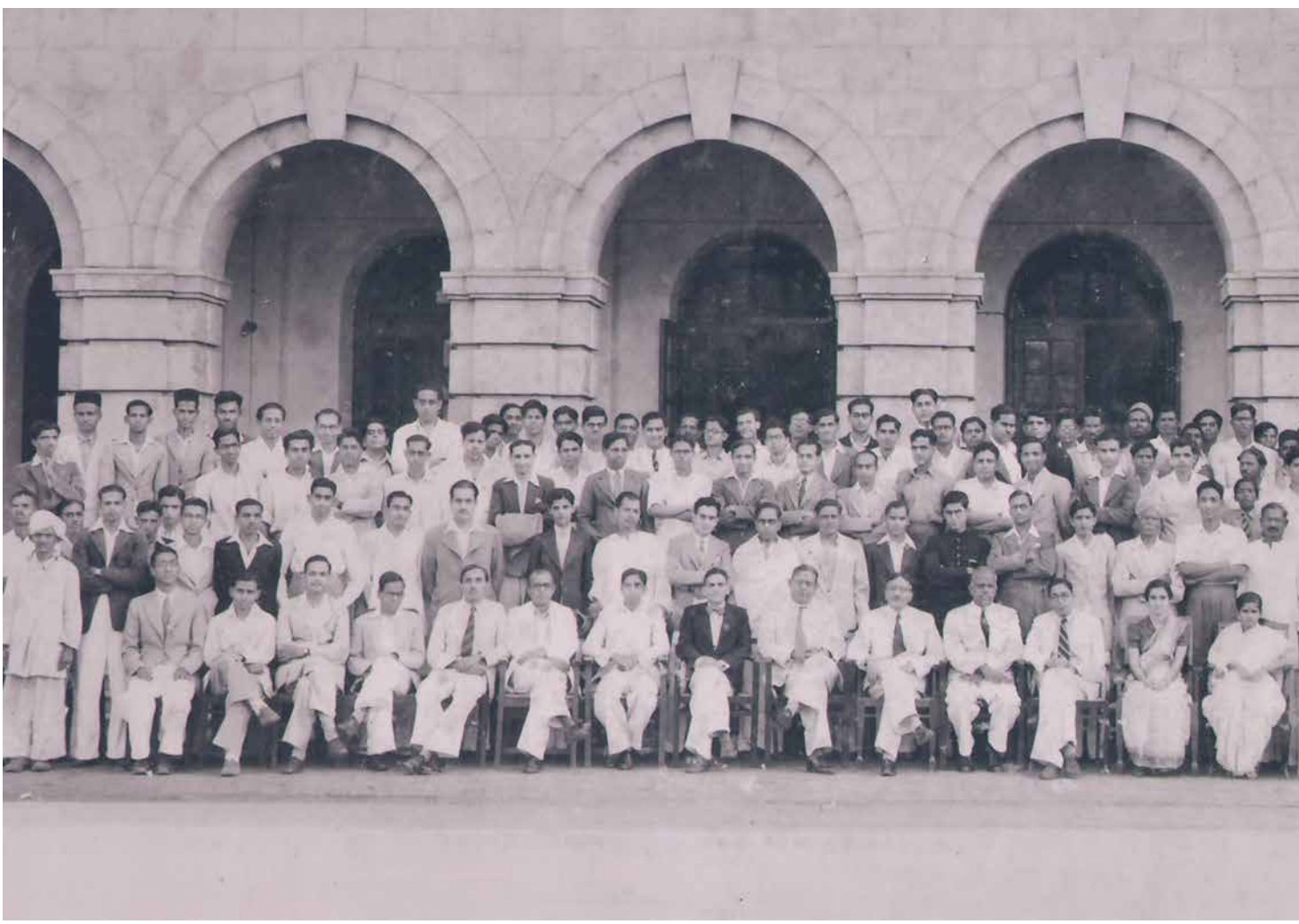
JC Ghosh and Neelima at IIT Kharagpur. The photograph also hangs in the Nehru Hall of Residence at IIT Kharagpur

Calcutta University, his alma mater, in 1955. It is believed that when students at IIT Kharagpur heard that Ghosh was leaving, they went on a mass strike. Ghosh addressed them on the lawns of the campus to console them, where it is said, he himself broke down. "Yes, it did really happen," confirms Dipankar, who studied at IIT Kharagpur too.

> ***Ghosh spent his last few years in the family's ancestral home in Calcutta until his death in 1959.***

Ghosh, at this time, was also appointed as a member of the Planning Commission, along with the likes of PC Mahalanobis. But not long after, he became unwell. He was eventually diagnosed with stomach cancer, reveals Dipankar. He spent his last few years in the family's ancestral home in Calcutta until his death in 1959.

Photo courtesy: Dipankar Ghosh



JC Ghosh with members of the Inorganic and Physical Chemistry Department in front of the Main Building of IISc

Photo courtesy: Dipankar Ghosh

JC Ghosh (third from right) at a Planning Commission meeting in the late 1950s in New Delhi

Ghosh was appointed as IISc's Director on 1 August 1939 and served two terms. This was a critical period in IISc's history. His first task was to work on projects related to India's industrialisation. The Court of IISc recommended that Ghosh head a committee head a committee to work towards this (it also had the well-known physicist Meghnad Saha, then a member of IISc's Governing Council, on it). The committee met several times a year to draw up a "definite scheme for industrial research" and monitor the progress of several projects related to industrialisation. It was no coincidence that several engineering departments came up during his tenure: Aeronautical (now Aerospace) Engineering, Metallurgy (now Materials Engineering), Chemical Engineering, Internal Combustion Engineering and Power Engineering (the latter two departments gave rise to Mechanical Engineering).

The Institute was also called upon to help the British war effort. Towards this end, several new projects were carried out at IISc. Besides, the Institute's technical expertise was used to set up new industries to help the British.

Ghosh's obsession with work, however, came at a cost. He had little time for his family, according to Dipankar. "He was very busy. My father and the rest of the family interacted very little with my grandfather. He was aloof from my father, and uncles and aunts. They knew very little about him."

But the family had a good time in Bangalore, says Dipankar. "My father went to St Joseph's [Boys School] and my aunt to Baldwin's [Girls School]. The entire family loved Bangalore. They made many friends there. And until they passed on a few years ago, they would visit their school friends from the 1940s when they came here."

> ***Ghosh was appointed as IISc's Director in 1939 and served two terms. This was a critical period in IISc's history***

Dipankar says Ghosh was more focussed on doing "something much bigger than chemistry" during his time at IISc. "He was very proud of his legacy. He wanted to leave something behind that lasted forever."

CONNECT ASKS

If you had the power to change one thing in the world to mitigate climate change, what would you do?

"Replace all diesel vehicles with electric vehicles; that will contribute hugely to mitigate climate change because there will be much less pollution.

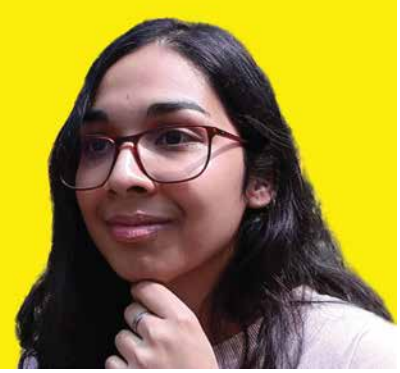
Ankita Ghoshal
PhD student in MCB

"Basically, there are two types of things. First is wants and second is needs. We need to control the amount of wants we have; all those leisure activities which are contributing to climate change. We need to have some restrictions on those. For example, some tasks which can be done easily [by ourselves], we are using electricity to do it. If you use electricity to do them, then ultimately it will cause a change in climate. Because electricity is made using natural resources.

Pranav Datar
MSc student in Life Sciences

"For me, the most personal I feel is about deforestation. I think I'd want to maintain all the good colonies of trees that are there. I'm from Mumbai, where there are places like Aarey colony. They have a lot of problems with deforestation. So, I'd probably make sure that the government doesn't sanction any felling of trees there.

Srishti Mandal
PhD student in MCB



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The major contributor to climate change is the growing number of personal vehicles. So first, I will take inspiration from countries like Japan and European nations. I will discourage personal transport and promote public transport. If we can improve upon newer technologies like electric engines and hydrogen engines, that would be a great help. So, the primary requirement as of now is to invest in such fields where we can encourage people to take public transport.

Sayak Maji
UG student in Physics

"

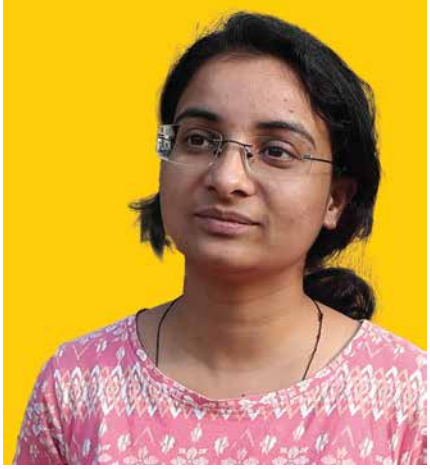
Invest in making solar panels more efficient.

Tarun Raghavendar
UG student in Chemistry

"

Minimal use of plastic can help because it's a root cause for a lot of our pollution, and that too for animals because they play an important role in our habitat. So that [plastic usage] would be one thing to stop.

Neha Gupta
MTech student in ECE



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In my perception, it is actually the greed of humans that has led to such a huge negative change in the climate. So, development is okay, technology-wise or industry-wise, but we should know at what point we need to stop.

Vishal Kushwaha
PhD, Robert Bosch Centre for Cyber-Physical Systems

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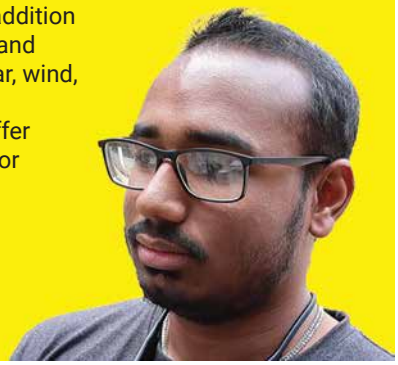
The first thing that comes to mind is reducing carbon emissions. And also try to move to nuclear energy so that we can move on from coal, petrol and those kinds of fuels. In addition to nuclear power, integrating renewable and eco-friendly energy sources such as solar, wind, and hydroelectric power into our energy portfolio is imperative. These sources offer zero carbon emissions, paving the way for widespread sustainable development.

Subham Das
UG student in Biology



‘People come up with labels, I enjoy the work I do’

- Sandeep Menon

Gagandeep Kang during her talk at IISc in December 2023

Gagandeep Kang is an interdisciplinary researcher famed for her work on enteric infections. She was part of the teams responsible for the development of two Indian rotavirus vaccines, Rotavac and Rotasiil, and has worked extensively on viruses that cause different types of diarrheal diseases and on typhoid surveillance networks. She completed her MBBS in 1987, her MD in Microbiology in 1991 from Christian Medical College (CMC), Vellore, and her PhD in 1998. She carried out her postdoc at Baylor Medical College, Houston, USA, before returning to CMC.

Gagandeep is the recipient of the Infosys Prize in 2016 and the first Indian woman to be elected as a Fellow of the Royal Society of London. She is currently the Director-Enterics, Diagnostic, Genomics and Epidemiology, Global Health at the Bill and Melinda Gates Foundation. On 18 December 2023, she was at IISc to deliver the Institute Lecture on "Enteric infections in impoverished communities" at the Faculty Hall. Following the hugely popular talk,* CONNECT *sat down with her for a freewheeling chat about everything from pandemics and women in STEM to zombies.

Photo courtesy: Prabhdeep Kaur

What is your role in the Gates Foundation?

I'm the director of a team that is called EDGE – Enterics, Diagnostics, Genomics & Epidemiology. We also have modelling. The way the Foundation works is that we have a defined strategy for each area. And in that strategy, we will find and fund programmes that lead us toward our goals.

One example I can give you is cholera. For instance, in India and Bangladesh, cholera is an endemic disease. We don't use cholera vaccines in our country. It's not recommended. Even if we wanted to use the vaccine, there is no supply because right now, Africa is having so many cholera outbreaks that whatever vaccine there is, it is going to Africa. One thing we are working on is to increase the supply of cholera vaccines in the world. We just gave a grant to an African company called Biovac in South Africa to try and get them to manufacture a cholera vaccine. We're also working with an Indian vaccine company for the same.

So, we find what the problem is, think about how to solve it and then implement that solution.

In the last couple of years, we've seen COVID-19 vaccines being developed quickly. Will this have any bearing on how we develop vaccines in the future?

I hope it does. Because we will develop vaccines faster in the future. Usually, if you do a vaccine trial, you will test the vaccine in 10,000-20,000 people. During COVID-19, each of those vaccines that came to the market was tested on 25,000-40,000 people. The trials were bigger. Usually, when you do vaccine development, you do a preclinical trial, stop and review the data. [For example], do phase one [trials], stop, and review the data. Then do phase two [trials], stop and review the data.

> ***'The biggest learning was that we can make vaccines faster if everyone works together'***

[During COVID-19 vaccine development], phases one and two were almost combined with a faster reviewing of the data as soon as they came in. All the testing was done, but those trials were done in overlapped phases instead of following stop, start, stop, start. The biggest learning was that we can make vaccines faster if everyone works together.

Photo courtesy: Prabhdeep Kaur

Gagandeep Kang engaging with the audience during her presentation at IISc in December 2023

Do you see the potential for another pandemic?

Yes! But is it going to happen tomorrow or in 10 years? I cannot tell you.

Let's talk about communicable diseases.

I think the biggest communicable disease battle that we have right now is TB (Tuberculosis).

Why is it so difficult to find a vaccine for TB?

Usually, vaccines against viruses are easy to make; bacterial vaccines are harder, and parasite vaccines are even harder. Even in bacterial vaccines, extracellular bacteria are easier, and intracellular bacteria are harder. TB is caused by an intracellular bacterium that can infect cells responsible for immunity. So, it becomes even harder to make a vaccine for TB.

Photo courtesy: Gagandeep Kang

Gagandeep Kang giving a talk in Goa in 2022

We are always concerned about potential diseases like Ebola.

It is a viral haemorrhagic fever. But it is a viral haemorrhagic fever that people have survived.

But the high mortality rate?

It is serious and can be fatal, but also look at mortality rate when people have gotten care at a good facility versus when they have not.

Is Nipah worse than Ebola? We have frequent outbreaks in India now.

Nipah is much worse, causing more deaths in the infected than Ebola. But Nipah does not spread as much as Ebola does. Also with Nipah, there is a certain amount of variability because in the outbreaks that we have had, some

people spread the virus a lot and some people hardly spread it. What determines who spreads to 15 other people versus somebody who spreads to one other person? We do not know this. It may be a difference in strains. It may be a difference in the host in terms of how the virus is replicating. We have this super spreader phenomenon. People who shed a lot of viruses and infect many people. So, it may be a host phenomenon rather than a strain difference, but we do not know.

Changing lanes a bit, you have done so much work on viruses that cause diarrheal diseases. Historically, diarrhoea was a killer. Now when you see how the disease is being managed, what do you think of that change?

It is fantastic! And it is down to better management protocol. Oral rehydration solution (ORS) is the biggest game changer that ever happened for most diarrheal diseases. The gut is an organ that replicates itself very fast. If you look at the lining of the gut, it takes you about one week to replace the whole lining. ORS is a solution made based on understanding the physiology of the gut and then addressing the issues of what is needed to have better absorption and less fluid loss. That is why it is a balanced salt and sugar combination.

> ***'Usually, vaccines against viruses are easy to make; bacterial vaccines are harder, and parasite vaccines are even harder'***

But while ORS is fantastic, the problem for many diarrheal diseases is that there is both vomiting and diarrhoea. So, when you vomit, then you cannot use ORS. So, even though we have ORS as the main treatment form, we still need IV rehydration and prevention strategies for diarrhoea where possible. The problem with doing IV rehydration is if a child has diarrhoea and vomiting, you want to start an IV. But starting an IV on a dehydrated child is very difficult. It can be done in a high-end facility but most of the children that get dehydrated will not come to a high-end facility and might die. That is why we want to have both prevention and treatment.

So, what is the biggest challenge and how to tackle it?

I think the biggest challenge for diarrheal disease is the same as for all public health. It is access to diagnostics, treatment, and preventive strategies. It is a difference in distribution, right? Rich people can get everything they want. Poor people cannot. So, it then becomes the responsibility of public health systems to be able to provide poor people with what they need. Just because you are poor, if you are not able to access medication or good treatment, it is unfair. We all have a right to health. If we have that right, why should your socioeconomic status determine how much access you have to healthcare?

How would you navigate that?

You look at the countries that provide universal health care, they are so far ahead of us in terms of development. Why should we not have that? All expenses are a question of prioritisation. What should you spend on, so that you have a healthy society tomorrow? You tell me.

Photo courtesy: Gagandeep Kang

Gagandeep Kang working in her lab at Christian Medical College, Vellore

Healthcare? Making food cheaper and safer?

You want healthcare, you want nutrition. What else do you want to have in a healthy developed society tomorrow?

Playgrounds?

Very good. That's part of healthcare, and what else?

Mental health, I guess, I'm not really sure.

Absolutely. You already know what should be prioritised for a healthy society, don't you?

Switching again. Since the time that you started, do you see an increase in the representation of women in science?

One of the things that people often ask about is why aren't there more women in science. And for India, I will turn that question around and say, why aren't there more women working? In terms of formal employment, what is the proportion of working women in India? I don't think we addressed that enough. Our socio-cultural context is that you get an education, at least that much has changed for some parts of society. But then it isn't accepted that you work in a tough, demanding job.

There is a belief that the high school level is where you must really encourage kids to follow a path. Another suggestion is to keep women who are working in science employed. I want to know your opinion.

If I think about it from the point of view of running a lab: If I have a PhD scholar that needs to take six months off for maternity leave, I must have the resources to cover that. So, while I do not think that this is how society should function, I can imagine that if you are a young PI (Principal Investigator) who only has three PhD students, the last thing you want is one of those PhD students taking off for six months. But what I have discovered, working mostly in a lab that had women, is that if you provide those resources to women when they need it – the flexibility, the time off – they will outperform all the men when they come back and work. It is just the way things are. People understand they have a responsibility and fulfil all their commitments. All they need is a little bit of flexibility. And if a system can allow for that flexibility, I think then there is no problem in judging women professionals and men professionals with the same yardstick.

> ***'If you provide those resources to women when they need it – the flexibility, the time off – they will outperform all the men when they come back and work'***

I know someone who was giving job interviews. She was around 26 and planning to get married at the time. They were concerned that she might need maternity leave soon.

This happens all the time. How many formal jobs do we have in this country? 90% of our jobs, even the so-called salaried jobs, are for daily wage workers and contract workers. Less than 10% of our jobs are proper salaried jobs. If there is a premium on those kinds of positions, people are going to be able to get away with unfair work practices. You should not have a bias against women because they might get married or pregnant or need time off for childcare. But it is going to take us some time to mature as a society and to realise that. We have to expand the job market. We must improve the working conditions for women. It is not necessary that one follows the other. We must focus on both together.

Taking another detour, your childhood...

Perfectly normal childhood *(laughs)*.

But I read 10 schools in 10 years...

Everyone wants the story, right? Lots of kids in the army change schools. Any central services official's children will change a lot of schools. I, too, did that. It was great.

Did you want to be an air hostess as a child?

Yes. My uncle had a set of comic books which were called *Classics Illustrated*. They were very old. Every time I went to Ludhiana to my grandparents', there was a tin box with all these comics, and I would read them. At the end of the comic, there used to be two half pages about future careers. I was fascinated with the idea of being an air hostess. There was no chance of me being a pilot at that time, that came later. But travelling around the world, seeing new places and things like that ... I was devastated when I discovered that you had to have a 6-6 vision to become an air hostess. At 14, I got glasses. If you have glasses, you can't be an air hostess. It was the end of my life. No ambition *(laughs)*.

So, how did the turn happen?

I read a lot. I loved biology. Physics, not so much. Chemistry and maths were okay. I also loved history, geography, and English. I liked studying everything, but then when it was a question of choosing, I thought history and geography, you can read anytime. But the other subjects require more study, so that is what I chose to do.

From there to now, when you are called the "Godmother of vaccines" in India, how does that feel?

People come up with labels. I like the work I do. I thoroughly enjoy it. I love working with young people and seeing them get excited about doing new things. That is the best part.

I wanted to end on a stupid question. I was reading about certain parasites that get into animals and then make them do things. So, is there a possibility of zombies?

Zombie ants do exist...

No, no, the *Resident Evil* or *Walking Dead*-type zombies we see on TV.

Hmmm... One way of thinking about it is that a lot of brain infections cause you to change behaviour. If you think about viral encephalitis, for example, one of the key [symptoms] is that people's behaviour changes. Sometimes clinicians pick up infections because a person is behaving oddly. So yeah, it's perfectly feasible to think about significant changes in behaviour caused by infections. Will they end up eating people? I do not know.

It was the inaugural event of *Rhapsody*, an annual fest of IISc, in July 2023. The JN Tata auditorium was packed with an ecstatic audience looking forward to a cultural extravaganza. Draped in red-and-black costumes, resembling ancient warriors, the members of the IISc Kalaripayattu club marched onto the stage to loud cheers. Tailing them were drum and trumpet players who settled into a corner on the stage, blending into the shadows. Agile and focused, the performers started with a series of body-warm-up movements involving bending, stretching and kicking exercises. This was followed by a *Namaskara*, a greeting to the sun and salutation to mother nature, intended to calm the body and enhance concentration and flexibility. The crowd went silent, waiting with bated breath for the show to begin. Demonstrations of swift, precise movements started, as they challenged each other with long sticks, spears, swords and shields, in a beautifully choreographed sequence of daring acrobatics. We watched, mesmerised, as the performers matched each other's moves by bending, buckling, crouching and leaping, in a display of composure, balance and dexterity. The whole crowd was clapping and cheering in sync to the rhythm of drums and the trumpet (called didgeridoo). Finally, the performance ended with a resounding standing ovation.

The performance was graceful, like poetry in motion. It was the first time I was exposed to Kalaripayattu, the ancient martial art that was once a lethal form of combat warfare.

Kalari club at IISc

Kalaripayattu or Kalari, which originated in Kerala, is considered one of the oldest martial art forms. In its crudest form, it is believed to be a way of hunting wild animals which was eventually refined into a systematic combat technique to overpower enemies and defend oneself. Kalari aims to understand and balance the harmony between the body's elements, leading to overall well-being with enhanced combat skills, self-discipline, humility and respect for opponents.

At IISc, the Kalari club was started in December 2018. “Before that, Jaideep Joshi, a PhD student, used to go to Guruji Sudarshan Sampath [in Malleswaram] for Kalari practice and he, along with Sudhanshu Rathore, former club convenor, initiated the club. They wanted to introduce this art form to IISc,” says Smriti Basnett, the Deputy Director of the South Asia hub of the Future Earth Programme at the Divecha Centre for Climate Change.

Guruji Sudarshan has been practising Kalari for more than 20 years. He holds a world record for performing non-stop Kalaripayattu for 90 minutes straight in 2019 at the age of 45 years, to bring awareness about this ancient martial art form. “Ten minutes of our performance takes a lot of effort. Sometimes, I want to just get done with it. Ninety minutes is a lot,” says Mehul Kumar, in admiration. Mehul is the current convener of the club and a PhD student at the Department of Chemical Engineering. He was always interested in martial arts from childhood. “I was in the fourth or fifth standard when I started learning Judo. Then I stopped. I got the opportunity again when I came to know about this Kalari club through an email in 2020, after COVID-19. I joined the club and have stayed on till now.”

Photo: KG Haridasan

IISc Kalari club members during a practice session at the Gymkhana grounds

Divakar Badal, an alumnus of IISc and Protik Paul, PhD student in the Department of Computer Science and Automation were the past conveners of this club. Both of them also got to know about the club via an email. “The idea was we would learn something different from what we were doing in everyday life, like doing lab experiments, running from one lab to the other or to the mess or to the hostel,” says Divakar. “And it turned out to be really interesting. You didn't need any tools, you didn't need any heavy equipment. You just needed to be present there. Our bodies have the capability to give us the strength and power to change the way we think about ourselves. Kalari was helpful and we could be more productive in the laboratories as well,” he adds excitedly.

Protik further adds, “Our Guruji is a very humble person and teaches so passionately. The classes always gave us so much extra energy which otherwise we didn't feel we had. And it's always nice to do these things, other than continuous lab work.”

> ***‘We would learn something different from what we were doing in everyday life, like running from one lab to the other or to the mess or to the hostel’***

Smriti joined the second batch of Kalari club and has been a member since then. “I did see that my posture was getting spoiled [by] working too much on the computer. I always wanted to follow some traditional form of movement and I don't like static sports,” she says. She has always been interested in badminton and table tennis and has played in national tournaments as well. But Kalari, she says, is unique. “When I used to play table tennis or badminton, it was only like the right side of my body working. I needed a warm-up for intense playing or I used to get injuries. But Kalaripayattu has slow warm-ups and slow cooling. It's so beautiful and rhythmic where you use a lot of your muscles, your energy and a lot of your breathing techniques. I am happy I joined it,” adds Smriti.

Training the body and mind

Kalari is a highly physical and energetic art form. It requires plenty of training sessions that are divided mainly into three levels, each level building upon the previous one. It starts with *Meithari* (basic physical conditioning) having rigorous exercises including yogasanas and breathing techniques intended to develop flexibility and strength. The intense physical training prepares the body for the advanced stages.

Photo: KG Haridasan

A highly energetic art form, Kalari practice begins with rigorous warm-up sessions involving kicks, splits and animal poses

Kolthari or stick fighting teaches the art of combat using wooden sticks. *Ankathari* provides training in unarmed combat techniques including strikes, kicks and grappling. Techniques learnt in *Kolthari* form the basis for advanced weapon training and those learnt during *Ankathari* focus on self-defence and healing.

The Kalari club has two classes per week, one taught by Guruji and the other by Mehul. The remaining days of the week are for practice sessions early in the morning. Divakar and Protik describe a typical session. "It's early morning, the sun is there, just rising above the skyline. At that time, you have to wake up from the hostel and go all the way to the Gymkhana. It's definitely challenging. But as the exercises start, our body slowly becomes active. Guruji always advises to have the sessions in the morning rather than in the evening. It's better because we mostly work all day and night. Early morning sessions are more beneficial to the body as well," says Divakar.

> ***'It's a beautiful experience. It's good to know how much our body can extend irrespective of our age'***

A significant amount of time is spent on warm-up sessions. "It started with Surya Namaskar, moving on to different body movements like rotating our hands in clockwise and anti-clockwise directions. Then came different types of kicks – straight, round and sidekicks – and a combination of kicks and splits. Then we would have a session with a combination of eight animal poses starting with the wild boar, then elephant, cat, lion, horse, snake, rooster and finally ending with a peacock stance. The routine ended with a few stretching exercises and meditation," explains Protik.

The first weeks of training are always a challenge for a new student. "During the first few weeks after joining, I couldn't even lift my leg, even though I play other sports extensively. When we did the kicks, it affected the muscles between the ribs. I could feel that. When I was resting or sleeping, I could literally feel the change in the rhythm of my breathing. While doing Kalaripayattu, we practised with a lot of exhalation. With each kick, we exhaled from the stomach. The exhales were, in fact, the counts. This was very fascinating," recalls Smriti. "During the classes, we might feel tired, giving our 50%, but when Guruji comes, it's like 200% energy. We might need to rest for the next two days. But that's a beautiful experience. It's just good to know how much our body can extend irrespective of our age."

A wide range of weapons are also used in Kalari, like a single-edged curved sword called *Vaal* for both defence and offence, *Kedahom* (shield) for blocking attacks and protecting the body, *Urumi* resembling a whip with a flexible metal blade, *Kuntham* (spear) for long-range attacks, *Kuttuvaal* (dagger) for close combat and *Kettukari* (long wooden staff) for training and sparring. Each weapon requires agility and finesse for effective wielding, with the intention rooted in self-defence rather than offensive aggression.

A growing club

The group has been performing Kalaripayattu at several events both inside and outside IISc. They have performed outside IISc at events like

Photo: KG Haridasan

Members of IISc Kalari club demonstrate different tools used in Kalari

Onam celebrations and the Kannada Film Festival. They have showcased Kalari at the G20 summit in Hyderabad too, where Guruji was invited to perform.

The performances are usually accompanied by the rhythmic music of drums and didgeridoo, which forms a major component of the art form.

Divakar explains, “The idea of Kalari is inspired from nature itself. If you are sitting peacefully in a forest, you can hear sounds of a river flowing nearby or rustling of leaves. The background music tries to mimic a natural sound.” Mehul further says, “The audience needs to connect with what we are presenting. Music binds the whole art.”

“Performing with the music just takes you to another level. It's like an addiction, you want to feel that again,” adds Smriti.

The group hasn't participated in competitions so far. “I haven't given a thought about participating in a Kalari championship. I'm mostly interested in performances. For championships, you need to be very focused and practice regularly. If I get the opportunity then it depends on whether I'm able to invest that much amount of time, keeping my PhD work in mind,” says Mehul.

The membership of IISc’s Kalaripayattu club changes each semester. They send out emails inviting students to join during every new academic session. There are usually a lot of registrations for the Kalaripayattu club in the beginning. Mehul says that most of them are PhD and MTech students. MTech students are here for only two years, with the last year mostly occupied with their projects and interviews for company placements.

> ***‘The idea of Kalari is inspired from nature itself. The background music tries to mimic a natural sound’***

In order to study and promote this art form, a fellowship has been instituted with a stipend of Rs 50,000 per month and an annual research grant of Rs 1 lakh. It is a joint initiative by the National Institute of Advanced Studies (NIAS), a sister institute of IISc, and UL Research Center in Kozhikode, Kerala. This is part of a research project on ‘Kalaripayattu and well-being’ which aims to scientifically study the different traditional Kalari practices and their effect on personal health and well-being.

“When I went to conferences, I was fascinated that some of the foreigners also knew what Kalaripayattu is and in India, it was equally surprising that many didn't know about it. I feel Kalaripayattu should have more advocacy and publicity, which it hasn't seen so far. Even in IISc, the other clubs are very active and very regular, but in Kalaripayattu I find a lot of dips and peaks,” reflects Smriti. “We also have plans to promote the club more. We are working on updating the webpage as well. Maybe with the new batches, we will resume this full-fledged again.”

Surabhi Chandra is a second year PhD student at the Department of Developmental Biology and Genetics, IISc, and a science writing intern at the Office of Communications

Managing the minutiae

- Sandeep Menon

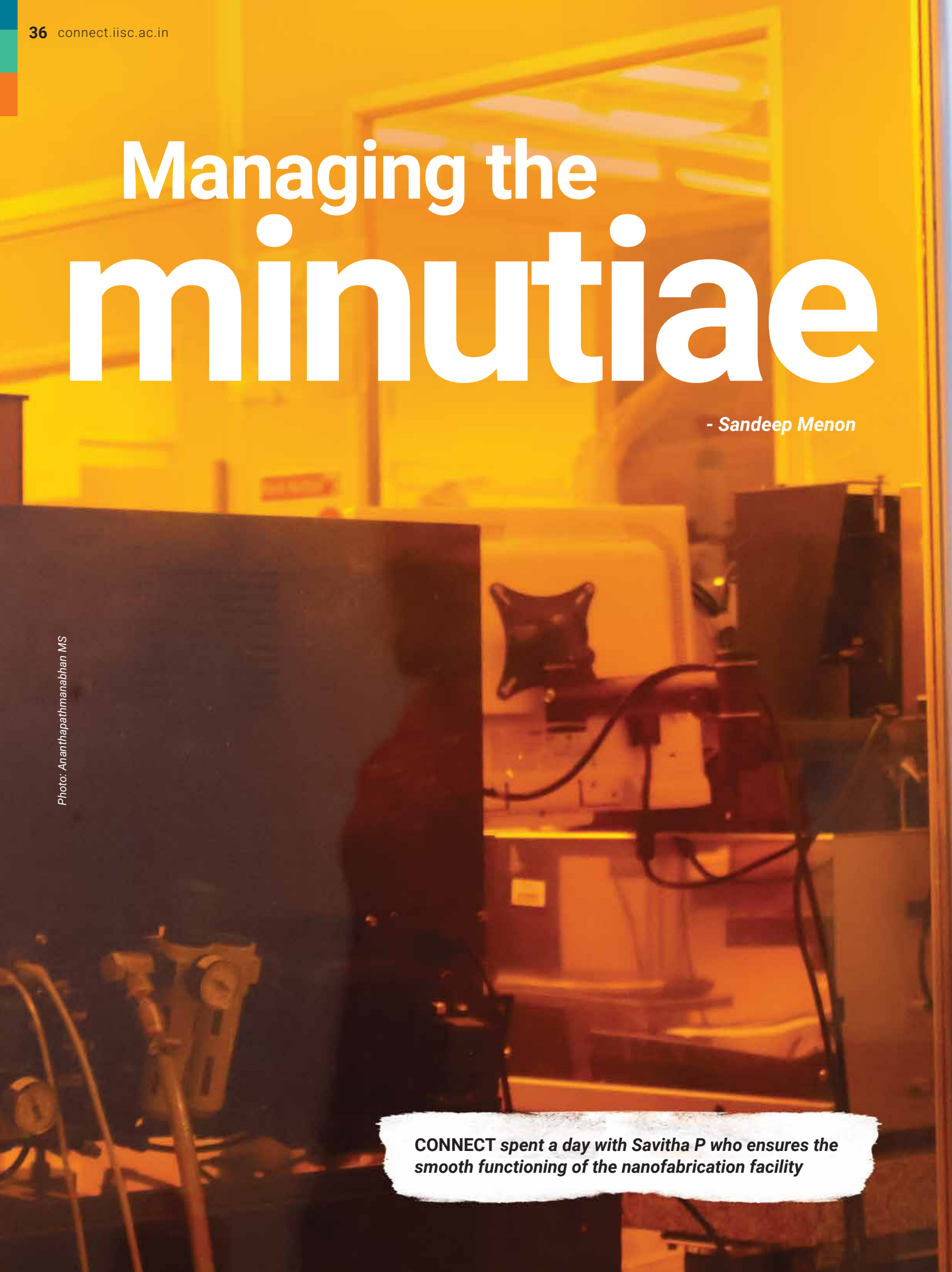


Photo: Ananthapathmanabhan MS

CONNECT *spent a day with Savitha P who ensures the smooth functioning of the nanofabrication facility*

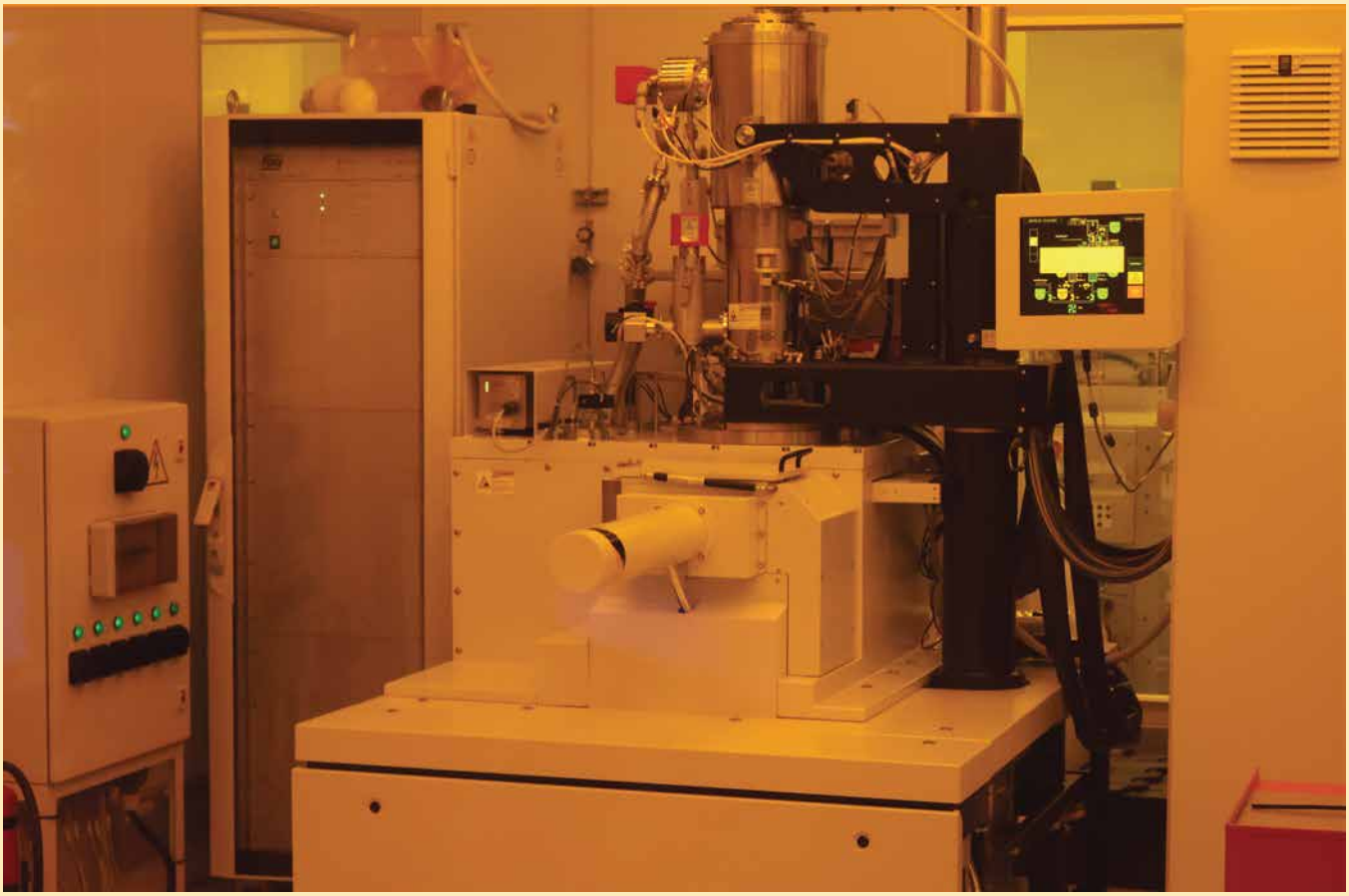
It is an office that speaks to the work that Savitha P handles at the Centre for Nano Science and Engineering (CeNSE) at IISc.

The office itself is simple – populated by a desk, a computer, a couple of chairs, a fashionable hourglass, a smattering of awards, and a few potted plants. A cupboard sits on one side, groaning with files and boxes of documents that betray signs of constant rummaging. There are keys hung neatly on the wall, meticulously marked and accounted for. If the National Nanofabrication Centre (NNfC) is the heart of CeNSE, then this room is its aorta.

Amidst the chaos, Savitha's desk is clean and organised, an appropriate metaphor for how she carries out her work as the Chief Operating Officer (COO) of the NNfC, part of the larger, living, breathing, complicated organism that is CeNSE.

Savitha's day starts bright and early. She is in her office by 9 am. On this day, she is a tad anxious. The NNfC, put together at enormous expense and with great precision and care, is getting a new tool – an electron beam lithography system called the EBPG 5150+. The new acquisition will form part of the 14,000 sq ft facility where one can experiment in various labs – such as the Lithography lab, etch and deposition – with work ranging from semiconductors-dielectrics to developing and fabricating everything from advanced sensors to sophisticated GaN transistors. The latter have promising applications in power electronic applications due to their higher breakdown voltage and power efficiency compared to traditional silicon-based transistors. The facility, bustling with activity, is used by researchers, students, entrepreneurs, and innovators from outside IISc as well. Since it was established in 2012, it has also given birth to several private companies that are working on cutting-edge areas of medicine, clean energy, and more.

Photo: Ananthapathmanabhan MS



The new EBPG 5150+ installed at NNfC

The nerve centre of the facility is the clean room – a room free of dust and other contaminants – which is now shut for yearly maintenance, making it the ideal time to introduce the new tool. Savitha's mind runs through a laundry list of all the things that could go wrong – from potential damage to the new piece of equipment to dust and vibrational effects (the facility is constructed in a manner as to isolate or dampen vibrations that could affect the performance of the tools in the facility).

At 10 am, she rushes for a routine meeting with her colleagues to discuss the day-to-day running of the facility, one that lasts for the better part of an hour. As she bustles into the office again, there are two people and a crisis waiting. There has been a mix-up with a new software. Someone, it would seem, had tampered with the system and password. It takes a few minutes, but Savitha successfully manages to stop the crisis from escalating.

As she sits down at her desk, there is already a booking request waiting for the clean room. "The clean room is booked months in advance," she says matter-of-factly, about the demand for slots at the state-of-the-art facility, with people travelling from all over the country to use it.

"If something goes wrong, things get backed up. That has a huge effect on people who are travelling down and all such," she says. As Savitha goes through her email, she elaborates on her responsibility.

"I have to make sure things work well for our users," she explains. "It is on the operations team. You sit with various teams to understand what is happening and what is needed. You have to be on top of things constantly."

Besides having to ensure the smooth running of the facility, Savitha is also in charge of procurement. From tools to chemicals (the facility needs a high level of purity in the chemicals they use), most of it comes from abroad. Should anything go wrong, Savitha and her team have to figure out a solution themselves as the waiting period to get in touch with the companies that make and distribute them is often too long. To that end, CeNSE has an active programme in place to try and help build the local ecosystem for such products.

"A big part of my day goes in ensuring that things don't go wrong and if they do, that we deal with it," she says. Every decision she makes has a significant impact – whether it has to do with the functioning of the facility or its future. She recalls one such instance. When she was at a Fair Price shop one day, she got a call about procuring a new tool. The cost was around Rs 5 crore. Savitha cleared it saying that it can be budgeted. The ration shop owner was left wondering aloud what this lady, who speaks with nonchalance about spending crores, was doing there.

> ***'A big part of my day goes in ensuring that things don't go wrong and if they do, that we deal with it'***

As one would expect, Savitha and her team have drawn up protocols that need to be followed for everyone using the facility, as much for their safety as for that of the facility. A penalty point system has been put in place with suspensions and even permanent bans for breach of protocols.

At 12.15 pm, Savitha heads up a few floors in the CeNSE building for another meeting. This one, she says, is to work towards developing the nanotechnology ecosystem in the country. An important part of this agenda is to ensure the success of the central government's India Semiconductor Mission. One of the biggest challenges in the field is building precision equipment without always having to import them. Towards this end, CeNSE is working with a company to help improve the quality of one specific tool. There are six people in the room engaged in serious discussion about the instrument in question. Suggestions to rebuild certain parts are debated and explained. Flow charts and diagrams are projected onto the wall. Savitha makes copious notes and gives her feedback. At the end, the minutes of the meeting need to be transcribed. It takes an hour and Savitha heads down to have lunch.

'I love cooking. Every chemist is a cook. It is the same process, mix and heat it ... optimise and experiment'

Lunch is a comfortable ritual, with Savitha and her colleagues sharing their meals with each other. "I love cooking," she exclaims. "Every chemist is a cook. It is the same process, mix and heat it ... optimise and experiment."

A chemist is who she is. Hailing from Thrissur district in Kerala, Savitha completed her Bachelor's degree in Chemistry from Calicut University in 1996. She then did her Master's at the University of Pune (now Savitribai Phule Pune University) with the intention of eventually doing her PhD. But the culture shock of moving to a different city was a punch in the gut for someone who grew up in a safe environment. Having to converse in a new language, be it Marathi, Hindi or even English, was a struggle for her. Her resolve to finish her degree, let alone earn a doctorate, was tested. At one point, she even called her father, telling him that she wanted to come back home. Her father, rather shrewdly, had obtained a seat for his daughter in St Joseph's College back home as a backup. He was sympathetic to his daughter's feelings but said something that made a significant impact on Savitha.

"I thought you were not one to give up. This was your dream," he told her. Savitha remembers the words even to this day. She thought about it that night and next morning, called home to inform them that she was not coming back.

"If my father had said come back, it would have been very different," she says. After her Master's, she got into IISc for a PhD programme at the Department of Inorganic and Physical Chemistry in the early 2000s. Savitha has been at IISc since.

Photo: Ananthapathmanabhan MS

Following her PhD, she worked as Technical Team Lead at Cookson India Research Centre, which was housed in the Society for Innovation and Development (now the Foundation for Science, Innovation and Development) in IISc. After five years of working here, she moved to NNfC as a technology manager in 2010.

"That move was a big change for me," she admits. As a technology manager, she had to manage a high temperature chemistry facility. She learnt on the job and in a few years, she was rewarded. She was promoted to the position of COO in 2017.

Soon after lunch, Savitha marches into the NNfC to check on the new tool, the EBPG 5150+, which was arriving. A heavy table, which will hold the tool, needs to be bolted to the floor because the tool is sensitive to external vibrations. She watches anxiously as the installers lower the table. It had to go well. No, it had to go precisely. Or it will mean a further delay in reopening the cleanroom, which Savitha can ill afford. But before the installation is complete, at 3 pm, she rushes out for another meeting. The meeting is with a team that is making a video to explain the work that goes on in NNfC. The scripting process is ongoing. As soon as the meeting is over, she hurries back in to check on the installation. It had gone well. She breathes a sigh of relief.

'CeNSE is looking forward to the future. There are companies coming out of CeNSe that will make a big impact on people's lives'

There are two more meetings before Savitha can call it a day. One is a debrief, the other is with the head of the facility. Her work hours are long but flexible, she admits. She is always on call. The NNfC functions throughout the day. So, if anything goes south at any hour of the day, she is the one who must decide on what action needs to be taken. It can be stressful, but she doesn't mind. "CeNSE is looking forward to the future. It is an interdisciplinary space," Savitha explains. She is aware that she is in charge of a facility that is shaping the future. "There are companies coming out of CeNSe that will make a big impact on people's lives."

Photo courtesy: ISRO

Why it matters and what are the challenges confronting science historians

A quick internet search on the discovery of helium will be dominated by results that claim that helium was discovered by the French astronomer Pierre Janssen.

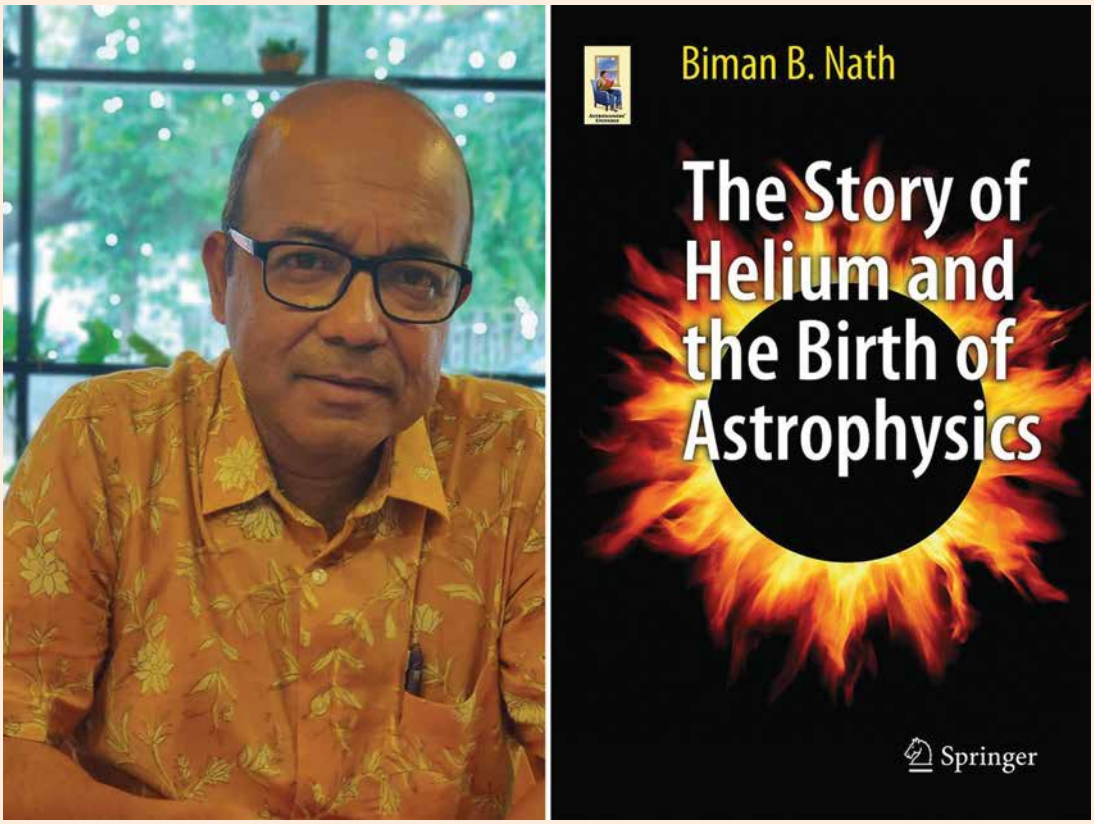
"While observing a solar eclipse in Guntur, India, on 18 August 1868, Janssen noted that the spectral lines in the solar prominences [large, bright features that extend outward from the sun's surface] – were so bright that they should be easily observable in daylight," according to the *Encyclopedia Britannica*.

"This is all wrong," says Biman Nath, a physicist at the Raman Research Institute in Bangalore and a science historian. In his book *The Story of Helium and the Birth of Astrophysics*, published in 2013, he writes that the discovery of helium was more of a collaborative effort that involved many other scientists including Joseph Norman Lockyer and Norman Robert Pogson. The book, a result of a decade of work studying research papers and letters from scientists, traces the history of helium, an element essential for high-speed computing and space exploration, but in short supply on our planet even though it is the second most abundant element in the universe.

Why science history

Besides correcting a popular but incorrect notion of how helium was discovered, Nath's book helps the reader understand the process of scientific research. Elaborating on the importance of science history, Richard Creath, a philosopher of science, goes even further. In his 2009 article published in the *Journal of History of Biology*, he argues that the history of science is integral to science itself. "The history of science is an essential part of each science," he writes. Thomas H Grainger, in his 1956 article in the journal *Improving College and University Teaching* titled 'Why Study History of Science', adds that studying the history of science helps "exhibit the sense, purpose, and reasoning to science."

Photos courtesy: Biman Nath



Biman Nath and his book The Story of Helium and Birth of Astrophysics

Nath, who has also written a biography of the well-known Indian physicist and pioneer of India's nuclear programme, Homi J Bhabha, also makes a broader case for studying the history of all human endeavours, including science. He believes that understanding history allows us to stay connected to our community and increases social awareness. "We belong to the community and cannot be devoid of any connection to society."

> ***Biman Nath believes that understanding history allows us to stay connected to our community and increases social awareness***

Jahnavi Phalkey, a historian of science, argues that knowing the history of science also allows us to understand how science developed over time. Now the Director of Science Gallery Bengaluru – a space for public engagement of science – she illustrates her point using the example of astrology, which was once considered a legitimate science. "Astrology at some point was not a pseudoscience."

According to her, as in the case of astrology, studying science history helps us understand how and why the boundaries between science and non-science have been drawn over time. She points to yet another infamous idea that was once considered "scientific." "Scientists found that women's brains were different to men, and therefore interpreted that women were intellectually and cognitively less capable when compared with men overall. We have seen how this has been corrected over time."

However, while it is the job of a science historian to reveal how a particular science developed, Jahnavi thinks that it is not a historian's job to judge what is true and not true. "It is a historian's job to understand why something is said to be true and what is the argument behind the claim."

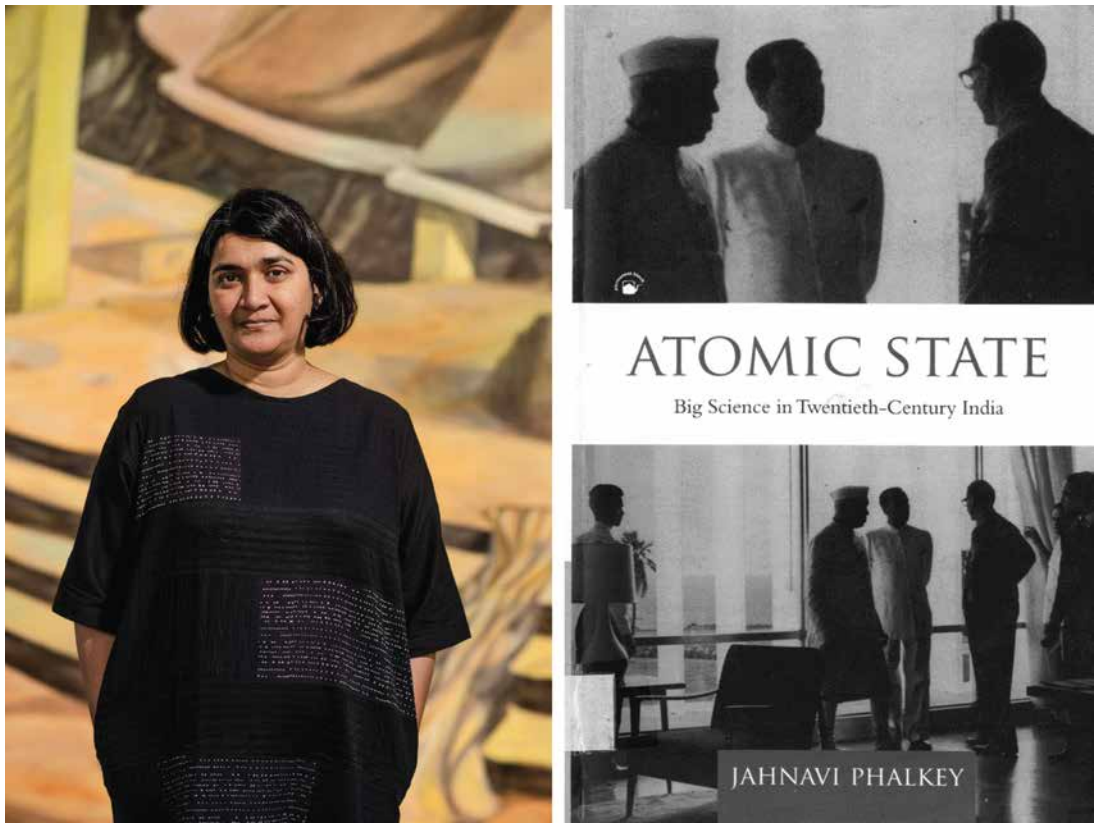
Challenges of doing science history in India

Jahnavi did her PhD in science history from the Georgia Institute of Technology in Atlanta. For her thesis on the history of nuclear research and education in India, she needed archives for photographs, letters, and official documents related to her research. But, as she found out, in India, accessing historical material was tough. "In my graduate programme, my colleagues who were studying in the United States or countries in Europe broadly identified their questions and then they knew the number of archives they would need to go to, and then they would go to those archives for a six-month time period to get the documents they wanted."

But for scholars working in India, "it is the other way around," she says. "For anyone to find interesting and important records in the archive, it might take years," as most Indian research institutions and universities do not have an institutional archive. "When I started, the Tata Institute of Fundamental Research [TIFR, Mumbai] Archive was the only one that was systematically working." The IISc Archives, she adds, was working but was in the initial stages of being set up.

> ***Personal papers of scientists, crucial for science history research, are not easy to get hold of***

Jahnavi alludes to yet another bottleneck for doing science history in India – the lack of appreciation of the importance of our science history. "Most others do not even keep the papers once the person passes away," says Jahnavi. If they are not thrown away, at times, important scientific papers tend to lie around in the houses of researchers or their family members after they have passed away. She even chanced upon documents related to ballistic missiles in the house of a scientist.

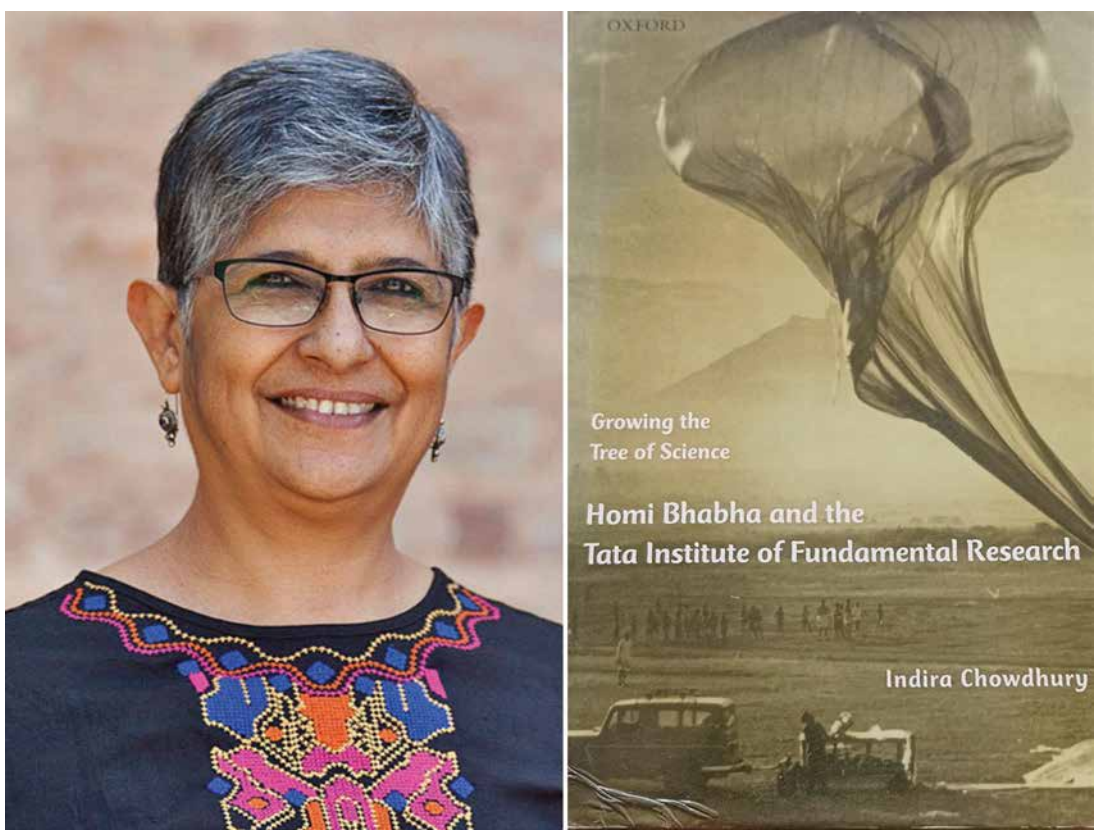


Jahnavi Phalkey and her book Atomic State

Photo courtesy: Jahnavi Phalkey

Jahnavi also points to another fundamental problem for research in science history in India – there are very few science historians. "There is no university in India that offers a history of science degree." But even if they do get trained, they are confronted with the problems she encountered in her research. "You can train people in history, you can train them to think historically, but they are going to need archives."

Indira Chowdhury agrees with Jahnavi's views partly because of her own struggles. Indira, a historian of science and archivist, until recently headed the Centre for Public History at the Srishti Institute of Art, Design and Technology in Bangalore. Indira's doctoral thesis focused on masculinity and the idea of nationalism, which she did from the School of Oriental and African Studies, London. It was during her PhD that she crossed paths with the history of medicine. She was particularly interested in the history of birth control in India. But she too struggled to find Indian archives that housed material useful to her research. In fact, many documents related to her work were sitting in archives in the United Kingdom. "At that point, I had felt that it would be really good to have lots of archives in India that had to do with the post-independence period." Yet another concern that Indira has is that archives in India seldom have institutional policies that make it conducive for science historians to carry out their research.



Indira Chowdhury and her book Homi Bhabha and the Tata Institute of Fundamental Research

Photo courtesy: Sagar Chetri

Amrita Shah, a well-known journalist, too faced several obstacles while she was researching the life of space scientist Vikram Sarabhai, about whom she wrote a biography. "There was no full-fledged biography of Sarabhai. His name was not mentioned in any accounts of modern India that I came across."

Sarabhai's official archivist gave Amrita only Sarabhai's speeches which had already been published and some tributes after his death, and showed her a few pages of Sarabhai's diary.

"ISRO had some oral histories that were extremely helpful," Amrita adds.

Looking ahead

Science historians are unanimous in their view that we should have more institutional archives to carry out research and tell stories about Indian science and scientists. "Archives contain primary sources of information that can give us insight into the actions and decisions of governments, institutions, communities and individuals, as well as hold our memories," writes Deepika S in the June 2022 issue of *Connect*, explaining the role of an archive. Indira says that at a time when propaganda machines work to disregard a scientific past and mix the mythical past, archives are important spaces to make people aware of science which will help them understand their past as opposed to getting a convoluted view of the history.

> ***Science historians are unanimous in their view that we should have more institutional archives to carry out research about Indian science and scientists***

Jahnavi believes that all relevant research documents that belong to a scientist should ideally be in an institutional archive or museum. Indira also makes the case for not just having traditional archives, but also oral archives. According to her, archiving oral histories will provide information that goes beyond facts. They reveal how one arrived upon the decisions they made. "I take a very long view of the history and I feel the more the material we put in the archives, the more we make people aware of how we can understand the past," stresses Indira.

Indira believes that more scientists should take an interest in understanding the importance of archiving. "My request to all scientists is to learn a bit about archiving, no matter how busy they are."

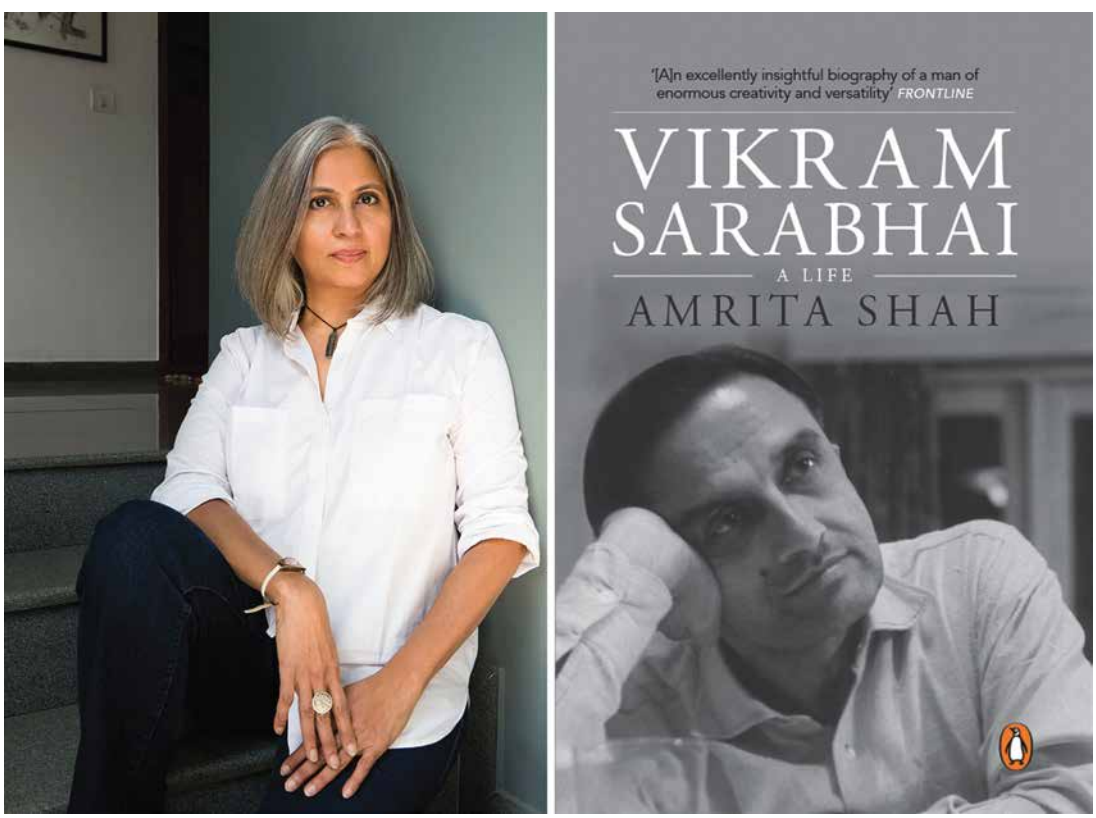
Jahnavi, however, cautions against merely having an archive for the sake of it without having a coherent institutional policy about how to establish and manage an archive.

"Institutions need to maintain their archives, and that doesn't mean just pushing files and papers into cupboards as they were found. They need to be organised, indexed, conserved, and furthermore, made accessible to the researcher, filmmaker, journalist, artist – or for that matter to any interested citizen."

The importance of a meaningful policy for collecting material and maintaining an archive is a view echoed by Indira. Indira herself has been associated with several institutional archives including the archives of the Tata Institute of Fundamental Research which she helped set up. Amrita too makes the case for more institutional archives when she says that it is imperative that we find ways of preserving "the history of science, the history of art, the history of knowledge."

Jahnavi maintains that we need more training – for both archivists and science historians. "We need training, and we need archives … without those two things not much will happen in a credible way." It is through these efforts, according to her, that a good "ecosystem" of science history can be built and help illuminate our scientific past. This will go a long way in helping us understand larger questions about why we are what we are, how we got here, and where we are headed as a society.

Photo courtesy: Clare Arni



Amrita Shah and her book Vikram Sarabhai - A Life


Abstracts, IISc Photography Club