Connect

WITH THE INDIAN INSTITUTE OF SCIENCE

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Bangalore blues
Taking on civic challenges

Crossing borders
Lives of international students

Building blocks
The promise of 3D printing

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Editorial

More than a century ago, with its bracing climate, Bangalore beat the likes of Bombay, Roorkee, Madras and Calcutta to become IISc's home. In this issue of *CONNECT*, we explore some of the ways in which IISc's researchers are stepping out into the city to solve some of its pressing civic challenges, as it buckles under uncontrolled growth and unending traffic jams. We also speak to urban ecology expert and alumna Harini Nagendra, who expresses her love for the city through her research, activism and fiction writing.

IISc is home to students who come to study from faraway places – even from outside the country. A few of these international students share with us their stories of adapting to cultures and environments alien to them. In staff stories, we write about the lives and work of Francis Jayakanth, a librarian with a passion for information science, and Rosa J Samuel, who has helped researchers in biological sciences for decades.

We interview Yamuna Krishnan, another alumna, whose work on molecular tools is revolutionising our understanding of the cell's interior – both its well-being and dysfunction. Scientists at IISc and elsewhere are also pursuing new frontiers in 3D printing, an emerging technology that has the potential to transform how everything is built – from jewellery to rocket engines.

In this issue, we also revisit a unique teachers' training programme that started in a sheep farm in IISc's Challakere campus. And we highlight the crucial role that institutional archives play in safeguarding history. Finally, we cover a women's cricket match that turned out to be just as exciting as a *Police-Chor* chase.

Happy reading!

Team Connect

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The chase begins

- Neelima Basavaraju

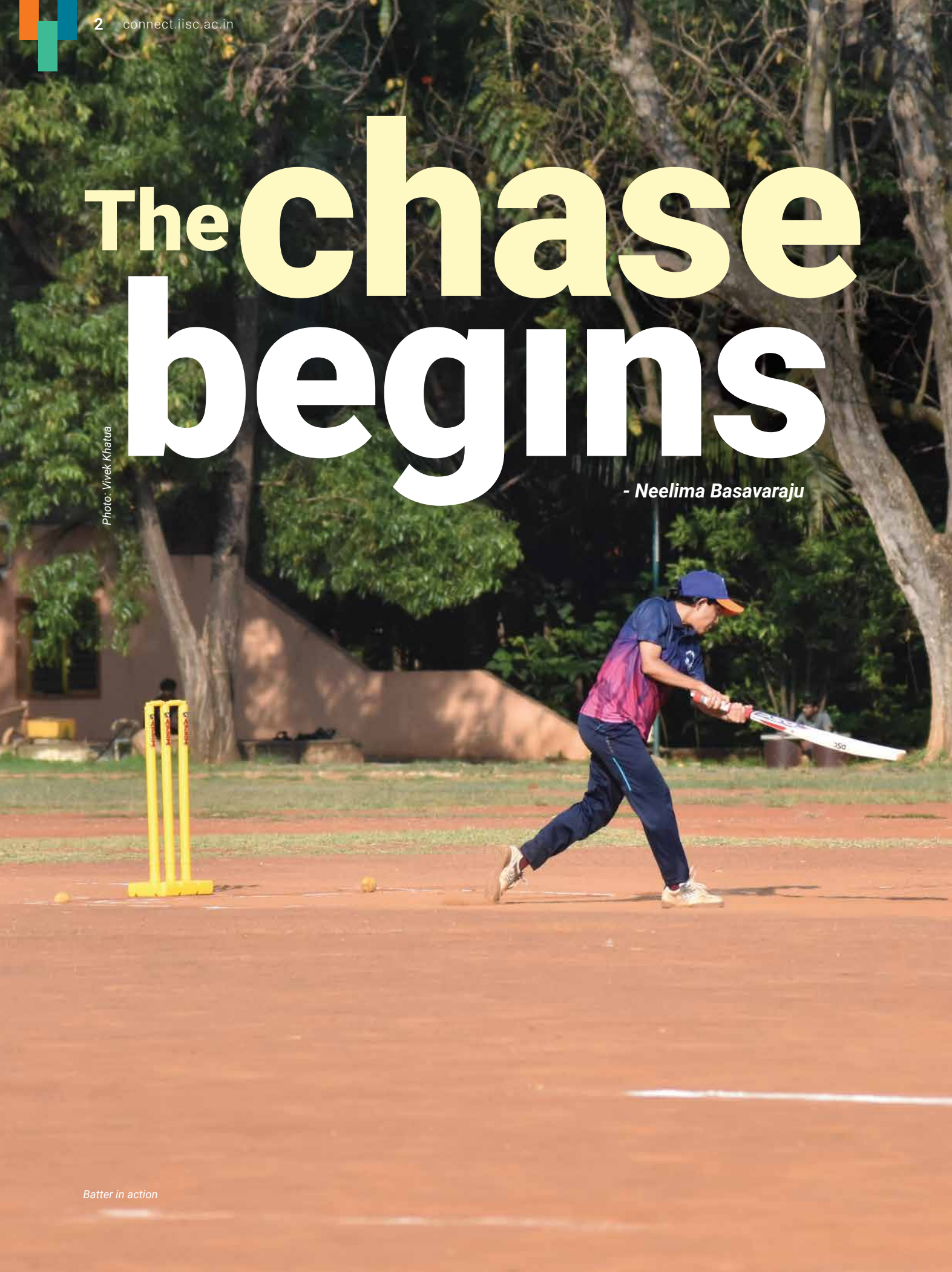


Photo: Vivek Khatua

Batter in action

A first-person account of IISc's women's cricket tournament

It was a hot Sunday morning in May. Under clear skies that offered little protection against the beating sun, a group of women gathered around at the pavilion in the Gymkhana to discuss strategies. It was the second match of the women's cricket tournament organised by the IISc cricket club. The team that I was part of, *Police*, had lost the first match held the day before, by 29 runs. Some fielding lapses had allowed the other team, *Chor* (meaning thief in Hindi), to rack up the runs needed to win. Naturally, the pressure was on our team to turn the result around on the second day. Various game plans and scenarios were discussed. The team captain was urging us to step up our efforts in the field.

I was pleasantly surprised when I saw an email from the IISc cricket club earlier in the month with a call to register for a women's cricket tournament. The tournament was open to everybody associated with IISc and I registered immediately. I had played cricket in the past just for fun but had never participated in matches of any sort. Having grown up watching the Indian national team play cricket and listening to passionate discussions and commentary among family and friends, it felt great to finally play proper matches. It was also thrilling to be part of IISc's first women's cricket tournament, from what I've heard.

The morning practice sessions started a couple of weeks before the matches. The men's cricket club pitched in, giving us tips and advice. Among the registered participants, a few had prior experience of playing cricket, but most were beginners. Although nearly 60 women had registered for the tournament, not many turned up for the practice sessions, probably due to the struggle of managing their course or lab timings. In fact, on a few occasions, we were doubtful about whether there would be enough members to even play the matches. It was quite heartening when many of them confirmed their participation towards the end and at least two teams could be finalised. Due to lack of time to design separate jerseys, both the teams decided to go with the same design. We booked the cricket ground to play two matches – we couldn't play more matches because the ground was available only for two days.

When the teams were being formed, the members wanted names that worked as a pair. After a few rounds of discussion, the names *Police* and *Chor* were born.

On the first day, team *Police* won the toss and chose to field. On the second day, team *Chor* won the toss and chose to bat. Funnily, on both days, *Police* ended up chasing *Chor*.

Shaking the blues

On the second day, having to bowl first, our team walked onto the ground and huddled for a team cheer. Given the first day's fiasco, there was a lot of pep talk going around. I remembered a cheer slogan I had picked up while playing a frisbee tournament a month before and told my teammates: "No pressure, no diamond." It hit a chord with them – they looked pumped up, and we set off to start the match.

Photo: Vivek Khatua

Players deep in discussion before the start of the match

The batters from the opposition team walked in pumped up too. Although they lost a couple of early wickets, one of their openers continued to hit boundaries to keep the runs flowing. We got a breakthrough in the eighth over, when we finally managed to take her wicket.

In the stipulated 12 overs, team *Chor* managed to put up 107 runs with a loss of three wickets at the end of their innings. There was indeed an improvement in our fielding and bowling as we restricted them to a lower score, as opposed to the 158 runs they had scored the day before.

Photo: Vivek Khatua

Team Police *celebrating the fall of a wicket*

Nail-biting finish

Next, the openers from team *Police* went in to bat, confident that the target was well within reach. We also had to deal with some early blows as we lost two wickets back-to-back in the second over. However, the third wicket partnership remained steady and runs kept coming at a decent pace for a major chunk of the innings, before accelerating towards the end of the stipulated overs.

With team *Police* needing 14 runs from the last over, the tension was palpable on both sides and even among the audience in the pavilion, which included the chief guests – Dipshikha Chakravortty, Professor at the Department of Microbiology and Cell Biology, and Nibedita Rath, an alumna of IISc and Scientific Director, Open Source Pharma Foundation. With quick running between the wickets and a few extras from the bowler, team *Police* managed to successfully chase team *Chor* and seize victory by eight wickets.

Photo: Vivek Khatua

Players from Team Chor *waiting for their turn with the bat*

Wrapping up and moving forward

Having won a match apiece, both teams ended the tournament in high spirits. The players congratulated each other and left the ground, walking towards the pavilion for the post-tournament presentation, chatting away with great camaraderie. There was a pang of disappointment at not being able to play a decider as the cricket ground was booked from the next day for the men's tournament. Since there was no tiebreaker, team *Chor* was declared the champions based on the net run rate.

The felicitation ceremony started with the players and cricket club members sharing their experiences of organising and participating in the first women's tournament. Everybody expressed their joy at how tournaments like this help them to spend time outside their labs and get some relief from academic stress. The chief guests then felicitated the players with medals, trophies and cash prizes for both teams.

Photo: Vivek Khatua

Both the teams together with the chief guests

Following the ceremony, both teams posed for pictures, after which the players left the ground and gathered again at the Sarvam eatery complex in IISc. While sharing and savouring condiments and snacks, we reminisced about our experiences and perspectives. We also regretted not having had a chance to play a tiebreaker and made up our mind to play more matches once the cricket ground became available, with the same teams. With promises to practise more, and each team issuing a challenge to outdo the other, we dispersed soon after.

After the tournament, some of the women participated in the Independence Cricket Tournament organised in August by the IISc cricket club to commemorate Independence Day. Six teams participated in the tournament, each team consisting of at least two or three women playing along with the men. The tournament was a lot of fun and a great learning experience. Meanwhile, efforts are ongoing to replace the members who finished their courses and left IISc, to resume and keep alive the *Police-Chor* rivalry.

Neelima Basavaraju is Data Officer at IISc's Office of Data

For the love of Bangalore

- Pratibha Gopalakrishna

Photo courtesy: Harini Nagendra

Harini Nagendra is a Professor of Ecological Sciences at Azim Premji University, Bangalore. She also leads the university's Centre for Climate Change and Sustainability. Over the past 25 years, Harini has been studying the impact of urbanisation on both the ecology of a city and its people. For her interdisciplinary research, she has received many awards.

Harini has written several books based on her academic research, including* Trees and Canopies *and* Nature in the City. *In recent years, she has also ventured into the world of fiction and written two critically acclaimed books that are part of her crime series:* The Bangalore Detectives Club *and* Murder under a Red Moon. *She was recently in IISc, her alma mater, where she gave a talk about her research.* CONNECT *caught up with her for an interview in which she discussed her passion for urban ecology and writing.

What got you interested in ecology?

In retrospect, I think it happened serendipitously. I did a BSc from St Joseph's College in Bangalore. I majored in Microbiology, Chemistry and Zoology. I then applied to IISc. When I got into IISc, I joined the integrated PhD programme in 1992 with the idea that I would do microbiology or molecular biology.

In the third semester, I did a lab project cloning a gene and purifying a protein. I absolutely hated it. It was just not for me. I would go in at 5.30 or 6 in the morning, leave at 12 at night, and things wouldn't work. I was also worried about using these restriction enzymes – they were expensive, paid for with taxpayer money and I would get zero results; I suddenly realised that I'd spent thousands of rupees on something over the past week. That was a lot of money in 1992. And then, I just felt terrible. I was dissatisfied and was thinking of quitting.

At that time, the Centre for Ecological Sciences (CES) had its 10th anniversary, and there was an interesting talk on evolutionary biology. I went to listen to that talk, but by accident, I ended up hearing Prof Madhav Gadgil's talk. He was talking about the same things that I was thinking of – that India should tackle problems relevant to the Indian context. We should do low-cost research. It was very inspiring. I got to speak to him and ended up doing my first project in CES.

What I've realised now in hindsight is because I was always a city child, I went with my parents for lots of walks in parks. I had an interest in trees, which is ironic because I took zoology, not botany, as I couldn't draw all those diagrams in botanical records. As soon as I started ecology, I realised: "This is it. This is my thing." It was complete serendipity and good fortune that I attended Madhav's talk when I did.

Why did you switch to urban ecology?

After years and years of working in the Western Ghats, Nepal, West Bengal, Central India and other places, I realised that doing work in which I could apply the policy was impossible. I was always partnering with an NGO or an organisation that worked in that local area. I was very particular that we don't do parachuting research, where you come in, you publish, and you go. That was never the aim. The aim was to contribute to something local, but the fact that you are not there, you can't follow up, and given the realities of the Indian Forest Department or the ways in which conservation happens on the ground means that often science is not really taken into account. There is a lot of gap between the two [science and policy], in India and many countries across the world. That was beginning to bother me.

When I came back after my postdoc at Indiana University, I started urban ecology to help activism – by doing very simple things. We had BSc students volunteering with me. I would say, "Let's go count trees and see whether government estimates of trees to be cut on the road are the same as our estimates." We used to find that our estimates were often double [the government's numbers]. We would then put out a citizen's report saying that this is the environmental impact of tree felling on this road or that lake destruction.

Then I started working on a lake rejuvenation project near my house, not as a scientist, but adding that scientific part to the community aspect on lakes, their interconnectivity and hydrology. How should you restore this lake? Why should you not concretise it? Why should you not have lights, parking, and a food court in the middle of a lake? Why is ecology essential? Slowly, I realised that it had far more impact than my scholarly, more in-depth forest work. I also realised that there's a huge need [for science in urban issues]. I find that a lot of younger people want to know what is going on in their cities. They want this information, and they want people to work with them and give them an idea of how to do scientific studies of these things.

Photo courtesy: Harini Nagendra

Book launch of Nature in the City *in Bengaluru. From Left to Right: Girish Karnad, Sugata Ghosh, Harini Nagendra and Ramachandra Guha*

Has your time at IISc influenced your work in any way? If so, how?

My time at IISc was my earliest introduction to ecology. In many ways, the early discussions with Prof Gadgil on this strong idea that we should do locally relevant, low-cost science, and use our brain to come up with ideas are things that have influenced me from the beginning. I was also at IISc when the Indian Academy of Sciences started *Resonance*, a journal of science

education, and I was one of its early writers. I think my interest in science communication and engagement with societal problems came from that environment. The other thing is because of the integrated PhD, I could switch [subjects]. How many people have the fortune of saying, okay, I'm in microbiology, but I want to do molecular biology? The challenge was I knew nothing about ecology when I came in because my course work had no statistics, no ecological principles, no remote sensing software, no GIS.

So, I taught myself everything: coding, statistics, landscape ecology, remote sensing, GIS; I taught myself coding because we didn't have money for software. Self-learning has its limitations, but it also gave me a sense of awareness that I can move into other areas which is, to me, a tribute to IISc's open approach. That's how I took up social science and then, history. Because it never occurred to me [then] that if I don't have the training, I can't do something.

Through your research, you have studied Bangalore's ecological history very closely. Using it as an example, could you explain why the ecology of a place should be a crucial consideration when we develop a city?

People tend to think that in cities, ecology is not the primary concern; development is the primary concern. When they say development, they mean economic growth, and for that, they think you need flyovers, tall buildings, underpasses, and a metro. Of course, you do need them to some extent, but you can't live in a city without clean air, good water, and wellbeing. Why do we need economic growth in cities? It is for wellbeing. But if we don't put wellbeing first, we tend to put economic growth and say, "Never mind if wellbeing is sliding down, we have economic growth" – that is a very lopsided thing.

For example, we have shown that pollution – including suspended particulate matter and harmful gases like sulphur dioxide and nitrous oxides – is hugely reduced just by having trees on the roadside. The surface temperature of the tar road is reduced by about 20-25°C and the ambient air temperature is reduced by about 3-5°C just by having trees. That's huge in terms of its impact on urban heat islands. It has spillover effects whereby if you have trees, you don't need air conditioners; you can travel in a bus, you can cycle, you can walk.

Ecology in Indian cities also provides community social goods – acting as a place of recreation that also encourages people to come together. Migrants say that they bond with the city after being at a restored lake. They say, "I saw a bird or a tree or a flower that reminds me of my village." It could be migrants of all kinds – from migrant labourers to people working in the IT sector, grandparents or elderly people coming to live with their children, and retired people. We were talking to some transgender communities, and they said, "If we stand anywhere, the police keep chasing us, saying you're loitering. But at the lake, we can sit and look at the water. The lake doesn't judge us."

In a city like Bangalore where there is either flooding or drought, the lakes and the wetlands are very important because they are the sponges that hold on to flood water in the rainy season and give it back during the dry season. There are many things that we need nature for, and I think we forget all of this. You cannot import it. I can't think of any way you can have wellbeing in the city without nature.

How can people go about getting educated about their city and giving back to it?

I think we need much broader public education of various kinds: from schools to educating the public, to working with the government because they are the biggest actors at scale – you can't do any public action or education without the government. It is also important to educate corporates because they tend to be very narrowly target-focused – they want to plant trees. But education is more critical than simplistic targets such as planting 10,000 trees. For instance, many companies want to fund sewage treatment plants (STP) to revive a lake. Maybe you don't need that. Maybe what you need is to use this money to restore the wetland upstream of the lake, and that will actually be more sustainable. Because the company may only fund this project for a year; it isn't sustainable – to maintain an STP requires electricity. In contrast, a wetland functions on its own.

Another intervention suggested by my economist colleagues, including Amit Basole and others at Azim Premji University, besides me, was that, just like the Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA), we should have a National Urban Employment Guarantee Scheme. Through this, you could fund a history, sociology or science graduate in every ward in Bangalore, for instance, and embed them in the ward committee to work alongside the corporator. Their job would be to go and document the lives of people in their place, their histories or microhistories, the nature of communities, and their traditions of engaging with nature. They would also document the temperature across the ward and generate a heat map, find out the waste dumping spots, document the local environment and identify troublesome spots, and put it up on a portal. They get jobs, they get training; the public gets information, and it can be a win-win situation. It is a work in progress.

We've been pushing it for a while. Some state governments seem to be interested, but it's a long haul to get something like this actually implemented. In Bangalore, it's very sad that we are an IT city, and we have no good data, not even something as simple as a tree count.

What are some of the biggest challenges you face in urban ecology?

Schools and colleges have been very responsive to our outreach and public education efforts, but to reach out at scale, it is challenging. If you want to work with all the colleges and schools across Bangalore, you need some support from the government. Some departments of the BBMP [Bruhat Bengaluru Mahanagara Palike] were excellent, like the Lakes Department. We worked closely for many years with a really good officer called Mr BV Satish, who was their chief engineer. We managed to get several lakes restored based on good ecological principles. Yet, sometimes it's almost impossible to work with the government on the problem of saving trees because of infrastructure projects. You are often caught in the "Are you anti-development?" talk.

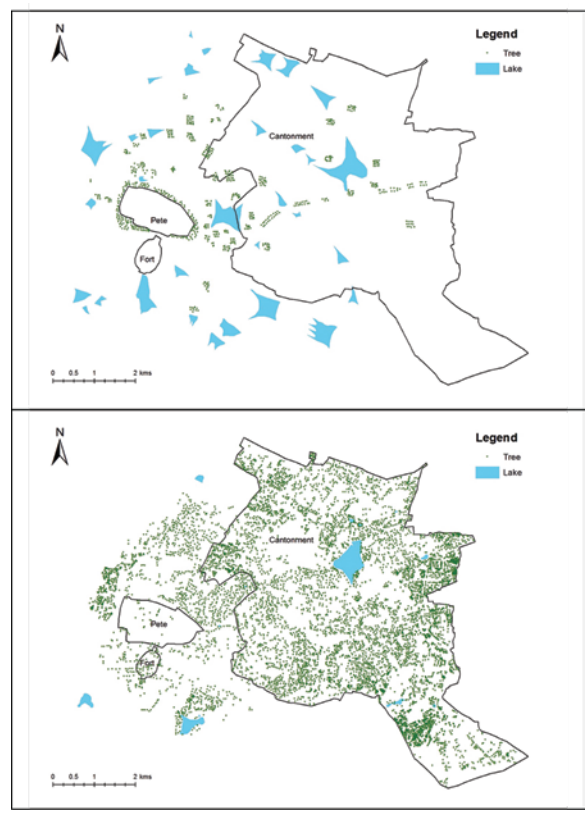
What we ecologists or any experts across the board would like is for the government to involve the public and experts before they start planning the metro lines or before they start thinking of the next five-year plan of growth. That kind of systematic engagement with BBMP doesn't exist – it happens only occasionally, in fits and bursts. As a larger initiative across the city, such engagement also should not be only with one group of ecologists. It should be with the entire community – there are so many groups working in Bangalore.

The other challenge has been to get corporates and industries to engage with ecological restoration in a very systematic way. One or two companies will be keen to intervene sustainably, keeping ecological principles in mind. But most want something done very visibly and quickly. They're not really thinking of the long-term impact. How do you work with them as a group across the city? Where I come back to in every example, is the scale issue. You can work in pockets in the city and those pockets have been very successful. Things are going well in some spots, but how do you actually scale this up across many cities – including Bangalore, Coimbatore, Bombay, Delhi and other locations?

What would you say to a student who wants to pursue urban ecology?

I would say there's no better time than this to work on urban ecology. I've been going to the Student Conference on Conservation Science in Bangalore [a major conference held annually in six cities across the world] for over 20 years. Initially, students would come up to me and say, "I want to do urban ecology, but everybody laughs at me and I'm so excited that you are actually here in this conference talking about urban ecology," or "My professor discouraged me; my fellow students are telling me that this is not worth doing." Now you see at least 30% of the presentations have something to do with urban ecology – it could be about foxes, eagles, vultures, or ants. Yet, there is still not enough emphasis on social sciences related to urban ecology, which I think is a gap.

I feel like jobs are also opening up in the sector now because several corporate groups have an officer working on sustainability. They realise that sustainability is not just turning off the lights, but a lot of it has to do with the ecological processes around them. I meet many sustainability officers when I go to give talks in companies and many of them are environmental science or ecology graduates, which is very nice. I would say for anyone wanting to do this, this is a really good time to do urban ecology in India because opportunities are opening up like never before.



Images courtesy: Harini Nagendra

Maps of Bangalore. Top: 1791, Bottom: 2015

You are now also a well-known novelist. What prompted you to take up writing fiction?

When I was a child, I used to write a lot. In Delhi, where I lived then, there was a Shankar's international children's

competition for art and writing – I won a couple of medals. I also had a small article published in *Femina* – for a children's competition to write plays. When I was at IISc, I wrote scientific articles for *Resonance*, but alongside I also wrote children's stories which got published in *The Hindu* and *Deccan Herald*.

Even when I was in Indiana University, I took a writing class, and wrote a couple of short stories – one got published in an online literary magazine. But somewhere along the way, I stopped writing fiction and science writing took over. My last fiction piece was probably written in 2001. Sometime in 2007, the idea of writing what later became *The Bangalore Detectives Club* came into my head. I'd never written a full book; I'd written lots of short stories but writing a full book and that too a detective fiction novel took a while. It took me about 12-13 years to complete the book – not that I was continuously writing. At some point I just took the plunge and said, "Let me finish this." For me, writing fiction is a return to a first love.

Why did you choose to write a detective series? And how has your research shaped your fiction writing?

I was reading so many archival documents about old Bangalore and came across a lot of rich material which was not directly related to ecology – I wanted to integrate this into a story. Detective fiction, for me, was a natural way to do this, but also an important and useful handle because it's something a lot of people read. You can use mysteries to discuss important issues in a non-preachy, non-judgmental way. I can talk about issues like equity and justice, or discuss what a good life in an Indian city looks like, and speak about communities and collectives. A big part of my work is to showcase how collective power leads to ecological protection. In *The Bangalore Detectives Club*, a group of women – and men – gets together and solves mysteries, along the way addressing societal problems and women's problems. Writing the book really let me explore all of these ideas of justice, collectives, and other issues of urban life together.

I have so much research to draw on – including maps of the city and old newspaper accounts. For instance, from the *Proceedings of the Mysore Representative Assembly* in the 1920s, I got to know about the issues they were discussing, like the budget spent on lakes. I also came across documents with interesting historical details – for example, one detail I had put in the first book was that a tigress in Lalbagh once had cubs and she was not suckling them. So, the zookeepers brought in a local street dog, and she started suckling the tiger cubs. I often find that I have so much fascinating archival material on hand that I don't have to search for anything to put in – I have more than I can use.

Photo: Pratibha Gopalakrishna

Cover of Harini Nagendra's book, The Bangalore Detectives Club

You have a new book coming out in September 2023 called *Shades of Blue: Connecting the Drops in India's Cities*. What is it about?

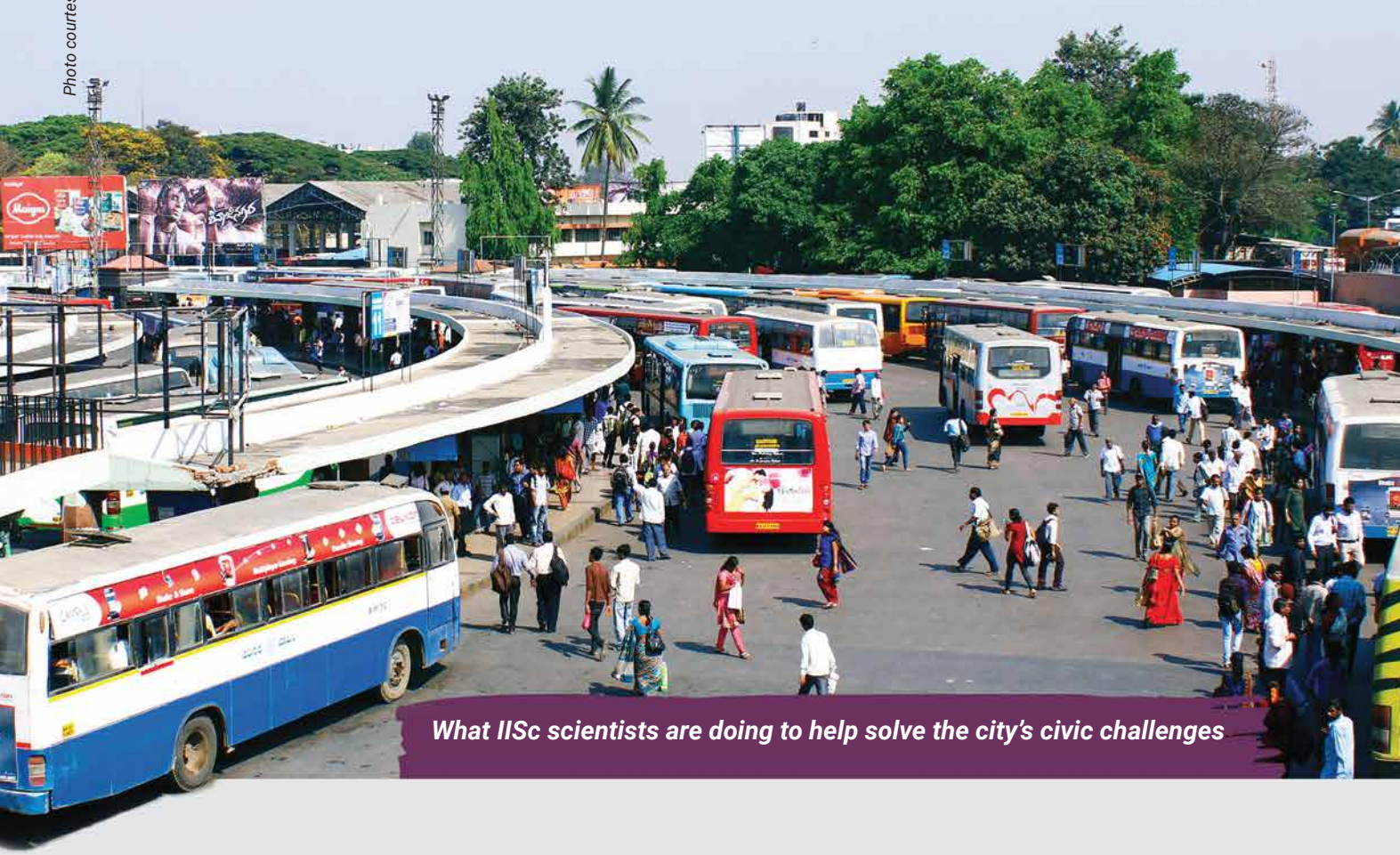
Yes, this is a book written by me and Seema Mundoli, my colleague. When we wrote our previous book *Cities and Canopies*, which was about trees in Indian cities, our editor at Penguin – Mansi Subramaniam – approached us with a book idea to write about rivers in Indian cities. After thinking about it for a while, we agreed to write a book but not only about rivers. In our book, we have short chapters diving into different aspects of water – wells, mythical beasts and water monsters, music and songs around the lake, the ecology of restoration, water warriors, how lakes and water bodies have been used for transportation, and so on. There are also short chapters on cities like Kolkata, Udaipur, Bangalore, Hyderabad, Bombay, Delhi – cities whose histories are closely tied to water.

We try to take off our scientist hats and relate to how people think of water from many perspectives: ecology and culture, science and spirituality, and at the core, the idea of organising communities around water. We cover a range of topics, from issues of justice and equity, to who gets the water in an Indian city, to the ecology, geography and chemistry of water and so much more – maps, mythology, music, history and everything else you can think of. Writing this book was great fun.

Easing Bangalore's pains

- Sandeep Menon

Photo courtesy: Hayathkhan.h/Wikimedia Commons



What IISc scientists are doing to help solve the city's civic challenges

In the 2014 Malayalam film *Bangalore Days*, the character played by actor Nivin Pauly is asked during a job interview about his opinion of being posted in Bangalore city. With a shy smile, he thinks, "Who can say no to Bangalore?"

That one statement conveys the attraction the "garden city" holds in the hearts of those seeking a better life. Many parts of the country have their unique allure, but not many can deny that Bangalore remains a popular destination. Scores move to the city in search of better education and job opportunities. Bangalore is an IT hub, a fertile ground for ideas and startups.

But Bangalore is also a city struggling to come to grips with this mass migration. This influx has led to the city ballooning unscientifically, its urban sprawl gobbling up newer lands as the city heaves under the demands of an exploding population. Traffic, infrastructure, waste management, urban flooding, and demand for water and electricity are all increasing, bringing greater and newer challenges every year.

In the heart of this burgeoning city, IISc occupies a sprawling canopy-covered piece of real estate. But what is the Institute, known for its century-old legacy of nation building, doing to help alleviate the maladies of

Bangalore? How are its scientists helping the city tackle its infrastructural and socio-economic problems?

"People sometimes ask what is IISc's contribution to society," says Anjula Gurtoo, Chair of the Centre for Society and Policy (CSP), IISc. There are scientists at the Institute who do fundamental research, she adds, but many of them also work on application-oriented research – some even addressing the city's problems.

Anjula's own group, for example, works with the state government to make policy decisions that can make the city safer for women. "Women often face harassment in buses. Our centre has provided a research-based policy document to the government, recommending steps to be taken such that women can travel without any apprehension," she says. The Directorate of Urban Land Transport (DULT) took their recommendations seriously and is implementing some of these policy decisions, Anjula adds.

It is not just policy recommendations that IISc scientists are helping with. Many of them have actively stepped out into the city to produce solutions for civic issues such as urban flooding, power supply interruptions, infrastructure collapse, and traffic congestion, working closely with government organisations.

Out on the streets

If there is one thing Bangalore's visitors complain about, it is the city's never-ending traffic woes. Fortunately, several scientists at IISc have been trying to develop solutions for such mobility challenges. IISc's Centre for infrastructure, Sustainable Transportation and Urban Planning (CiSTUP), for example, has faculty members and students working on traffic congestion, public transport, and urban planning, as do researchers in the IISc Sustainable Transportation Lab of the Department of Civil Engineering (CiE) run by Ashish Verma.

"We are working on several projects with the authorities, including Metro master planning, feeder routes, and schedules for last-mile connectivity," says Ashish.

His lab's partnership with the Bangalore Metropolitan Transport Corporation (BMTC), Ashish explains, has helped the agency rationalise bus routes and services, improve the reliability of public transport operation, and address safety issues in public transport. "In the last 14 years, we have worked on all aspects related to this area."

Ashish and his team have long preached the virtues of focusing on last-mile connectivity and improving public transport infrastructure to help ease the city's traffic woes. Their research shows that the city needs 80% of its daily commute to be via public transport. But expecting people to change their behaviour – switch from private vehicles – without improving footpaths and roads or offering better last-mile connectivity, is pointless, he explains. "Metro cannot come to your door."

To highlight how public interventions can change people's attitudes, Ashish's lab embarked on an interesting experiment in November 2020, partnering with UK and Indian government agencies. They picked one of Bangalore's iconic streets – Church Street – and decided to restrict it to pedestrians on the weekends.

One of the most famous streets in the city, it attracts huge footfalls, is easily accessible via public transport and has become more pedestrian-friendly with recent renovations such as expanded sidewalks. The findings from the project were significant. During the test period, footfall in the metro station increased by more than 100%. Restaurants and gift shops also saw an increase in footfall. Street vendors enjoyed unprecedented sales. There was a 25% improvement in air quality, a reduction in noise pollution, and an 11-15% increase in a shift to public transport, walking, and cycling, according to Hemanthini Allirani, a PhD student who worked on the project.

Photo courtesy: Ashish Verma

People enjoying their walk on Church Street during the time it was pedestrianised

Two years after the test, the social activities that picked up pace during the test period – live music, street shows, and artists selling paintings, jewellery, crafts, and other trinkets – continue to this day.

"Pedestrians are reclaiming the street by themselves. It has induced a positive behaviour change. These kinds of spaces become vibrant social places and help social wellbeing," Ashish remarks.

Such has been the success of the project that the authorities are mulling over the idea of expanding this project to other parts of the city. "DULT has identified eight such streets to implement this project," adds Hemanthini.

Ashish feels that just doing such research is not enough. He believes that scientists should also be active participants in social discourse, attending town halls and citizen discussions. He himself has attended and spoken at several such spaces; most recently he lent his voice against a proposed flyover on Sankey Road, which he believes – a view backed by research – will not help solve the problem of traffic congestion in the area.

"Mobility is an area where we do research and come up with solutions, [but] we do not have the power and privilege to implement it," explains Ashish. "You can empower common people. A research lab like ours can go and educate [people] so that they are empowered to ask the right questions to their elected representatives. It is a way to translate your research for the betterment of society."

Photo: courtesy: Ashish Verma

Ashish Verma (centre) speaks at a public meeting organised by the Bengaluru Bus Prayanikara Vedike (BBPV), where testimonies of bus commuters were heard

Water, water everywhere

Two other areas that have been feeling the pinch of the city's growth are water consumption and sewage treatment.

A few years ago, the state government decided to carry out a large project to tackle these twin issues. The booming population meant that the city's water consumption, and by extension the amount of sewage water generated, had increased. At the same time, neighbouring districts like Anekal, Chikkaballapur, and Kolar were facing a water shortage with reduced rainfall and falling groundwater levels. To tackle this, the Government of Karnataka decided to treat the sewage generated in the city of Bangalore and transmit the treated water to existing lakes and tanks in neighbouring districts. The key issue was to ensure that the sewage water was treated properly before sending it to the water bodies in the neighbouring districts of the city.

But the project faced legal hurdles due to complaints that the treated sewage water had heavy metals and hence there were delays in the execution of the project, according to KS Nanjunda Rao, Chief Research Scientist in the Department of Civil Engineering. IISc was approached to check the quality of treated water before it reached different lakes.

Faculty members from the Centre for Sustainable Technologies (CST), HN Chanakya and Lakshminarayana Rao, were at the forefront of this investigation. They checked the processes put in place for treatment and transmission and made suggestions; their findings convinced the Supreme Court to vacate the stay order it had placed.

"Currently the project is in its fourth phase. A huge number of tanks in Chikkaballapur, Chintamani, Kolar and so on, are now filled with the treated water. The water quality – according to the report submitted by the CST faculty – is good, and they can use it for irrigation," Nanjunda Rao says.

He adds that IISc researchers have been working with the Bangalore Water Supply and Sewerage Board (BWSSB) for over a quarter of a century, on projects like redesigning infrastructure to speed up the pumping of Cauvery water to the city.

Removing excess water is equally challenging. Urban flooding has quickly found its place in the popular lexicon thanks to factors like rapid and unplanned urbanisation and encroachment of natural water bodies.

To address this problem, IISc scientists have developed high-resolution 3D terrain maps to understand how water flows during urban floods. The project, fronted by the Interdisciplinary Centre for Water Research, with collaborators including the BBMP and Karnataka State Natural Disaster Monitoring Centre (KSNDMC), focused on a holistic approach – from estimating the water level in different localities to improved forecasting, better land-use management, and urban planning. The team also suggested measures like adding more lawns and gardens, using porous concrete to allow groundwater recharging, and large-scale rainwater harvesting.

Nanjunda Rao points out why it is important for scientists to work on such solutions, even if they are not challenging research problems. One reason, he says, is that engineers in government departments may not be up to date with current technologies and advances, and may be bogged down with routine work, like site visits and preparing tenders. "We have updated knowledge, being academics. Adopting new techniques and involvement of faculty from the institution will help build safe and economical infrastructure," he says.

Lighting the bulb

A few years ago, when an ambitious Smart City project was launched on a sprawling 4,000-acre patch of land in Kempe Gowda Layout, a key challenge was planning the electricity supply and layout for the entire infrastructure. Which is why the authorities decided to rope in scientists from IISc's High Voltage (HV) Lab in the Department of Electrical Engineering (EE), and the Department of Electronic Systems Engineering (DESE), as consultants.

"We looked into the design of cabling sizing, HT and LT electrical installations, sewage treatment and pumping

stations, 11 kV RMU, feeder pillars, smart street lighting, earthing and lightning protection schemes, and so on. We looked at the finer design aspects of each and everything," recalls B Subba Reddy, Chief Research Scientist at the HV lab.

Another project that Reddy and L Umanand, Professor in DESE, worked on was technical validation of an overhead 25 kV electric traction interference with a 750 V DC metro traction system. This complication arose over a 600 m stretch where a metro line, a traction railway line and a road overlapped. Rail Infrastructure Development Company (Karnataka) Limited (K-RIDE), which was coordinating with the Bangalore metro and state government, was worried about the different electrical lines crossing each other. Reddy's team suggested a novel design for minimum static clearances and special shielding arrangements to ensure safety. They also came up with recommendations for mitigating electromagnetic interference (EMI) and earthing, with three layers: the first for vehicles, the second for rail traction and the topmost layer for the metro.

"[But] there were concerns that there could be EMI and electromagnetic compatibility issues. So, we did a lot of simulation studies and gave a design with shielding [included]. The project just got government clearance."

Image courtesy: B Subba Reddy

Representative diagram of an innovative three-layer transportation solution given to the authorities to overcome space complication in the city

This is not the first time that researchers from these departments have worked with government agencies. Reddy adds that some of them have played a key role in the setting up of the Central Power Research Institute (CPRI) and have worked on several consultancy and research projects for the defence and space sectors, and other industries. They have also designed, evaluated, and tested components for 400 kV and 800 kV power transmission systems, and the first transmission lines set up by Powergrid Corporation of India Limited, according to Reddy.

Reddy himself has been working with Namma Metro and BESCOM (Bangalore Electricity Supply Company Limited) on several issues related to underground cables, overhead transmission, and substations for years. "Whenever industries, utilities or any other agencies approach, we help," he adds.

BESCOM even took the help of EE researchers to help tackle the overwhelming volume of calls during power outages, especially in the summer. Researchers from the Institute, led by Gurunath Gurrala, Associate Professor and AG Ramakrishnan, Professor in EE, worked with a couple of startups and proposed a project to develop an AI-powered human-like voice bot that would field routine calls, with only the more complicated issues being passed on to human operators. The team sifted through the calls, classified them into categories, and crafted automated replies for the voice bot. What they found to be the biggest challenge was the language itself.

"We realised that Bangalore is a city with linguistic diversity, mixed accents, and mixed languages in a single sentence," says Gurunath. "One of the main problems a voice bot faces is differentiating between accents. We worked on a proposal for building a tech that worked on mixed languages, especially recognising speech with mixed sentences." However, the proposal didn't take off at the last minute due to the state government change at that time, he adds.

Infrastructure challenges

In 2018, the Bengaluru Metro Rail Corporation Limited (BMRCL) had a quandary on its hands. Its engineers had noticed that a railing was cut near Trinity Station. Further investigation found structural issues with pillar 155 – a 2 m deep crossbeam in which the concrete had not been compacted properly. Unsure of how to proceed, the authorities contacted JM Chandra Kishen, Professor in CiE.

"One of the bearings got crushed because it was tilted. They could not replace the bearing," he recalls.

It was a defect that should have been rectified in the construction stage itself. Finding a solution now, with the metro line in full operation, was not going to be easy. "We told them that the whole structure must be lifted and the bearings replaced. But if you lift the whole structure, and you are not careful, it will crack at many places," Chandra explains.

Chandra's team set to work. On a Sunday evening, metro operations were stopped. The team deployed almost 30 electrical resistance strain gauges to monitor the lifting and replacement.

"We had a large monitor, and the procedure was done carefully, step by step, so that the concrete doesn't exceed a certain limit of tensile strength. We lifted the viaduct, including the crossbeam that had developed gaps in concrete, before reinforcing the damaged part's structure. We had specially made bearings to fix the issue."

The team then monitored the structure for the next month to ensure that there were no complications.

"When there is some damage or problem with infrastructure, they consult us: BBMP, BDA, NHAI, Indian Railways, Indian Army ... our work is on out-of-the-box solutions and health monitoring of infrastructure," says Chandra.

Chandra's lab has been working on such solutions since 2007, when they were first approached by the Indian Railways to check the strength of the Dudhsagar bridge near Goa, as they were worried about the load-bearing capacity of the bridge, constructed during British rule. "The Indian Railways wanted to upgrade their infrastructure. They were transporting iron ore from Goa to other places." The Railways wanted the bridge to have a carrying capacity of at least 25 tonnes per axle. Chandra's team did extensive testing with sensors and found that the bridge could easily carry up to 35 tonnes. "This was the first project where we did an actual field test," he reveals.

Since then, his lab has been in regular contact with various government agencies on projects ranging from checking the structural integrity of infrastructure to postmortem analysis of structural failures. When the metro pillar collapsed earlier this year on Outer Ring Road in Bangalore, tragically killing two people, it was his lab that was roped in to analyse the damage and cause.

Photo courtesy: JM Chandra Kishen

Testing of the Dudhsagar bridge near Goa with loaded railway wagons

Another recent example is a 4.2 km long bridge in Goraguntepalya near Peenya, which has remained shut for heavy vehicles for well over a year, as it started showing signs of distress. "Fifty-eight cables inside the structure have snapped with corrosion. Demolishing an old bridge and building a new one will cost around Rs 4,000 crore. We did extensive study and load tests on the bridge. We looked at how this can be retrofitted. We also suggested adding additional cables to the existing structure to enhance the flyover's carrying capacity." Based on his suggestions, the authorities have started adding about 240 cables, two cables per span (the distance between two pillars), Chandra says. The modifications have helped keep the cost down to just Rs 30 crore, apart from preventing the damage, dust pollution and noise that would have been caused by building a new bridge.

Photo courtesy: JM Chandra Kishen

Picture showing the broken cable inside the bridge near Peenya

Chandra adds that working with diverse government agencies has helped them apply learnings from one experience to another. He was once involved in an aqueduct project to bring water from the Western Ghats to the city, which allowed him to work with large prestressed concrete structures. "Everything was done on the ground, lifted, and placed in its position." Later, when he was asked to consult on the ongoing metro construction near the airport, he realised that similar precast structures could be used to build the viaducts.

"The structures for moving water are so huge that two trucks can go inside. So, with the metro structure being lighter, we suggested that they go for precast technology. Now the airport line is all precast." He adds that this approach can cut down two years of construction time. "There are no textbooks to find solutions for these kinds of failures or challenges," explains Chandra.

"We work on different techniques to try and find unique solutions based on each case. We [also] take students and train them in real-world situations."

The projects that Chandra and others have worked on are only some examples of the city-building work that the Institute's researchers have done. But an arguably more important and less visible contribution has been training students and producing graduates capable of tackling such problems out in the city and the world.

"IISc gives PhDs, which is the first step in enabling solutions. Students leave the Institute, enter different industries, and take [their learnings] forward," says Gurunath. "That is the Institute's role, to produce independent thinkers and arm them with knowledge."

The Digital Librarian

- Karthik Ram

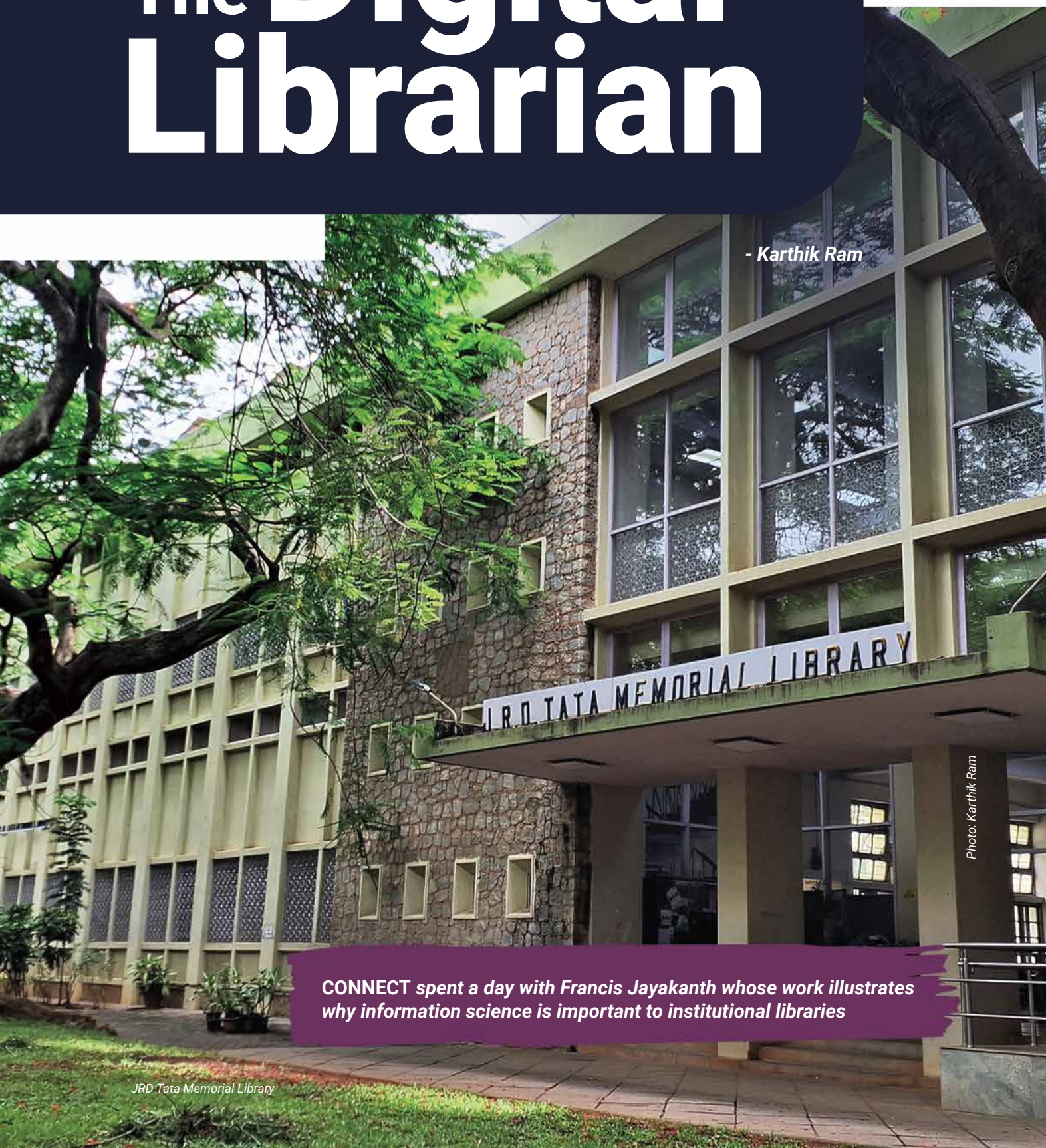


Photo: Karthik Ram

CONNECT *spent a day with Francis Jayakanth whose work illustrates why information science is important to institutional libraries*

JRD Tata Memorial Library

Despite the overcast mid-July sky, the campus of IISc wears an inviting look. It has been bathed in recurring showers, courtesy the monsoon which by now is in fine fettle. Down the main gate of the Institute, along the Gulmohar Marg, stands a large but understated building from the early 1960s, housing the JRD Tata Memorial Library. In the south wing of the first floor, a conference room doubles as the office of Francis Jayakanth, as he awaits the renovation of what will be his more permanent office.

The makeshift office has computers, filing cabinets and old-school steel Godrej almirahs holding neatly arranged books, files, and other official documents. At the centre of the room is a large, oval table with several office chairs around it, many still protected by the plastic wrap in which they came. Francis' workstation – closer to the window on the right side of the room – comprises a desk, a computer, an office chair, and a printer. The room, although crowded, does not feel cluttered because of the high ceiling and four large windows. The windows offer an impressive view: Snaking brown branches of Gulmohar trees are interspersed with their characteristic vibrant green compound leaves; and perched precariously on these leaves are the blazing orange-red petals of the flowers that were ripped out by the overnight storm.

Francis, wearing shades, arrives at the library at 9.15 am and immediately scurries up to his office upstairs. The 62-year-old Scientific Officer is dressed in a neatly pressed powder blue full-sleeved shirt and black trousers. A pair of brown shoes and a brown leather belt complete his attire. He replaces his shades with regular glasses, tidies up his office, and puts away the teacups and saucers from the previous evening.

Francis sits at his desk and opens his mailbox to check emails that may require urgent attention. "For instance, someone may have asked for credentials to login to Turnitin [plagiarism detector software]. Or quite often, students ask for initial registration links for various academic databases that IISc subscribes to."

"No such emergency emails today," he says, satisfied.

The next order of business which Francis attends to, at 9.35 am, is to check the library servers that are on the cloud. "Last night, one of the servers, which we manage with SERC [Supercomputer Education and Research Centre] – on which the electronic thesis and dissertation repository runs – was down. So, I wrote to DIGITS [IT support at IISc] and Mr Filbert Minj from SERC. There was a technical issue, and he has fixed it."

Francis continues with his emails, occasionally taking a sip of hot water from his aquamarine thermos.

About 20 minutes later, he gets up from his chair. "I can't sit for long periods." As he stands up, as if by magic, the desk starts rising too – it is one of those standing desks whose height is adjustable.

Photo: Karthik Ram

Francis in his makeshift office

At 10 am, Francis receives a request from the Chair of a department at IISc. The Chair has suggested that the library subscribe to a few additional journals and has asked whether IISc can have a read-and-publish agreement with the publisher of some of these journals. The agreement would ensure that the subscription will include the article processing charge (APC), a fee that is often charged by a journal to authors publishing in it. The APC for a journal can be quite high, ranging anywhere from $600 to $11,000 per paper, Francis says. So, in the last few years, IISc's library has been entering into such read-and-publish agreements with journal publishers, if it is cost-effective for IISc. "For example, in 2021, we entered into such an agreement with Cambridge University Press [CUP]. The cost difference was not much, but in the process, we also got access to more journals. Previously, we used to pay around £7,000-8,000 for seven or so titles. Now we pay £14,000 and get access to all the science journals of CUP – more than 130 journals. Besides not having to pay APC, there is one more advantage. Once published, an article [by our authors] automatically becomes open access." What Francis means when he says "open access" is that the article can be accessed by anybody reading online, free of cost.

Francis' primary responsibility at the library is to manage subscriptions for academic journals and databases. "IISc's library has about 65-70 subscriptions with journal publishers. Our present budget for online journals and databases is Rs 20.50 crore. Books and e-books are not included in this budget."

Each year, at the start of the last quarter, the library receives renewal invoices from the publishers. Although there is room for negotiation, they typically hike the subscription cost by 4-6% annually. IISc's faculty members also request access to new journals. So, the library has to prioritise its subscriptions. "What

we do is to take the usage data for each journal from the first three quarters and determine what is called the *cost per download* for that journal. If this is high, then we write to the respective departments and seek their feedback. If they insist that we continue with the subscription, we go by their suggestion because they are the ones who know the value of the content." Francis then creates a budget proposal with the information he has gleaned from the journals and the departments, and he presents it to the Institute's Library Purchase Committee. "By December, we get the budgetary allocation, and the renewal process starts."

But the arrangement with publishers is not without its challenges. "Sometimes, what happens is that we have visitors on campus, who are invited by faculty or students. When they see the journals they can access, they end up downloading too many articles. This is called systematic downloading. At times, even our own students do it if they are graduating and feel that they may not have access to these journals in the future." In the event of a *systematic download*, access to the journal is cut off by the publisher. It is Francis' job to convince them to restore access.

Photo courtesy: Francis Jayakanth

Francis (standing, second from left) with his teacher and classmates at Nirmala Rani School

While subscriptions are important, having an easy-to-access library website for users is equally critical. And for this, the library needs a well-designed content management system, one that would help manage and retrieve huge amounts of data. The IISc library's content management system was conceived and developed by Francis. "We use Drupal [a free, open-source software] for managing our content. I had experience in it. So, I started working with it in the background at home. Once it took some shape, I brought it here and we started configuring computers and adding content."

At 10.15 am, Francis moves to his next task: Getting a document ready for an external audit of the subscription purchases, conducted annually by the office of the Comptroller and the Auditor General (CAG). The whirring sound of the printer suggests that the document is ready, which he decides to take by himself to the Finance and Accounts (F&A) section.

As he steps out of the library, Francis switches back to the dark glasses. "My eyes are sensitive to light. I used to live in Basaveshwara Nagar but because driving at night was becoming difficult, I moved back to campus," he says.

Francis says he moved "back" to campus because this is where he grew up. He is the son of GD David, who served as Secretary to Satish Dhawan, IISc's former Director. Francis' favourite memories of growing up in IISc revolve around sports. "I used to be a sports enthusiast. I would go to TMC [Tata Memorial Club] to play carrom and table tennis. I would also play table tennis at the Faculty Club. We had a couple of grounds where I would play cricket," he recalls.

Francis went to several schools, including Nirmala Rani Primary School in Malleswaram. He graduated from MES College, also in Malleswaram, majoring in Physics, Chemistry and Mathematics. His first job, which he started in 1982, was in the Department of Post and Telegraph. "I had a permanent position there, but somehow, I was not happy." During this period, he became curious about computers and joined computer courses in FORTRAN and COBOL being offered at the Centre for Continuing Education and at the Department of Chemical Engineering at IISc.

In 1984, Francis learnt about a Project Assistant position that had opened up at IISc. The position required the candidate to work with the mainframe computer and have a knowledge of COBOL. "I applied and I got this job and took it up even though I [already] had a permanent position." He worked on the project until its completion in 1986. As it wound up, he came across another job opening in IISc, but this time it was for a permanent position at the National Centre for Science Information (NCSI) which had been established just a few years earlier. He applied for the advertised position and was hired.

Francis, who ended up spending most of his working life at NCSI, spells out its mandate. “Our former librarian, TKS Iyengar, came up with the idea of the Centre. Its goal was to provide information services to researchers in all universities in India, in all STEM fields.” It would subscribe to leading databases of abstracts of research articles – which were then available electronically on magnetic tapes – and construct a profile for each registered researcher based on keywords they provided. NCSI built software, a separate one for each discipline, to match researchers with abstracts of articles that would be relevant to their research.

“Researchers could then approach the library for full-text versions of articles. NCSI would also subscribe to some leading journals. Apart from that, we had a tie-up with the British Library and the National Library of Australia for full texts of articles of some other journals. This was a very successful venture.”

During its heyday, the Centre also had a one-year training programme, which was eventually upgraded to an 18-month course. Its goal was to train newly minted library graduates on how to handle digital information services. “Over 150 students were trained as part of this programme and its alumni are well placed in academia, government and the corporate sector. In fact, our former Librarian, whom we unfortunately lost last year, Dr Anand Byrappa, was a product of this programme,” says Francis.

While he was at NCSI, Francis also did his PhD from Bangalore University in information sciences. “Luckily, I got a Fulbright Fellowship and went to the Old Dominion University in Virginia for six months.”

Photo courtesy: Francis Jayakanth

Francis at NCSI (the building now occupied by the Office of Communications) with magnetic tapes holding scientific abstracts to his left

In 2012, IISc merged NCSI with the library. Not long after, Francis received a job offer from the Indian Institute of Management Bangalore for the position of Librarian. “I took up the job. But instead of resigning [from IISc], I joined them on lien. In terms of position and monetary benefits, it was much better than IISc.” But he missed the Institute. So, he came back a couple of years later to continue his work at IISc’s library.

Photo courtesy: Francis Jayakanth

Francis (top row, third from left) with NCSI colleagues and other faculty members

By 11 am, Francis is done at F&A and heads to Nesara restaurant for a quick cup of coffee. He talks extensively about the changing nature of libraries and librarians, as well as what IISc’s library should do to adapt.

Francis is back in his office at 11.30 am. He attends to a work-related phone call and then checks for posts in LIS-Forum, an online discussion group for librarians and information professionals across India, that he has moderated for over 25 years. It comprises over 6,000 library professionals from across the country.

Like voluntarily moderating LIS-Forum, which is not part of his job description, Francis often goes beyond the call of duty. During the COVID-19 pandemic, not everyone from IISc could access online resources. “People were confined to their homes. Though IISc had in place mechanisms for them to access online resources remotely through VPN, there are people in the IISc community who do not automatically get a VPN connection – project assistants, postdocs, etc. Besides, there is a limit on the number of users the VPN server can deal with simultaneously. So, we had to come up with a solution quickly.”

The solution involved an open-source software called Shibboleth, which Francis says is secure and time-tested. “In about two weeks, we were able to set up the server. Anyone with an official IISc email address could gain access to online resources.” The service, adds Francis, continues to be popular even after the pandemic.

Yet another project that Francis has been involved in is ePrints, an open-source repository of publications and pre-prints from IISc. It started in the late 1990s, when the open-access movement was gaining popularity. "We are still updating it on an almost daily basis. Today, we have over 62,000 IISc publications on this repository. It is not exhaustive, but I estimate that about 85% of all publications are part of this." Francis, however, is disappointed that in the case of papers published in journals that IISc has no subscription to, he is only able to upload the final accepted version of papers, and not the publisher's version. He feels that it is, therefore, important that IISc implements an open access policy, which will ensure that copies of all the accepted publications are given to the library.

Francis has also been involved in several training programmes outside IISc. "We have conducted many workshops to help other institutions do what we have been able to do, especially in our early days – for instance, setting up open-access institutional repositories and content management systems. We helped set up facilities in places like Bangalore University, National Aerospace Laboratories, Indian Academy of Sciences, National Institute of Advanced Studies, etc."

In recent years, Francis has been associated with yet another information technology project. In 2017, the Institute decided to move its IT infrastructure, including servers, to the Microsoft Azure cloud platform. The library, at that point, oversaw five on-premises servers for services like ePrints and electronic theses and dissertations. Three of these servers were in the library and two in SERC. "All of these had to be moved to the cloud platform," says Francis, "which we did in six months in early 2018."

Back in his office, Francis works standing at the desk in front of the computer, until he breaks for lunch at 1.15 pm. "I go home for lunch. Typically, it is proper South Indian food – sambar rice, pallya and curd rice," he says.

Francis returns to work at 2.15 pm. "Afternoons are when I try to implement some new things at the IISc library. For example, now I'm trying to set up a repository for data management. We already have them for theses and dissertations and IISc's publications, but we don't have one for data [data generated during research]." He pauses and continues, "See, we have so many labs where students are generating data day in and day out. Once the end goal is achieved, what happens to the data?"

"So, we need a dedicated, centralised repository. I have already experimented with one open-source software. Now I am experimenting with a second, C-KAN [Comprehensive Knowledge Archived Network]. It's a software which even the governments of India, Singapore, and Australia use." Francis hopes to set up a prototype using sample data from a few labs and introduce it to the campus community so that it can become part of the library's regular service.

At 2.30 pm, Francis joins a Zoom meeting to discuss C-KAN with members of the DST-Centre for Policy Research (DST-CPR) at IISc, with whom he is collaborating to conduct a workshop soon. Once the meeting is over, he points to the three computers on the right side of the room and says, "These systems are used for such projects. I have a trainee who comes regularly and helps with some of our routine work as well as this project."

Francis is consumed by the C-KAN experiment for the rest of the afternoon, only to be interrupted by the arrival of a cup of tea, which he drinks sitting at the oval table.

Francis uses this opportunity to reflect upon his journey at IISc, one that he describes as "enriching". "My time here has been nothing short of transformative, shaping my professional and personal growth." He is, in particular, grateful to the former Chairs, Coordinators, and his colleagues at NCSI. "Prof V Rajaraman, Prof N Balakrishnan, Prof S Ramashesha, Prof AG Menon, Prof NV Joshi, the late Dr TB Rajashekar and several others have guided and inspired me throughout my journey at the Institute." In the same breath, he also mentions the name of one of India's leading information scientists and currently a Visiting Scientist at DST-CPR, Subbiah Arunachalam, who has been Francis' cheerleader for many years now.

Photo courtesy: Centre for Internet and Society

Francis was the first winner of the EPT (Electronic Publishing Trust, UK) Award for excellence in promoting open access in the developing world. He received the award from MS Swaminathan at a special function organised in Chennai in 2012. Also seen is Subbiah Arunachalam

After he finishes his tea, Francis continues to work on C-KAN until 5.30 pm when he packs up, puts on his shades, and leaves the library building, only to be back here the next morning at quarter past nine.

When teachers become students again

- Bitasta Das

Photo: Bitasta Das

Trainees at the chemistry laboratory performing a salt analysis

Tracing the growth of a model training programme at IISc's Challakere campus

Smita Bala Panda is among the 112 teachers who have travelled from Odisha to participate in the Teachers' Training Programme at the Talent Development Centre (TDC), in the IISc Challakere campus. She covered the journey from Ganjam district to Bangalore via train, then took a bus to finally reach Challakere late on 3 August 2023. The 10-day training will begin early next morning. Smita teaches biology to students from class nine to class 12 at the Odisha Adarsh Vidyalaya school in Hinjilicut, a small town in Ganjam district. She manages 160 students almost single-handedly – teaches them theory, conducts practicals, organises "doubt" sessions and remedial classes. Though there is no lack of infrastructure in her school, there is a pressing need for trained instructors, as only one demonstrator is available to teach all three disciplines – physics, chemistry and biology – for all four classes, each having two sections with 40 students per class.

The role that teachers like Smita play is critical to society. By training the next generation of leaders, professionals and citizens, their impact goes far beyond the classroom – to communities, cities, and the overall development of the nation. Hence, it is crucial that such teachers keep themselves updated with novel and effective teaching methods and pedagogical approaches. Unfortunately, their demanding work schedules do not allow them to stop and evaluate their own teaching process, or clarify doubts, or update their knowledge. It is this gap that the TDC, established more than a decade ago, sought to address.

Making a difference

In 2019, when the TDC was nearing 10 years of existence, its convenors decided to carry out a self-assessment study among 24 randomly selected government schools in Vijayapura, a district in Karnataka. In the study, the percentage of students who scored more than 60% marks in science and mathematics in the Secondary School Leaving Certificate (SSLC) exam was plotted for five consecutive years (2015-2019). Strikingly, in certain schools, the number increased by 30% between 2015 and 2019. It turned out that the science and maths teachers in those schools had all been trained at the TDC.

India has various teacher training programmes organised by several institutions under diverse schemes. TDC stands out amongst them because of its approach – learning by doing. The residential programme offers training to teachers from the high school (standards 9-10) level to the MSc level, in physics, chemistry, biology and mathematics. The duration of the training varies depending on the content that is required to be covered. High school teachers spend 10 days, whereas BSc and MSc teachers spend up to 16 days at the Challakere campus. Science teachers are trained using experiments, while mathematics teachers are taught problem-solving approaches. These experiments and problems are designed, devised and disseminated by the TDC.

"Almost every line of the National Council of Educational Research and Training (NCERT) textbooks has been converted to an experiment or a problem," says DN Rao, former Professor at the Department of Biochemistry, IISc, and the present convener of the TDC. "These experiments and problems – and their corresponding manuals – cannot be found anywhere else. The equipment and experiments are designed in-house at the Centre."

The Centre also has ample laboratory facilities; at any given time, 50 individuals can carry out the experiments. The state government nominates the participants for the high school teachers, and the respective school boards nominate the 11th and 12th standard teachers. Besides this, the Jawahar Navodaya Vidyalaya schools and the Kendriya Vidyalaya schools also send their teachers every year. Each batch consists of about 100 teachers. About 18 such batches are trained per year. Karnataka has 18,500 high school government science and mathematics teachers. As of June 2023, 16,000 of these teachers have been trained. A total of 18,000 teachers from across the country have been trained at the TDC.

Photo: Bitasta Das

Chemistry models built in-house for teaching

Born on a sheep farm

This is not the first time that IISc has trained teachers, which could be a possible reason why the Institute has been able to sustain this programme successfully. In the late 1970s, some faculty members, motivated by the virtue of giving back to society, travelled to rural parts of the state to train high school teachers. Since the 1980s, under the aegis of the Centre for Continuing Education (CCE), IISc faculty members have been travelling across Karnataka to train science and mathematics high school teachers.

But it was only in IISc's centenary year (2009) that a consolidated teachers training programme was conceived at the newly acquired Challakere campus. The then Director, P Balaram, reached out to MS Hegde, who was then Professor at the Solid State and Structural Chemistry Unit (SSCU) and was actively involved with CCE's teachers training programme. Balaram asked Hegde if a full-fledged teachers training programme was feasible at Challakere, and if the latter could spearhead it. A committee was formed, headed by BN Raghunandan, former Professor at the Department of Aerospace Engineering, to assess the programme's prospects. Armed with ideas, the committee, along with Hegde, set out to visit Challakere.

At that time, however, the newly acquired campus had no infrastructure to house such a programme. Around the same time, the Government of Karnataka's Department of Animal Husbandry freed up two buildings that once used to be sheep breeding farms, close to IISc's Challakere campus. These two buildings were loaned to IISc to start the programme. Hegde located another 28 buildings and a dilapidated sheep

breeding farm in the vicinity that could also be used. It was decided that the programme would start under this temporary arrangement until the campus infrastructure was ready. Funds for the programme came in the form of a Rs 2 crore grant from the Department of Science and Technology, Government of Karnataka. On 26 February 2011, the then Chief Minister of Karnataka, BS Yediyurappa, inaugurated the programme and TDC at Challakere. In March 2011, the report from the first training programme was presented before the IISc Court and was instantly appreciated. The Government of Karnataka approved a grant of Rs 1.5 crore for the subsequent year.

Hegde recalls that it was a satisfying but uphill task to get the programme off the ground. "It was a tough job; everything did not go through easily. It was an extremely underdeveloped district. There was only one source of water: a borewell. There were times when it failed and there was no drinking water. Initially, electricity was available for only three hours and we had to make special arrangements for constant power supply so that the classes could go on uninterrupted. There were times without electricity at night in sordid summers. Cooking gas was limited, and food arrangements were very difficult. It was [also] difficult to get GST numbers or vouchers and invoices for the money spent."

The programme grew stronger in the subsequent years. In 2015, it caught the attention of the Prime Minister of India, Narendra Modi, during his visit to IISc's Bangalore campus. A grant under the Pandit Madan Mohan Malaviya National Mission on Teachers and Teaching was approved to provide training to teachers from outside Karnataka as well. This additional grant continued till 2021.

In 2016, with a CSR grant provided by Hindustan Aeronautics Limited (HAL), development of infrastructure at the Challakere campus began in full swing. The campus today has two primary training units, the HAL-IISc Skill Development Centre, to provide training and supplementary coaching in engineering skills, and the Talent Development Centre, under the aegis of which the teachers training programme operates. In April 2020, the teachers training programme finally shifted from the sheep breeding farm to its own location on the Challakere campus.

Photo: Bitasta Das

A class in progress at TDC

Practice over theory

The distinguishing feature of the training programme is its engrossing curriculum that emphasises practice over theory. Out of the eight hours in a typical workday, three hours are dedicated to classroom lectures, three hours to laboratory or problem-solving sessions and the remaining two hours for breakouts during breakfast, lunch and tea. Every day, an assignment is given to the teachers to solve and present the next day.

The rigour of the programme also demands dedicated individuals to drive it. Each discipline has one coordinator, at least two Research Associates and two Project Assistants. The teaching is done almost entirely by IISc faculty members who travel from the Bangalore campus to Challakere for a few days and return after their session is over. Hegde says, "The methodology of the programme has evolved over time. I must admit that our very first training was a failure because we did not know how to gauge its effectiveness." He then decided to introduce pre- and post-training tests from the second batch onwards. The trainees are given one test before the session begins and another at the end of the training programme, to assess if they are able to imbibe what was being taught during the training. There have only been a handful of instances when the trainees have not made a drastic improvement in the post-tests, Hegde says. "Utmost care is taken so that the difficulties of pre- and post-test question papers are of the same level."

Well-known mathematicians CR Praneshachar and Venkatachala BJ are the current coordinators for mathematics. Praneshachar, who has been associated with the programme since its inception, says, "It has progressed to become more systematic now. Many teachers have told us that they have not solved as many problems in their entire careers as they solved during these 10 days. Their attitude towards the subject changes, from an average to a more rigorous understanding." Praveen Shanbhag, Abisha V and Shreedhar Byakodi are Project Associates in mathematics. They prepare the question papers and assignments and tutor the trainees in solving them. They have developed unique paper-cutting methods to demonstrate complex mathematical problems and their solutions.

Aravinda S, Jugeshwar Singh K and Prabhu KR are the present coordinators of biology, physics and chemistry respectively. Aravinda, who has also been associated with the programme for a long time, says that having a separate campus location for such a programme makes a lot of difference. When the training was held at the sheep breeding farm, the chemistry and biology disciplines had to share the same lab facilities. Now, there is more space, and each discipline has its own lab and modern equipment, and therefore they are in a better position to plan and design the courses.

Aravinda points out how facts like the presence of bacteria everywhere are only mentioned in textbooks but never demonstrated. He adds that they do simple tests which ensure that there is no scope for doubt among the teachers after their training. “We prepare multiple petri dishes with nutrient media and expose them to the soil, air and water. Within 24 hours, the teachers can observe the growth of bacteria and see them under the microscope.” Similarly, the instructors demonstrate the release of carbon dioxide during germination by putting a few germinating seeds along with potassium hydroxide inside a flask connected to a tube. Water is placed at the other end of the tube. When the seeds germinate, they release carbon dioxide, which absorbs the potassium hydroxide, creating a vacuum, allowing the water level at the other end of the tube to rise up.

Photo courtesy: TDC, IISc

Convener DN Rao (bottom centre) with instructors and trainees deputed as part of the Karnataka Department of State Educational Research and Training high school teachers training programme 2022

Raghavendra MK, too, has been associated with the TDC since the beginning. He teaches physics. He was also an instructor with the Institute’s UG Programme at the Bangalore campus. “I used to see expensive imported instruments at the UG labs and devise them locally at TDC at dirt-cheap cost. For example, for measuring projectile motion, simple tools like a big protractor and desoldering pump are used. Arrangements are made to enable the desoldering pump to project a small ball at different angles. The ball leaves a mark on the carbon sheet kept in the ground as it falls. This enables us to measure things like distance, angles, and so on. The teachers get to spend a little more time with the concepts.” He adds that the teachers come with excellent information but very little bent toward analysis. They start appreciating the training once they realise the small corrections they must make in their teaching. After this, they themselves ask for topics they are doubtful about and this sets the agenda for the subsequent two days.

During the training, the trainers and the trainees are constantly on their toes, says Sneha Ramachandraiah, Project Associate in biology. “It is a demanding yet satisfying role.” Prasanna, Project Associate in chemistry, has been pursuing his doctoral studies while working at the TDC, and has published six papers so far. He explains that the TDC provides sufficient support for the staff to pursue their own academic interests outside of the training hours.

Road ahead

The programme, which began with the training of Karnataka government school teachers, today trains teachers from across the country, both from public and private schools and colleges. The trainees stay in hostels set up specifically for this programme on campus. A vehicle is provided to and from TDC and the hostel, and breakfast, lunch and dinner are arranged at the TDC. Many trainees say that it is a hectic programme, but they find it quite rewarding. Sukhdev Kaur, a JNV high school teacher from Faridkot, Punjab, says that she thoroughly enjoyed the atomic configuration session – all her doubts were clarified and she feels she is better equipped to teach her students henceforth. TDC has also signed MoUs with state governments in Odisha and Goa to train their entire set of government school teachers. Talks are in progress with a few state governments in northeast India. A BSc-BEd programme under the TDC is also in the offing.

Rao believes that there is still room for improvement. Both he and Hegde admit that a programme of this scale cannot run without permanent staff and teaching faculty. Challakere is still an underdeveloped region with a limited supply of daily requirements like groceries. It gets blisteringly hot during the summer, and the water supply has only recently been improved through a pipe connection from the Vani Vilasa Sagara dam. More roads and residences need to be built. Rao adds that if these logistical aspects are addressed, the TDC can grow in leaps and bounds.

Crossed Cultures

- Harsha PM

Photo: KG Haridasan

The lives and experiences of IISc's international students

Fourteen years ago, before Fekadu Mihret Geremew came to India for the first time to pursue his Master's, he had heard a lot about how it was not the ideal place to live. The image he had in mind was a country of traffic congestion, overcrowded streets, and hot weather. But after finishing his Master's degree and returning home to Ethiopia, he decided to come back to India for a PhD. By this time, his opinion had changed. "[It's a] beautiful country. It is rich in diversity. People should come and study in India," says Fekadu, who is currently pursuing his PhD in the Department of Electrical Communication Engineering (ECE) at IISc.

International students playing a football match as part of International Day in March 2023

Like Fekadu, every year, many international students come to IISc to pursue their dreams. The Institute has around 65 international students currently enrolled in various academic programmes. Many of the full-time international students are from Nepal, but a few also represent other countries in Asia and Africa. "International students bring diversity and openness to the campus," says Amita Sneh, International Relations Officer at IISc's Office of International Relations (OIR). "People from different backgrounds provide a sense of togetherness in a diverse environment."

While Fekadu got to know about IISc from his Indian friends, Abass Toba Anifowoshe, who was keen on studying zebrafish genetics, had never heard about the Institute until he stumbled upon a social media post. "I applied to one institute in Mumbai called ICAR-Central Institute of Fisheries Education. When I got admission there, I was unable to go because the fees were too high for international students, and I could not afford that. They were not paying a stipend," says Abass, who comes from Nigeria. He has done his PhD from the Department of Developmental Biology and Genetics (DBG) at IISc, and is awaiting his thesis defence.

Like Abass, Elhassan Ali Fathi Emam too learnt about IISc from social media. "If I do PhD in my country, I will have to pay money, and it takes time, and the truth is that the facilities for research would be limited. Here, it is better, because you can do research and there are funds," explains Elhassan, a student from Egypt pursuing his PhD in the Department of Microbiology and Cell Biology (MCB), IISc.

Abodh Kumar Jha, another MCB student hailing from Nepal, says, "I came to India in 2012 for my Bachelor's degree. My elder brother also came to India in 2000 and he studied optometry. He suggested to me that we have many options in India compared to Nepal in terms of education and jobs."

For international students applying for admission to IISc, their first point of contact is OIR. "We take care of all their queries, from the eligibility criteria to application submission, and coordination with the departments to screen the candidates for interviews," explains Amita. Once the students are selected, OIR helps them with the admission and visa process by providing the required documents and certificates, and reaching out to the Indian embassies of the respective countries.

OIR continues to assist the students after their arrival. "Once they arrive, we connect them with their home department as well as the academic section," Amita adds. Except for students of Nepal and Bhutan nationality, other international students need to register themselves with the Foreigner Regional Registration Office (FRRO), a government agency that keeps a track of all international visitors to the country. The registration is mandatory and done annually.

Sometimes, faculty members and students also help the newcomers feel welcome when they first arrive. "My senior from the lab came to the airport to pick me up. So, I didn't feel very worried," recalls Bita Afsharinia, a student from Iran pursuing her PhD at the Department of Management Studies, IISc. OIR also makes arrangements for the students' accommodation and getting them things that they need for their stay, like mattresses, Amita adds.

First impressions

Among the first things that international students get to see is the greenery on campus. "The campus is heaven," says Bita. "When I entered through the gate, I found that the weather had changed immediately. That was my first time seeing an institute that has a lot of trees," exclaims Abass. Fekadu and Elhassan also echoed these thoughts.

But the initial amazement soon starts fading when culture shock kicks in. And food is a major contributor. "I am a non-vegetarian, and most of the food I was eating here was vegetarian for the first time in my life, and I fell sick because of that," recalls Abass. Elhassan and Abass both agree that the amount of spice used in Indian cooking was initially too much for them to handle; Abodh, on the other hand, recalls that the spicy food in B mess reminded him of his hometown in Nepal.

It's not just the taste of the food, but also the experiences and memories linked to eating that some of them struggled with. "Initially when I was alone eating at home, and not yet joined any mess, I was not able to eat properly, since in Iran, we would always have food together. Therefore, this environmental change led to difficulties in eating and health issues," says Bita.

Over time, however, the students adapt to the new cuisines. "Now, I am a supporter of Indian food," says Fekadu. Elhassan has also taken a liking to chai.

From left to right: Abass Toba Anifowoshe, Fekadu Mihret Geremew, Rishi Kesh, Abodh Kumar Jha and Elhassan Ali Fathi Emam, at the Sarvam food court

Photo courtesy: Abodh Kumar Jha

Another cultural difference that Abass felt was in the clothes he wore. "I know a lot of eyes are on me whenever I dress in my own way," he says. Initially, he felt self-conscious, but at one point, people came up to him and appreciated his traditional Nigerian attire, and even clicked photos with him, after which he became more comfortable, he explains.

For Abodh, the culture shock wasn't as stark. "We had Bollywood movies playing in the theatre. Because of that, I knew how to speak Hindi."

Linguistic challenges

Despite knowing a bit of Hindi, Abodh admits that he still had to work a lot on his communication skills. For many international students from other countries, language can be a barrier. Abass explains how he could not understand some of the lectures because of the difference in English accents. "Even in the lab meetings, they could not understand my presentation, and sometimes I could not [understand them]. But my professor told me, 'If you speak slowly, everybody will understand you.' So, I started adapting to that," Abass elaborates. Over time, he managed to differentiate between Indian languages, at least enough to know whether someone was speaking Malayalam or Bengali.

Bita, who is a native Persian speaker, had a different experience. Although she found Parsi people in India with whom she could speak in Farsi and even celebrate festivals, she still felt left out in the beginning. "Everyone was talking in different languages, and I was just blank with certain misunderstandings," she recalls. Coming from Iran, where English is not spoken widely, she remembers her struggle over the years to develop her English communication skills.

Fekadu says his neighbours helped him improve his communication skills – for example, by teaching him how to talk to cab drivers. Elhassan has already learned bits of Hindi, enough to purchase groceries in local shops, he says.

"Students in IISc have already qualified many exams and they are very good at speaking in English," says Abodh. "And when I see myself, I am not like them. But IISc has taught me in the past four years, and I like to think that I have enhanced my communication skills with the help of people here."

Dealing with homesickness

Elhassan says that another challenge he struggled with was homesickness. "I've gone home twice since I first came. Whenever I go home and come back, I feel like leaving my PhD and going back there."

According to Bita, in the beginning, she also suffered from homesickness to the extent that it affected her health. On the other hand, for Fekadu, it was easier because even in his country, his home and the place where he worked were far apart. "For example, if your family is in Bangalore, and you are working in Delhi, you are far away. If I go to my country, I feel the same. As long as I was communicating by phone, it was not a big deal." Abodh had a similar experience growing up. "I was away from my hometown, because my hometown is in a village, and my mom used to stay in the village. And my father used to stay in the town. So I was away from my mom, even from my childhood," he reminisces.

Homesickness was even harder to deal with for international students during the pandemic when they could not go home. "I was really scared, and I did not know what I should do, and there was no international flight. And [I thought] if I travel, I might get COVID, then take it to [my family]," Bita remembers.

But what has helped some of the students tide over such challenges is staying connected with each other. "We have a WhatsApp group where we have added all the international students, and apart from that we also have a Nepalese group," says Abodh. "We don't interact very often, but we are always active if there are any problems. We are like a family here."

OIR, for its part, is exploring different ways to maintain a bond between international students and faculty on campus. Earlier this year, the office organised its first International Day, spread out over two days. Sports activities like table tennis, badminton, and football, as well as cultural programmes were held, and winners were felicitated by the Director. Informative sessions by FRRO representatives were also hosted to make students aware of the rules and guidelines for foreigners in India. Last year, OIR hosted a Christmas get-together for the international community, where the Director, Chair of OIR and staff members met the international students and visitors and their families, exchanged wishes, and shared festive refreshments.

Photo courtesy: Elhassan Ali Fathi Emam

Elhassan Ali Fathi Emam (fifth from right) participating in an Eid celebration at a mosque in Bangalore

Some of these students also say that they enjoy participating in Indian festivals that bring the campus community together. "My first memory when I came here was the Holi celebration," recalls Elhassan. "It was nice with all the colours." Elhassan and Abass also recall how they enjoyed sharing their traditional recipes with Indian students. "I actually went on YouTube, and showed them a lot about our culture, our food," adds Abass. "And I have cooked for several groups in my apartment."

Photo courtesy: Abass Toba Anifowoshe

Abass Toba Anifowoshe (right) collecting water samples at the KRS dam for his PhD work

Pursuing passions

When Abass started his PhD at IISc, he became interested in studying the effect of microplastics on fish in the Cauvery River. To work on this problem, he had to travel often to the Krishna Raja Sagar (KRS) Dam in order to collect samples and interact with local fishermen for two years. When the study – which found that the microplastics were causing skeletal deformities in the fish – was reported in the news, he was delighted. "I was able to see our work published in almost every national newspaper. I have a publication in a reputable journal for the first time; I have achieved what I couldn't imagine."

Abass also got a chance to travel to many places in India and Europe to participate in conferences and workshops, with fellowships from the Department of Biotechnology (DBT), and The World Academy of Science (TWAS), Trieste, as well as funding from the General Academic Research Provisions (GARP) at IISc.

"I have learned a lot in IISc. Not just learned to do experiments, but to think about doing the experiments. I feel that IISc made me prepared and ready to be a future scientist," Elhassan says. He is doing his PhD on studying DNA damage and repair mechanisms in *Mycobacterium tuberculosis* and plans to pursue a postdoc position abroad after this.

Bita says that her PhD supervisor provided a "wonderful" environment for research. "She has given me several work opportunities, trusted me, and supported me in every aspect of life. Whatever I've become today, it's always because of her support and her inspiring personality." Bita is wrapping her PhD work on investigating how a crisis, like the COVID-19 pandemic, can affect children's nutrition in India. She has also worked closely with the Akshaya Patra initiative, focusing on environmental factors impacting a child's dietary requirements. Abodh, too, is about to wrap up his PhD work on identifying *Mycobacterium tuberculosis* genes that play a crucial role in disease progression. "My professor and my seniors have helped me a lot," he reminisces. Fekadu is all set to go back and resume his job as a lecturer in Ethiopia after completing his PhD in microwave photonics. "The work culture is interesting in IISc," he says, adding that his professors gave him a lot of freedom to do his own work.

Photo courtesy: Bita Afsharinia

Bita Afsharinia at the COSMAR conference held at IISc in 2019

Abass, however, feels that there are some things that can be done to make the life of international students easier on campus. He strongly believes that an international student representative should be a part of the Students' Council so that their unique challenges and experiences can be shared with others on campus. Since food and accommodation are a major concern for these students, he suggests that having a separate mess and hostel for international students would help. "Africa is a big continent with 54 countries and a lot of international students are from Africa." He feels that making provisions for the students to cook their own food would also be helpful. Some steps, like financial support for international travel from their home country and visa processing, would also go a long way, he suggests. Elhassan adds that the Institute and OIR could organise trips across the country that would not only help the students explore India, but also bond with other Indian students.

Despite these challenges, most of the students admitted that there are many things they will miss when they move on from campus. "I feel a belonging at IISc," says Fekadu. "It will be very difficult to leave this Institute."

Harsha PM is a PhD student in the Department of Developmental Biology and Genetics (DBG), IISc and a science writing intern at the Office of Communications

Keepers of history

- Malavika P Pillai

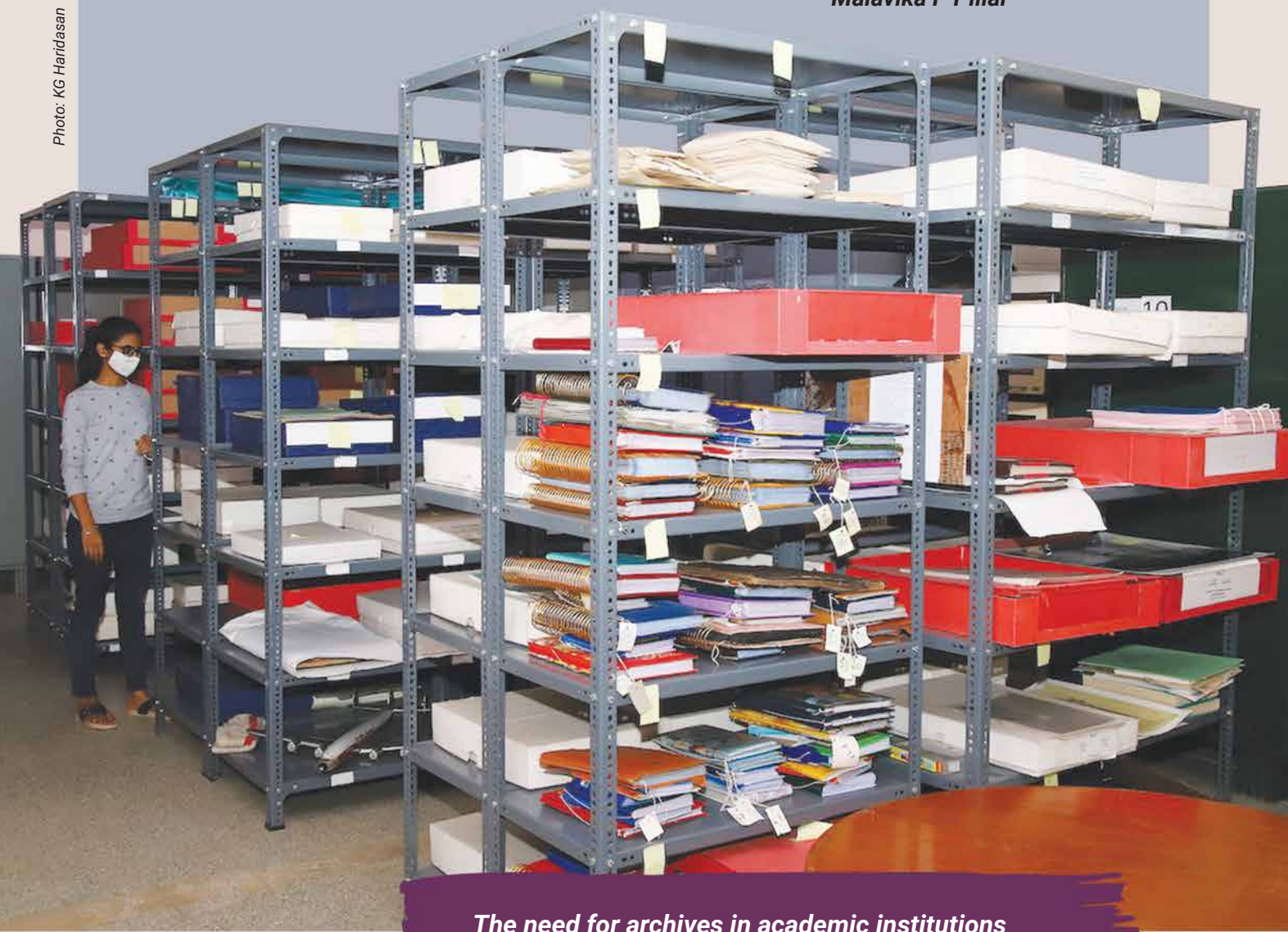


Photo: KG Haridasan

The IISc Archives

The need for archives in academic institutions

In a pivotal scene in the sensational Christopher Nolan film, *Oppenheimer*, the protagonist, J Robert Oppenheimer, meets Danish physicist Niels Bohr while struggling with his research at Cambridge University in the early 1920s. Bohr urges Oppenheimer to move to Germany and study under the famed physicist and mathematician Max Born, a move that marked a turning point in Oppenheimer's life and the eventual development of the atom bomb. Many people know about Born's contributions to quantum mechanics, and of his role in inspiring leading scientists of that time, such as Oppenheimer and Werner Heisenberg. But how many know about the time he spent at IISc, a short six months as Reader in Theoretical Physics?

Step into the archives of IISc, and you will find letters exchanged between CV Raman, the then Director of the Institute, and Born. These letters don't just outline Raman's job offer to Born, but also reveal the former's ambition to expand the Institute's scientific horizons. Born, a Jewish scientist who had to leave Germany because of the Nazis, accepted Raman's offer. But Born's visit to IISc came at a time of turmoil. Raman and some of the Institute's faculty members were at loggerheads, their disagreement escalating when the former attempted to secure a permanent position for Born. The conflict that unfolded – recorded in bits and pieces in minutes of the Institute's Council and Senate meetings from 1936 and 1937 – eventually led to Born's departure from IISc and Raman resigning from his role as the Director in 1937. It is only from piecing together information in various letters, Annual Reports, Council minutes and other documents, painstakingly preserved for over a century, that we are able to tell such stories from the Institute's past – proof of how valuable archiving can be.

An archive is a storehouse of wisdom, holding inside its quiet rooms a treasure trove of knowledge that can help shape our understanding of the world. Archives function akin to a time-travel device, enabling us to journey backwards and peek into past lives and events.

An archive functioning within an academic institution holds a vast collection of works produced by faculty members, staff, and students. Its collections usually go beyond scholarly articles such as journal publications, and include documents containing the written words of its researchers and administrators that provide snapshots of academic and student life, and details about the institution's evolution. These include letters, reports, meeting minutes, old photographs of significant events, notes, and memos of people joining and leaving the institution. One may find a mix of documents belonging to or about both well-known and lesser-known individuals. Each institutional repository has a different focus. Materials stored in the archives are both physical and digital – housed in servers and online repositories.

At the archives of the Indian Institute of Management, Ahmedabad (IIMA), for example, among the many valuable documents are a series of letters and notes from the office of Harry L Hansen, a former Director of Harvard Business School's Division of International Programmes, who spent considerable time at IIMA and played a key role in advising its faculty members in its formative years, explains Abhishek Mishra, archivist at IIMA. Other documents include letters, notes, committee meeting records, reports, building plans, curriculum details, policies, staff information, and administrative papers. The IIMA archives also houses special collections, such as oral history recordings related to the history of computing and advertising in India, documents related to the history of Indian management institutes, and directories of stock companies and investors from the early 1900s to 1950s.

Institutional archives, such as the ones at IISc and IIMA, are different from public archives like the National Archives in New Delhi. Public archives store government-related documents, material related to different communities, and culturally significant artefacts. On the other hand, the collections in institutional archives are "more flexible and organic," observes Anjali J, archivist at the National Centre for Biological Sciences (NCBS), Bangalore. Materials in public archives are curated and categorised based on their importance. Not all original pieces are necessarily collected; archivists choose the most vital and representative ones for preservation, she adds.

Institutional archives are first and foremost committed to their parent institution, prioritising the collection of materials unique to that institution's history. They are usually located within or near it, symbolising their strong connection with the institution's identity. They are often supported by the parent institution, but external agencies, philanthropists and alumni also contribute funds to support such archives.

Some institutional archives have gone beyond just preserving their parent institute's history. An example is the Archives at NCBS, which has now evolved into a public repository for contemporary science, housing special collections like that of entomologist Leslie Coleman, oral history recordings of Indian scientists, and a large collection of papers and materials on MS Swaminathan, considered the father of India's Green Revolution. Institutional archives also collaborate with other organisations and companies to curate and exhibit their material. "The response from our wide array of stakeholders and users guided us to conduct exhibitions, and collaborate with the Ministry of Culture," says Abhishek. "In the long run, we aim to be a business history research hub."

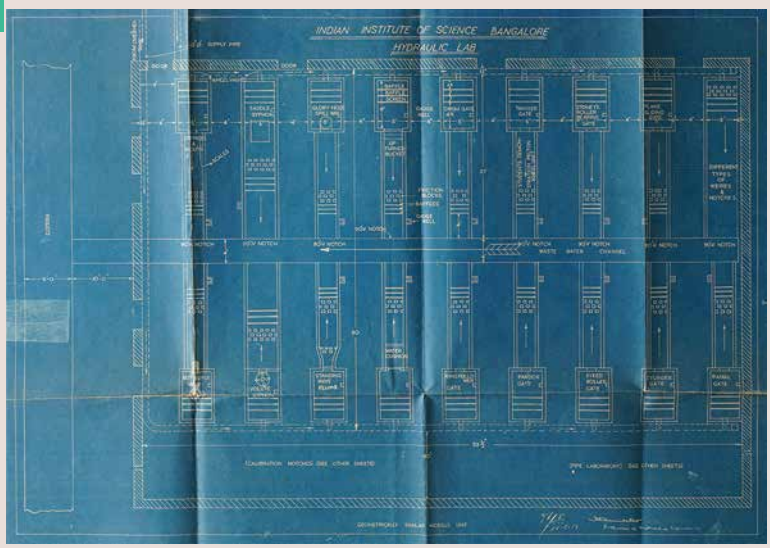


Photo: IISc Archives/KG Haridasan

Blueprint of a Hydraulic Lab apparatus

Preserving IISc's history

As one of the first institutions in the country to focus solely on advanced scientific research and education, IISc has remained one of the main characters in the still unfolding story of Indian science. Preserving its historical material can not only help safeguard its legacy but also provide lessons and learnings for the Institute's advancement. The IISc Archives, housed within the Office of Communications (OoC), is the custodian of most of the Institute's historical documents sourced from various academic and non-academic departments – papers, reports, photographs and artefacts that capture various moments in its history.

As an in-house archive, its collections are somewhat unique. For instance, it houses a rare collection of blueprints of labs, buildings and research equipment. One of these is a blueprint showing the structure of a liquid-liquid extraction column dated 13 November 1957. "Blueprints were used to get multiple copies from a single drawing. When making them, the drawing is done on a transparent sheet with black ink or pencil. This sheet is placed under another sheet treated with ammonium citrate and exposed to sunlight for a certain time. The parts exposed to light turn blue, while unexposed parts under the ink remain the same," explains Sindhu Nagaraja, a conservationist who consults at the IISc Archives. There are also blueprints of the construction plan for the Primate Research Laboratory, dated 1975, and maps of faculty housing colonies printed using an ammonium printing technique that uses a UV machine instead of sunlight. These were some of the early methods used to make copies of building designs and lab apparatus. "The signatures and notes inside these materials add an extra layer of intrigue to the collection," she adds.

At the IISc Archives, there are also detailed reports from the years 1922 to 1936 that were written by hand, and letters that used iron gall ink – a mixture of iron and resin extracted from plant seed that initially appears light brown, but turns darker as it oxidises over time. Such ink is no longer popular.

Sindhu suggests that even if the content in the archival material is scientific and not easy to understand – for example, drawings of chemical structures, research papers or lecture notes – one can still appreciate their historical value. Archival material also contains a wealth of information hidden inside. For instance, a photo of a scientist from a certain time, say the 1990s, isn't just about them. The photo also tells us about the photography methods and equipment used at that time, the studios where the photos were taken, and the names of the photographers of that era. Even background details, like the labs the scientists worked in or the buildings they stood in front of, tell stories, adding social context to their scientific activities. The IISc Archives also house mementos of kinship among scientists. For instance, in 1961, the staff and students of the Department of Inorganic and Physical Chemistry gave a specially designed silver scroll to one of their retiring professors, KR Krishnaswami. This scroll and a moving letter they penned to him are now kept in the IISc Archives.

When it comes to conserving such materials, there are several questions. First, how do you choose what materials to keep? When managing materials from an institution, there's usually a structure to think about that is specific to its setup. At IISc, there's a hierarchical structure that includes the Court and Council, the Director, and six academic Divisions under various Deans (previously Chairs), and administrative sections under the Registrar. The Archives hold documents from these different levels, so there's a need to organise and preserve them in a structured way .

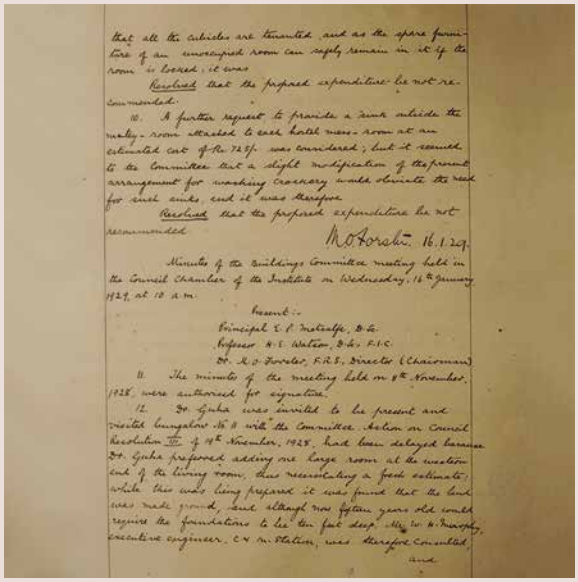


Photo: IISc Archives/KG Haridasan

A page from Council Minutes handwritten using iron gall ink

Sindhu explains that one of the many challenges a conservator may face is in prioritising the materials to be conserved. In such cases, one may need to make decisions about which elements to preserve and which ones to store separately to ensure their safety. Discussions with other experts and stakeholders are essential to make informed decisions about conserving damaged materials, which requires careful consideration of the urgency and importance of each item. Some treatments, like encapsulation or fumigation, can take significant time.

Documenting all the details and procedures undertaken during the conservation process is also crucial. Proper documentation helps in understanding the condition of the materials before and after conservation, as well as any significant alterations or separations made. For instance, if the material was exposed to fire, water seepage or extreme change of weather, any resulting marks left on them will be recorded in the condition report. This will provide a better understanding of the history of how the materials were handled.

Photo courtesy: Sindhu Nagaraja

Conservator Sindhu Nagaraja working on an old photograph

Every archive also needs to keep in mind two principles of archiving – the principle of provenance and the principle of original order. The principle of provenance focuses on the history of ownership, how the records were created, who their owner is, what their purpose was, and how the material changed hands over time. The principle of the sanctity of the original order means that records should be kept in the same order that they were originally organised.

But a general problem in India, Anjali points out, is that there is no strong archiving culture, even in households. “For instance, during the Aadi month in some of the southern states or other festivals, items are discarded to make way for new ones, which symbolises a fresh start,” she explains. “From our cultural perspective, archiving day-to-day amenities is often perceived as a niche concept, as many Indians tend to dispose of things rather than preserve them.” "However," she adds, "we have a rich archiving culture in terms of oral history. When it comes to preservation of material goods, modern day archival methodology could help preserve and conserve historical material for the future. This is a specialised field that is gaining recognition and being implemented in India.”

The need for preserving history

In addition to the more routine considerations like prioritising and choosing materials for conservation, there are more significant questions that the archive must address. First, it is the responsibility of the archive to establish a significant level of trust with not only people who donate to it but also people who need to access it. In countries like India, some experts believe that there is a prevalent sense of distrust towards governmental institutions. An archive should strive to not only faithfully preserve the materials, but also safeguard their use, says Anjali.

Second, it is important to understand that archiving is not solely about highlighting the merits and achievements of the institute. From their archives, institutions can access a wealth of information about past decisions, successes, and failures, and learn from them, Anjali adds. For instance, in 1943, IISc decided to construct a new building that included a dining hall and auditorium. This new facility was intended to provide a single dining area for all students, replacing the nine separate eating spaces that existed based on students’ eating preferences – which some argued were along the lines of caste division. The IISc archives houses a letter from 12 March 1943, written by a student named M Jagannadha Rao, who opposed the plan for a common dining hall and even went on a hunger strike to protest it. Despite resistance, the dining hall was eventually built. These letters show how the Institute grappled with a social problem at that time, and the steps it took to address it, which may also have lessons for dealing with similar situations in the present and future.

The resources and information in archives are but small fragments in a broader historical context. With the current information boom and advances in technology, it becomes crucial for us to accurately record facts for posterity. As Debra Steidel Wall, Deputy Archivist at the National Archives and Records Administration, USA, points out in the magazine *Archival Outlook*: “Now more than ever, in our age of information overload, misinformation, and disinformation, access to and an understanding of authentic documents is powerful and necessary.”

‘I have worked with generations of students and staff’

- Rosa John Samuel

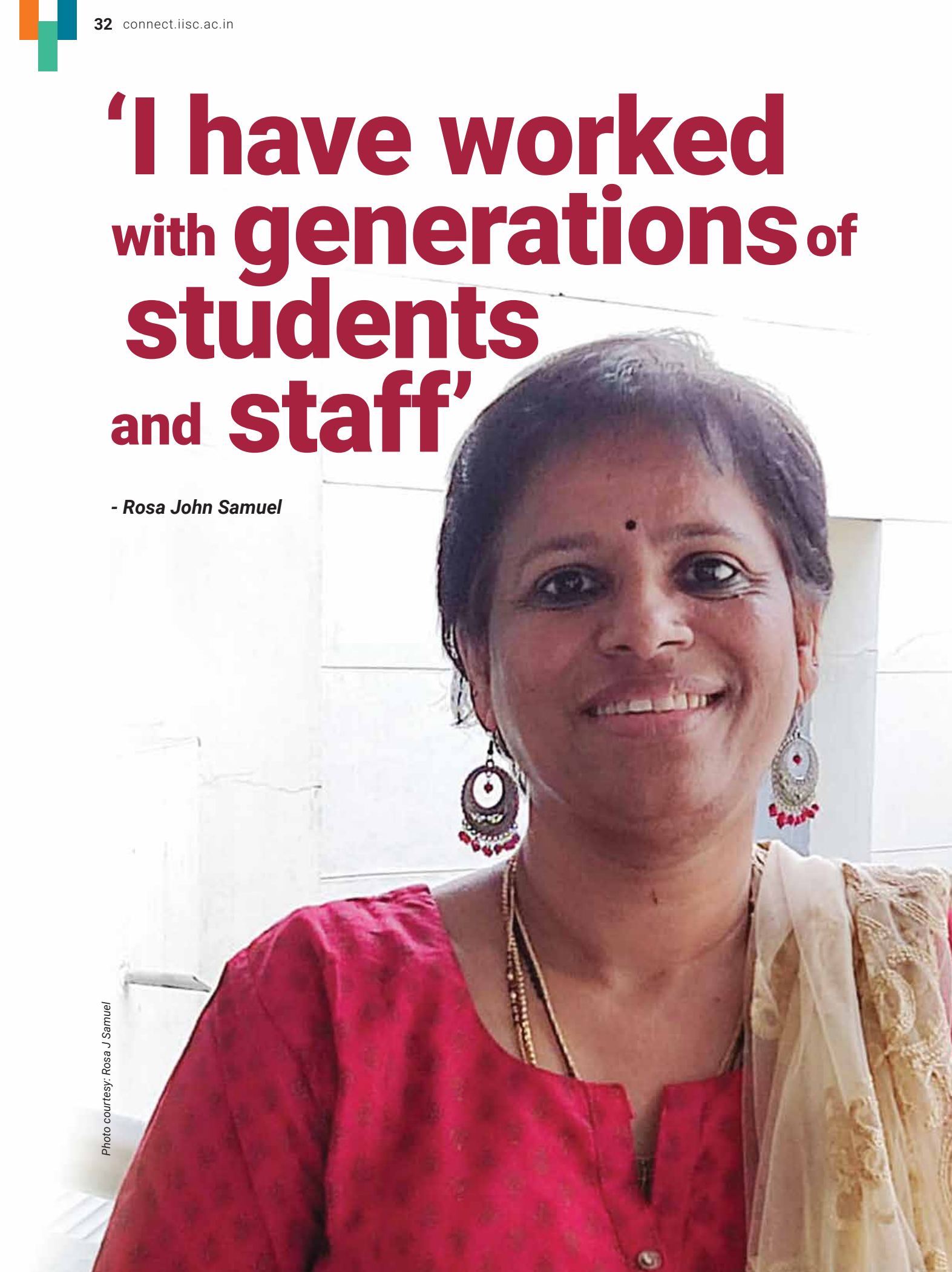
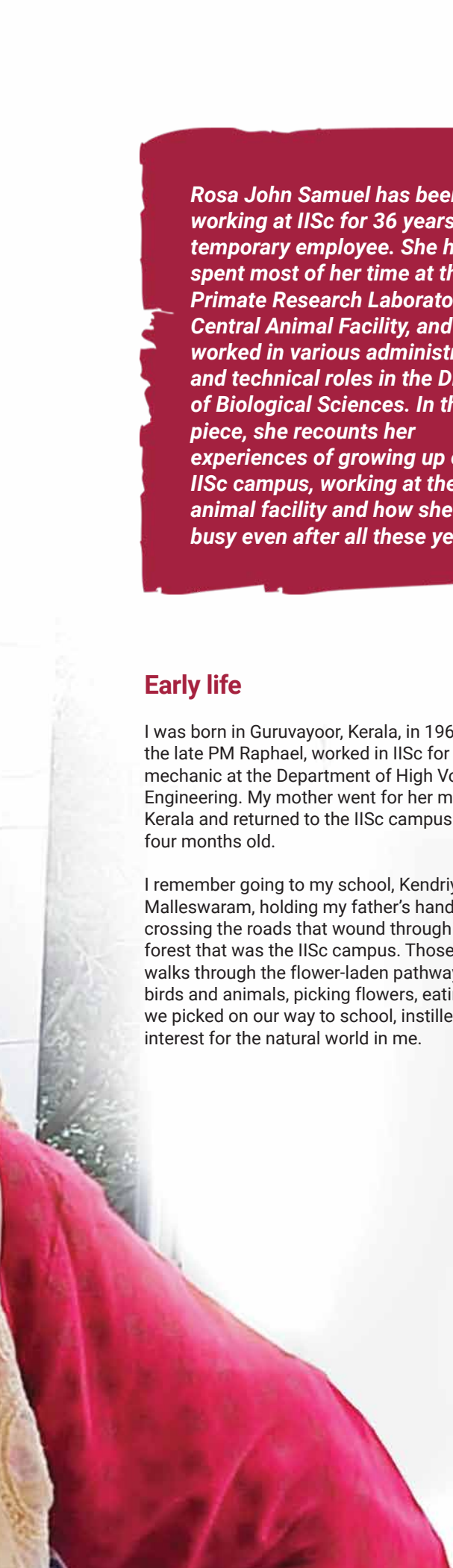


Photo courtesy: Rosa J Samuel

Rosa John Samuel has been working at IISc for 36 years as a temporary employee. She has spent most of her time at the Primate Research Laboratory and Central Animal Facility, and has worked in various administrative and technical roles in the Division of Biological Sciences. In this piece, she recounts her experiences of growing up on the IISc campus, working at the animal facility and how she keeps busy even after all these years.



Early life

I was born in Guruvayoor, Kerala, in 1966. My father, the late PM Raphael, worked in IISc for 39 years as a mechanic at the Department of High Voltage Engineering. My mother went for her maternity to Kerala and returned to the IISc campus when I was four months old.

I remember going to my school, Kendriya Vidyalaya in Malleswaram, holding my father's hand while crossing the roads that wound through the dense forest that was the IISc campus. Those early morning walks through the flower-laden pathways filled with birds and animals, picking flowers, eating the fruits we picked on our way to school, instilled a deep interest for the natural world in me.

Back then, we lived in the IISc staff quarters, which were tiled houses, each with a backyard, a small front yard and beautiful gardens; the bigger houses were for librarians, and the Registrar. Each house had its own garden where kids from different households would play together. We would go to watch movies as families on most Fridays at the Gymkhana. During Founder's Day celebrations, we would perform music and dance shows on the stage in front of the Main Building.

My family ran on my father's IISc salary and my mother's income from tailoring. I completed my Bachelor's degree in Chemistry, Botany and Zoology from Mount Carmel College, Bangalore, in 1987. To strengthen my job prospects, I followed the trend at that time of taking typing and shorthand classes. I also joined a computer course which was not very popular then. But when my parents' income became insufficient to educate my brother and sister, I decided to start working instead of pursuing a Master's degree. That's when Balakrishnan, a friend of my father's from the Department of Biochemistry, IISc, informed me of a lab assistant position with Prof MRS Rao. I made the decision to attend the interview the following day, after my computer class. After qualifying for it, I started as a Laboratory Assistant with a salary of Rs 1,200, which was very good compared to the income of those in similar positions at that time. This was the first step in my journey at IISc. My father had the dream of sending at least one of his children to IISc. In a way, I am glad that his dream came true through me.

After working for a year on a project in Prof MRS Rao's lab, I moved to Prof NR Moudgal's lab. It was there that I saw the first Apple computer, which Prof Moudgal had purchased from the USA. We also had cutting-edge machines of that time, such as electronic typewriters.

Initially, we were in the Department of Biochemistry, and later moved to the present Primate Research Laboratory (PRL). One of the key research activities in the lab was on male contraceptive vaccines. Interestingly, we housed around 520 monkeys for the study. I worked with Prof Moudgal for 11 years. I took care of the administrative responsibilities under the guidance of Mala, who was the first to teach me about the work involved. I had to take notes in shorthand and prepare letters on time, as Prof Moudgal was very particular that all the letters get dispatched by 3 pm on the same day. We were considered a rich lab with lots of funding – so coffee and snacks were provided. We would go for picnics once a year. Students would take us once in a while to the mess for lunch or tea. When a student completed their colloquium, submitted their thesis or published a paper, they would give us a treat. I have

helped students in typing their theses, as well as organising national and international conferences and workshops. In those days, students from other labs used to approach us to request chemicals or borrow tools. However, we now have an abundance of resources, and there is no need for anyone to ask for chemicals or share materials. I have worked with multiple generations of students and staff over the years.

At the animal facility

Over the years, IISc has not only become my home, but also a nurturing environment that has provided me with opportunities for growth and fulfilment. After interacting with professors, PhD students and postdocs, my desire to continue further education, which I had to put on hold only strengthened. When Prof Moudgal retired in 1993, I moved to the Central Animal Facility (CAF) as Junior Project Assistant. By 2004, I completed my Master's in Ecology and Environment in distance education mode from Sikkim Manipal University. Soon after that, I was promoted to the position of Project Assistant. Gradually, CAF turned into my second home.

There, I was involved in animal breeding, blood collection, administration of fluids and drugs, and immunisation of animals for scientific experiments. I took care of conventional strains of mice and rats, as well as rare ones like nude, knockout and transgenic mice. I learned that animals can become comfortable with humans but can also pose a danger. Mice may suddenly bite, which can be quite painful.

I helped in conducting several workshops on the health monitoring of lab animals for PhD students, Project Assistants and postdocs. In the meantime, I finished my MPhil in Environmental Science from The Global Open University, Nagaland in 2012 and defended my PhD in Environmental Biotechnology

Photo courtesy: Rosa J Samuel

Rosa Samuel (fourth from right in first row) and her colleagues at Central Animal Facility (CAF), IISc

from Bharathidasan University, Tiruchirappalli. The Government of India, through the Committee for Control and Supervision of Experiments on Animals (CCSEA), chose me as a *socially aware nominee* to oversee animal experimentation in 23 different research institutes. Animal research is necessary for scientific work, so it cannot be completely eliminated. However, I believe that it is important to carefully evaluate the proposals to ensure that the experimental methods used are ethical and that there is no misuse or inhumane treatment of animals. In addition to my role in approving animal usage, I have established a network with [my counterparts] in various educational institutions.

In the past, there were some unfortunate practices carried out on animals. However, the CCSEA recognised the need to stop such practices. Nowadays, we follow strict rules and regulations to ensure the ethical treatment of animals. We have made significant progress compared to the past; for example, from keeping animals in normal polycarbonate cages to using individually ventilated cages, from bedding made of paddy husk to sparcobb or wood chip, and better nutritional feed to monitor their health and prevent infections from spreading among the animals.

Almost all faculty members from the Division of Biological Sciences use animals from CAF for their research. Even though the faculty members I worked with initially have retired, I still maintain a connection with all of them. Many studies and experiments rely on the availability of animals. I made every effort to provide the animals on time and to uphold the trust they had in us. Research scholars and students would come to us every morning, requesting animals of a specific weight, age group, and breed for their studies. They would also share their experiences and discuss their problems with me. Whenever they published a paper or submitted a study report, they would come with a box of sweets as a gesture of gratitude. Things changed after the COVID-19 pandemic, but before that, every student who completed their colloquium would invite us and acknowledge the CAF in their thesis, often showing us a hard copy of their work. These gestures made us feel valued. When old students come back to visit their faculty advisors, they go out of their way to also meet us. It is these instances that made me appreciate the fact that small things make a big difference.

From October 2021 to November 2022, I was involved in supporting research as Project Manager in the Evolutionary Venomics Lab, Centre for Ecological Sciences. My other responsibilities involved managing the lab, administrative work, and coordinating with the forest departments and the National Biodiversity Authority to obtain necessary permits, working along with students. I also helped in setting up an antibody facility.

A sense of community

I have solid relationships with many people from different departments and maintain a large network of contacts with whom I make an effort to keep in touch. I take it upon myself to ensure that they don't feel neglected. I frequently arrange meetings among staff members who have been part of IISc for a long time, and live close to each other. Many of these individuals, who were once colleagues of mine, find themselves living alone. We often gather at the Nesara restaurant in IISc to enjoy a cup of coffee or engage in conversation. Additionally, I try to call retired individuals whenever I have some free time, to share updates and stay connected. Maintaining these relationships and demonstrating support to the individuals who have been part of my journey here is important to me.

Currently, I work as a Consultant at the DST-Centre for Policy Research (DST-CPR) at IISc. In August 2023, I completed 36 years of service in IISc as a temporary staff member even though my personal connection with IISc dates back to my childhood days. Though I couldn't secure a permanent job at IISc, I never felt I was not in the system or treated differently. I was able to complete my education, and fulfil my dream of pursuing my PhD in Environmental Biotechnology, with help from several faculty members and students, while working at IISc. I received a Young Investigator award for a poster I presented at the 4th Asian Federation of Laboratory Animal Science Associations Congress (2010), held in Taipei, Taiwan, and the Best Poster Award at the 8th Asian Federation of Laboratory Animal Science Associations Congress (2018), held in Bangalore. I was able to support both my sister – now a Senior Scientist working in Texas, USA – and my brother, who is a Vice President at an IT company in New York, USA, and also help my daughter pursue a medical course in Canada.

In retrospect, I am grateful for the way IISc and its landscape have woven themselves into my life, as reflected in my favourite verse from Robert Frost's poem:

The woods are lovely, dark and deep,
But I have promises to keep
Miles to go before I sleep
Miles to go before I sleep

As told to Malavika P Pillai

Layer by Layer

- Soumya Mishra

Hemang Kumar Jayant working on a hybrid 3D printer at FSID, IISc

Photo: Arun Kumar

3D printing is revolutionising manufacturing

As a young kid, Shashank HR was fascinated by how things, including his toys, were made. So, he would be thrilled whenever he had a chance to visit his father's metal fabrication shop, where he witnessed how sheets and rods of steel were shaped into garage doors, gates and window grills. As he grew older, he became more and more interested in tinkering with things and building them himself, especially after he got a new toy – a hobbyist 3D printer.

It did not take long for Shashank to realise that 3D printing was his calling. After majoring in Materials from IISc for his undergraduate degree, he did his Master's from the University of California, Berkeley, where he studied Materials Science and Engineering. He is now with a San Francisco Bay Area company called Velo3D, a leading provider of metal 3D printing solutions. Shashank is among an entire generation of young people working on the technology of 3D printing or, to use the industry terminology, additive manufacturing (AM).

To illustrate the meaning of AM, it might be useful to understand how things are traditionally manufactured. The process typically involves fashioning raw materials into finished products using techniques that are subtractive in nature – material is removed from a solid block to achieve a desired shape, much like what a sculptor does with a hammer and chisel to create art.

AM, on the other hand, involves adding materials, layer by layer, to build something new, just as its name suggests. It is not unlike children building cars or houses with Lego bricks. AM does the same but with Lego bricks that are invisible to our eyes. The process begins by creating a digital 3D model, which is then fed into a specialised software. The software decides how best to virtually slice this model. Each slice is then printed, like in traditional 2D printing, and the layers are placed on top of each other to get the final product.

A new revolution

3D printing has gained much attention in recent years because it does not have the constraints of traditional manufacturing methods. Big tech giants are already realising its massive potential. General Electric has switched to AM jet engine parts to increase durability and save costs. Many international airlines, including Air India, are now using or have placed orders for LEAP engines in their aircraft. Developed by CFM International, LEAP is the first jet engine to include 3D-printed parts, making it lighter than conventional engines. These developments are transforming the aviation industry. "It is no longer a toy. It is no longer a prototype technology. It is no longer meant just to make models or lookalikes, but there is an actual service part that is being made," says Shashank.

AM is also revolutionising space exploration. Terran 1, the first fully 3D-printed rocket developed by an American startup called Relativity Space was launched earlier this year. This rocket is made exclusively from 3D-printed parts, including the fuel tank and engine. NASA has also been exploring the use of 3D printing in space itself so that astronauts can manufacture tools and spare parts when required.

Small and medium manufacturers are also joining the bandwagon. For instance, this technology is being used by jewellers to make casting moulds for more intricate designs and by fancy restaurants to create designer food items. Customised 3D printers for chocolates and pasta are now available in the market. It is also being used to make plant-based and lab-grown meat. 3D printing holds great promise for printing organs for transplants and making skin grafts for burn victims. Entire houses are being built using concrete 3D printing technology. Not only does this reduce the cost and amount of raw materials used, it takes just a fraction of the time conventional construction methods require.

In addition to making new customised parts, AM is also being successfully used for repair and refurbishment of components in several engineering sectors. In the past, even if there was minor damage, quite often, the entire part would have to be replaced, because there was no technology to repair high-end materials, such as those used in the aviation sector. "It takes not just time, money, and effort, but there are no takers to repair small quantities of parts in a short period of time to cater to the need of the customer," says Dheepa Srinivasan, an alumna of the Department of Materials Engineering, IISc, currently with the Pratt and Whitney R&D Centre in the Institute's campus. According to her, AM is a panacea for bringing in innovative technology for difficult-to-repair parts, thereby extending the service life of components. She and her team are now working on new 3D-printed high temperature alloys for gas turbine engine applications, including nickel- and cobalt-based superalloys.

AM is also allowing researchers to revisit alloys which are difficult to manufacture using conventional methods and hence have not had practical applications. For instance, NASA is working on using a 3D-printed alloy called GRCop-42 in rocket thrust chambers and heat exchangers. This alloy retains high thermal conductivity and strength at high temperatures, crucial for heat transfer in rocket engine components. “The material has been around for 30-40 years, but existing fabrication methods just didn't work. If you try to cast it, the material segregates. But today [with AM], it has become an extremely important material in the next generation of rocket engines,” says Shashank.

Photo courtesy: Dheepa Srinivasan

Dheepa Srinivasan in her office with photos of the turbine engine outlines in the background

”3D printing has also paved the way for researchers to delve into nature-inspired designs,” says Amaresh Chakrabarti, Chair of the Centre for Product Design and Manufacturing (CPDM), IISc. For example, we are now better placed to mimic the properties of the bone, one of the wonders of nature. Bones are made up of porous tissues which makes them lightweight, yet incredibly strong. Like bones, there are several designs in nature that can be mimicked using 3D printing, he suggests.

Not surprisingly, 3D printing is now making inroads into the world of lightweight prosthetics and implants. Conventional prosthetics produced using casting are heavy. Using 3D printing, it is now possible to design anatomy-specific devices for the patients, which are both customisable and lightweight. Such devices can dramatically improve the quality of life for millions of patients. It can be a great boon for both the clinicians as well as the patients, says Dheepa, who has also worked closely with doctors and rehabilitation centres, “to provide timely, restorative, custom-made 3D-printed solutions for the patient population.”

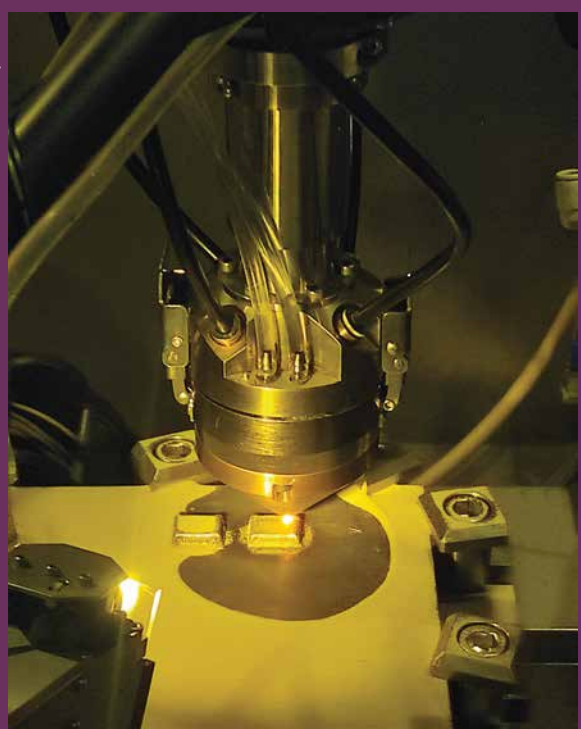
IISc joins the race

Recognising the increasing role of this revolutionary technology, IISc has taken many steps to encourage research and innovation in 3D printing. In 2019, CPDM started an MTech in Smart Manufacturing, and AM is an integral part of this programme.

Funded by Wipro 3D and the Department of Heavy Industries, Government of India, IISc has successfully built an electron beam metal 3D printer, which is ready to be marketed. It is the result of a collaboration between multiple departments, each bringing in its own expertise and resources. This equipment can be customised to accommodate different research requirements. For instance, thermal cameras and sensors can be added to it, which is not possible with machines currently available in the market.

One of the advantages of AM is that researchers and innovators can combine different materials to fabricate complex designs. And this is what HEM Dimensions Private Limited is doing at the Foundation for Science, Innovation and Development (FSID) in IISc. The startup was established by Hemang Kumar Jayant, a former PhD student at CPDM, in 2022. His team is working on multi-material AM that combines metals and polymers for printing smart electronic devices. One of their success stories is a device for real-time monitoring of heart activity. The metal and polymer materials are printed in layers sequentially to create functional electronic devices in one shot using a hybrid AM machine that his team has developed. “The hybrid AM machine will cut down the prototyping time significantly,” says Chakrabarti.

Photo: Subhodeep Jana



Metal 3D printer in action at CPDM

Dineshkumar Harursampath, Associate Professor in the Department of Aerospace Engineering, IISc, believes that multi-material AM technology will revolutionise the way we make things. “Customising structures with highly complex geometries and multiple material distributions will become a child’s play with AM.”

Dineshkumar’s lab is involved in yet another exciting project on materials called auxetics. When conventional materials like rubber bands are stretched, they become thinner. But auxetics, paradoxically, become thicker when stretched. The potential applications of auxetics are endless – as shock absorbers in body armours, as sound absorbers, as shoes that fit perfectly. But they are not easy to make and, therefore, are not yet used commercially. That, however, may be changing because of the AM revolution, according to Dineshkumar. “Built from repeating patterns, auxetics, by design, are best suited for AM. To mention a few potential applications [in the aircraft industry alone], this will be suitable for aircraft seat frames and luggage bins.”

His team is also attempting to use 3D printing to reduce carbon footprint. “AM has the potential to contribute to sustainable manufacturing practices.” They are exploring ways to develop efficient recycling methods for AM-produced parts, thus reducing material wastage, energy consumption and carbon emissions.

Photos courtesy: Shashank HR, Subhodeep Jana, Dineshkumar Harursampath

Top: 3D-printed engine made of Inconel 718 alloy; Bottom left: 3D-printed plastic parts; Bottom right: 3D-printed auxetic composite being tested

Challenges

However, several hurdles need to be overcome before AM realises its full potential. For one, raw materials for metal AM are expensive. Researchers led by Koushik Viswanathan in the Department of Mechanical Engineering are working on developing metal powders that are cheaper and more energy efficient. These powders have very similar characteristics to the commercially available powders, but could be produced at a fraction of the cost. Besides, the process of 3D printing itself is currently too expensive for mass production. Moreover, unlike conventional manufacturing processes, it builds one layer at a time and hence is slow.

There are also some myths surrounding AM which need to be debunked, according to Chakrabarti. One of them is that extremely high-quality powder is needed to produce high-quality finished products. “We throw in different sizes of powders and see what kind of quality comes up. And it turns out that the quality is not that different,” he says. Such parts made with powders of different sizes may not always be suitable for niche applications such as in the aerospace industry, but are more than adequate for consumer applications such as customised jewellery.

Chakrabarti highlights yet another challenge: 3D printing requires a different kind of expertise. “Some of the earlier wisdom about how you make things gets thrown out of the window and you have to do things differently,” he says. “So how do you change your design such that it is better amenable to being printed in an additive manner?” he asks rhetorically. 3D printing consists of melting a tiny piece of a material, one at a time, and glueing them together. “If you increase speed, then these little pieces will have less time to attach with each other. If you slow down too much, there will be too much energy, they will evaporate or they will remain molten or even melt the material that has already solidified. It will change the properties. So, you must find the right balance between the two.”

While researchers and innovators are confident of overcoming many of these challenges, Dineshkumar offers a word of caution. He says that despite its promise, the new technology cannot replace traditional manufacturing entirely. Instead, he envisions a future in which AM and Subtractive Manufacturing (SM) will work hand-in-hand in a synergistic manner leveraging the benefits of both, while minimising their deficiencies. “Addition and subtraction are an integral part of how nature makes things.”

Soumya Mishra is a PhD student in the Department of Materials Engineering, IISc and a science writing intern at the Office of Communications

Charting cells' chemical landscapes

- Narmada Khare

Photo courtesy: Infosys Science Foundation

Yamuna Krishnan is a Professor in the Department of Chemistry at the University of Chicago. In 2002, she completed her PhD in organic chemistry from IISc. Her passion for the exploration of the chemistry of biological systems evolved at the National Centre for Biological Sciences, Bangalore, where she spent eight years running her own lab before moving to Chicago in 2014.

A winner of several accolades, including the Shanti Swarup Bhatnagar Prize and the Infosys Prize, Yamuna's work is revolutionising our understanding of the environment inside cells. Today, her lab develops molecular tools to study organelles, the membrane-bound compartments found within the cells of eukaryotes (which include fungi, plants, and animals, but not bacteria, which are prokaryotes). Organelles perform specific functions for a cell, much like our organs do for our body. Yamuna has also established two startups that are translating research from her lab to create diagnostic and therapeutic tools.

Yamuna was in IISc on 11 July 2023 for a talk on her work. During her visit, she spoke to* CONNECT *about her interest in cell biology, research, and her startups.

What led you to choose scientific research as your career path?

When I was a kid, my dad used to always ask me questions about the world around us. If he had a glass with ice cold water, he would ask me why there was frost outside of it. They were very simple things, but they made me learn how to ask questions. He kept that curiosity alive – the education system tends to beat that out of us. My father was an architect, but he encouraged me to think critically. That was probably why I chose a career in science – because I always had this question in my mind: Why are things the way they are?

After studying chemistry, why did you switch to studying cells?

When I was in IISc, I ended up working in Sandhya Visweswariah's lab [Honorary Professor, Department of Developmental Biology and Genetics] for the very last part of my PhD thesis. Working in her lab was so exciting. She herself was doing experiments with me. The way she ran her lab was very egalitarian, and I liked it so much. That, and seeing how lipids I had made influenced DNA transfection [incorporation of foreign DNA into a genome] – the question I was working on at the time – convinced me that I wanted to do something related to biology. Sandhya was not my PhD advisor, but she has had a great influence on my thinking and my value system. I worked in her lab for a very short time, just six months, but it has had a lifelong effect.

Biology is chemistry that is very complex. When considering molecules and their chemistry, you go from simple systems to complex systems. Either you can go into the complexity of materials that are a mixture of many kinds of chemicals, or you can look at functional complexity inside a complex system, like a biological system. So, for those chemists who don't want to do "variations on a theme," it is a natural trajectory to go into either materials or biology.

Your lab is known for creating tools to explore the interiors of live cells for their chemical landscapes, and how they change during disease. Why is such an exploration necessary?

We started out by trying to understand how organelle function impacts cell function by mapping the chemical milieu within organelle lumens or cavities. In many diseases, when an organ malfunctions, this malfunction can be traced right down to dysfunctional organelles in the cells comprising that tissue. There is always feedback between organelles and cells. The organelle state and cell state are tightly coupled. If you want to understand how disease affects cells, such new avenues are ripe for exploration.

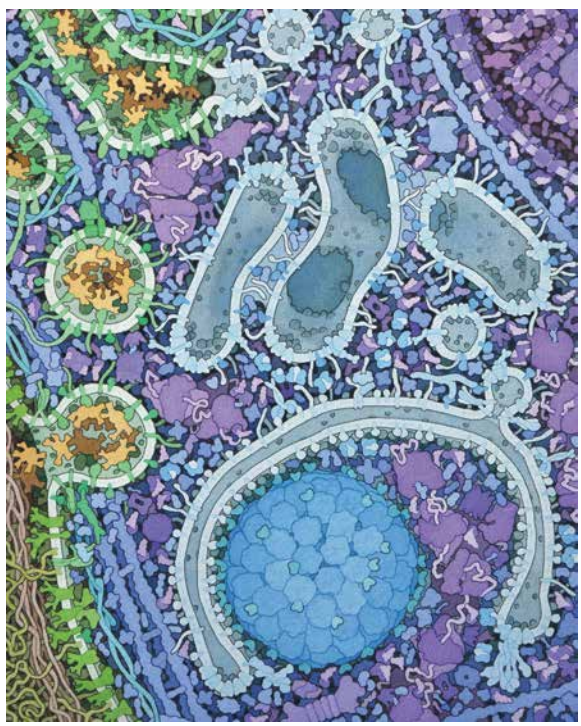


Image courtesy: David S Goodsell, Daniel Klionsky/Wikimedia Commons

Inside a cell: The illustration shows organelles like the Golgi complex and mitochondria, with a lysosome in the act of degrading some material

For example, in heart disease, we know that the Golgi complex is highly fragmented. Biologists and clinicians have known for decades about organelle dysfunction in disease. The reason, I feel, why they have not yet been able to leverage this knowledge, is because our description of an organelle is largely physical and morphological. We say: "It became bigger, or tubular, or crescent-shaped." But you see, there are molecules that are making this happen. And I believe, as a chemist, that until you get chemical measures and molecular measures of normalcy and abnormality in organelles, we will never be able to understand how organelle dysfunction has affected pathophysiology, and how organelles function in normal physiology.

If we can address such questions, then that might be a way by which we can diagnose, or possibly treat diseases. That's why my lab developed a platform to quantitatively image chemicals in organelle lumens.

You use nanodevices to study the chemistry of organelles. How do these devices work?

These are DNA-based reporters or probes. If you want to measure an ion inside an organelle, you need a probe that can perform two functions. First, it needs to have a measuring module like an ion-sensitive dye. And second, you need to be able to transport this device inside the target organelle.

Here, we use knowledge from biology. Say you want to target a certain organelle. You identify a shuttle protein that moves between the plasma membrane of the cell and that organelle. If you identify a molecular motif that binds to this shuttle protein and can glue it on to your device, then every single shuttle protein that comes out onto the plasma membrane will grab a DNA device and take it inside. After some time, your target organelle glows brightly because it has become a fancy cuvette containing your DNA sensor from which you can read out the concentration of your ion. With this technology, we can get quantitative chemical information. Here, the DNA probe is just a simple scaffold; it's like a coat hanger on which you can hang a green dye and a red dye and get a functional readout.

Here is an example. Take a chloride sensitive dye, attach it to one end of your DNA device, and a chloride insensitive dye, and hang it on the other end. Your device will also have a sequence that will help attach it to a shuttle receptor. Simply add it onto the cells, wait for a little time for the cells to internalise it. Wash it off from the surface. Over the next few minutes, the device will move from the surface to the target organelle. By simply imaging the cell using different wavelengths of light, you get a quantity, a number, for the fluorescence of each dye. We can use this to measure the amount of chloride inside that organelle.

What is the use of the two dyes? How do they help in sensing the changing chemical conditions?

Imagine that I have a constant red light. And then I have a green torch that can sense a certain ion. It is off to start with. As the levels of an ion increase, the intensity of the green light increases. For more amount of the ion, I have more intensity of green for the same amount of red. So, the readout will go from just red, to deep orange, to light orange, to yellow and so on, to lime green and green. That gives me an optical gradient that tells me how much of a certain ion is there. By just looking at green fluorescence becoming brighter or dimmer, my eye cannot tell me the exact concentration. If I have something constant that I can compare it to, then our eyes can gauge the difference. It is the composite that gives you a readout, that gives you a number.

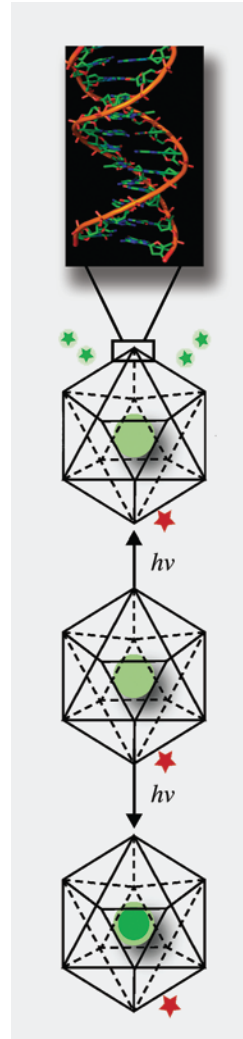


Image courtesy: Yamuna Krishnan

DNA nanocapsules that work using two different fluorophores. The red star indicates a constant (normalising) fluorophore

Where have such explorations led?

The organelle state reflects the cell state, and organelle composition defines organelle state. Just like your body temperature, blood pressure, heart rate, and so on are numbers that describe the state of your body, the levels of different ions inside an organelle can describe the organelle state. These numbers will vary when a cell is diseased. By looking at them, one can tell if the cell is healthy or diseased.

One of my companies, Esya Labs, is profiling lysosomes inside cells that are derived from skin biopsies of human patients, and we can diagnose Alzheimer's disease and many other neurodegenerative diseases way earlier, possibly before patients start manifesting the symptoms of these diseases.

Photo courtesy: Robert Kozloff/University of Chicago

Yamuna Krishnan with her team in her lab at the University of Chicago

So, DNA nanodevices sense the internal environment of cell organelles. What does this tell us about how cells work?

The devices sense ions. By telling us the levels of ions inside organelles, they tell us about how ion-channels – tunnels through which ions enter and exit – on organelle membranes function, and how this helps the organelle support the cell state. For example, if the cell is in an inflamed state, then the organelles will rise to the occasion – they will remodel, and all of them will function to maintain the cell's inflamed state.

Most organelles are enclosed within a complex network of membranes, and many of them dynamically connect with and separate from each other. Are lysosomes also part of this intracellular membrane network?

Each organelle is a reaction vessel carrying out a different kind of function. The chemical milieu within an organelle has been optimised over evolutionary timescales to promote the specific biochemistry required for its function. For example, the endoplasmic reticulum is creating proteins by joining together amino acids. In the Golgi complex, we are glycosylating – adding sugar chains to – proteins. Lysosomes are the well-known catabolic organelles of the cell. They are like stomachs of the cell, where obsolete or damaged proteins get digested. And yes, lysosomes interact with mitochondria, with endoplasmic reticulum, with plasma membrane – with most organelles.

Lysosome contains calcium inside its lumen. It gives out small spurts of that calcium, which acts like the signal necessary for its fusion with other organelles. This is required when, for example, the plasma membrane breaks, and lysosome goes and fuses at the breakpoint, providing the extra membrane for repair, acting like a band-aid. That's only one of its functions, there are so many others.

You have talked about cancerous tumours and how you can make them accessible to the immune system with the help of these tools. Can you tell us a little bit about this line of research?

If you inject our devices into a mouse, they go straight to a certain kind of immune cell called macrophages – white blood cells that eliminate diseased or dying cells, kill pathogens, and stimulate the immune system. Every organ in the body has resident macrophages.

In many types of tumours, nearly 50% of the tumour is made up of macrophages that are called "tumour-associated macrophages." When you inject the devices into a mouse with such a tumour, they head straight for tumour-associated macrophages. We still don't understand why they choose these specific macrophages over the ones that are present in any other organs in the body.

You and I are getting cancer every day. Our cells "go bad" all the time. But the immune system identifies these cells and kills them. So, a tumour is basically an indication that the immune system failed to see a cell that "went bad." Macrophages display fragments of these diseased or "bad cells" on their own surfaces via a process called "antigen presentation." By doing this, they alert T cells from the immune system to the location of cancer, which then take care of the bad guys.

The tumours that have very bad prognosis have very high numbers of tumour-associated macrophages. These macrophages are very "hungry," with hyperactive lysosomes. Lysosomes, as you know, degrade substances. So, they gobble up dead or dying "bad cells" within a tumour, and instead of politely snipping them into pieces and presenting them on the surfaces for the T cells to see, they digest the hell out of them all the way down to amino acids, so that they can make new proteins.

If you could somehow send a message to tumour-associated macrophages: "Please show those antigens here," then the T cells would come in and obliterate the tumour.

So, all we are doing now, is using our DNA nanodevices to send in inhibitors [certain small molecules] of those digestive enzymes that are present inside the lysosomes that chop up tumour cell proteins. These enzymes are called hydrolases. If they are very powerful, poof, everything is cut into amino acids. But if a small molecule binds and gums up these hydrolases, it blunts their activity. So, now the lysosome is not that hungry anymore. It chews up proteins only a little bit and spits out the rest onto the surface, presents the antigens, and now your T cells can come and take care of the tumour.

Thus, using our technology, we slow down the lysosomal action and allow the cancerous cells to become visible to the immune system.

You can send in an inhibitor attached to the DNA device. Is there a limit to the size of the probe that a cell can take in?

Yes, you don't want to use too much DNA. The more the DNA, the more expensive the therapeutic. You want to have just enough to do the job. That's why we keep the sizes of these devices to the minimum. We need DNA that is only long enough to keep the two strands together. For example, at room temperature, six base pairs of DNA will melt – that is separate from each other. We just need enough so that at body temperature, the two strands can stay together.

How are these nanodevices protected from degradation by enzymes inside lysosomes?

They are *not* protected from enzymes inside lysosomes. But remember, every reaction takes time. Every molecule has a half-life. You just work within that half-life. Even the medicines that you take are metabolised inside the body. It's not like nothing happens to them, right? You eventually excrete them in some other reacted form.

How do you imagine nanotechnology will change our understanding of basic biology and disease treatment in the near future?

This technology has already changed our understanding of basic biology dramatically; so, it is very difficult to predict how it will change. All we can say is that it will change, and change very fast.

In his work *Novum Organum*, Sir Francis Bacon famously states that "experiments of light," or discovery, must precede "experiments of fruit," or those inventions which would follow. As a scientist who has dabbled in both, is there one of these that you find more exhilarating?

"Experiments of light" and "experiments of fruit" are discovery and invention respectively. Two sides of a coin. Biologists are mostly discoverers. They want to ask why things are the way they are. Chemists are basically inventors. We take things of lower value, combine them, and make things of higher value. Both of these are different ways of doing science – discovery and invention. I never partition it and say, "I should do this much of invention and this much of discovery." It is a creative process, and we must do what needs to be done at the time that it demands to be done.

You mention in several of your interviews and talks from 2012 that you once insisted that you were "not here to do anything useful," and that you were merely trying to understand how cells work. Today, you are also devising potential diagnostic and treatment methods. What has changed in the last decade that made you revisit your approach?

If you are able to do something – even the most basic research – it may sometimes actually have larger implications. For example, take bacterial immunity. Why would anyone want to know about bacterial immunity, right? But it led to CRISPR-Cas9 [gene editing] technology. Things that seem so basic, that you think they can have no practical application, can sometimes end up with profound applications. So, if you have birthed a particular technology, then it becomes your job to take it to its logical conclusion. You want to have responsible stewardship of anything that you produce. That way you can also actively direct it as a force for good.

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