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Field Stations
Why they matter

Kanishka Crash Investigation
How metallurgy helped solve it

Birdbaths
Drawing avian visitors

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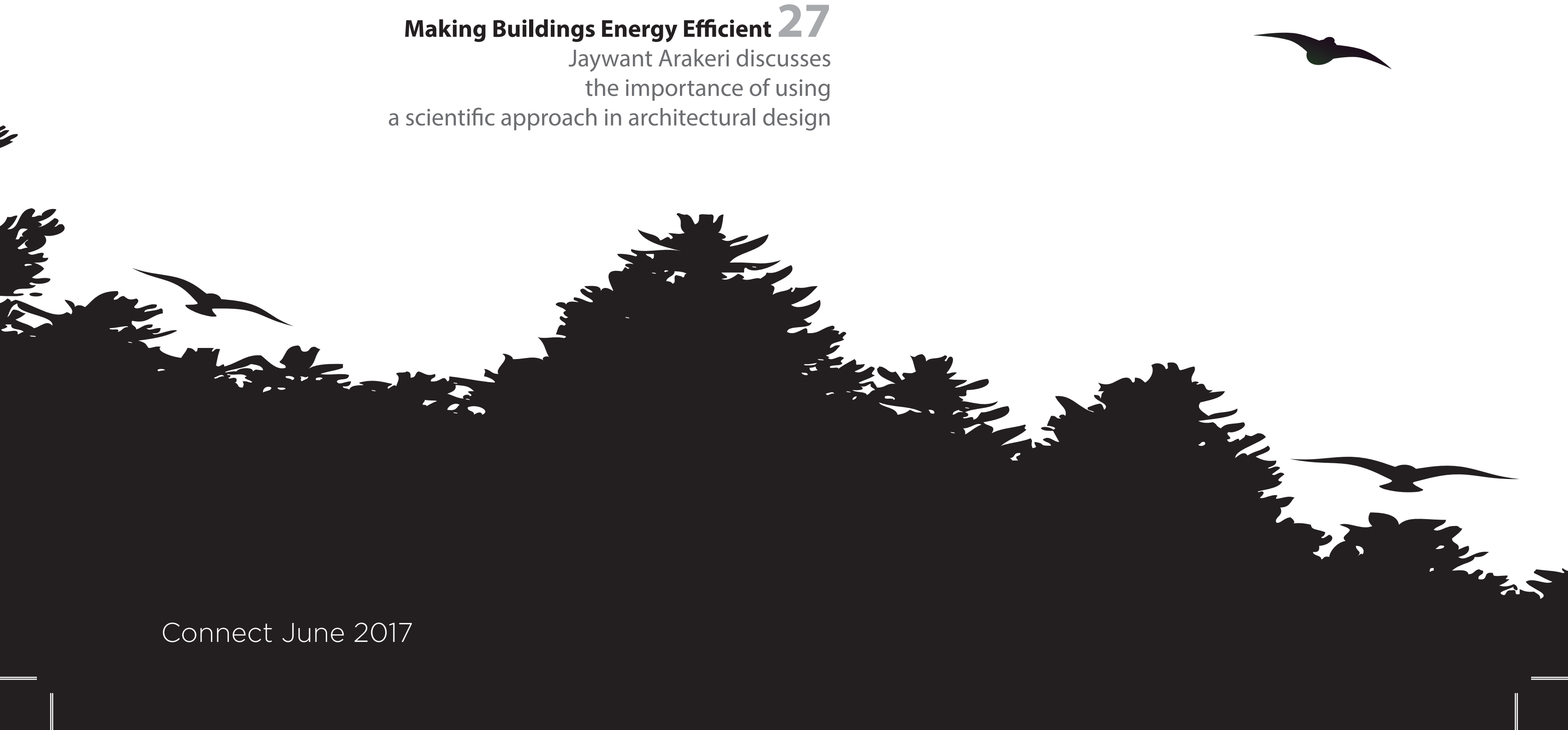

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EDITORIAL

After a brief hiatus, we are back. The break gave us an opportunity to reflect on our goals, and how to better reach out to our readers – old and new. As part of this exercise, the magazine has undergone a design overhaul. We now also have our own website (connect.iisc.ac.in), with more exciting stories and interviews, and readers can subscribe to a monthly online *Connect* newsletter.

In this issue, Deepika S explores what field stations mean to ecologists. They are such an essential part of many ecologists' lives, she finds, that for some they can almost become second homes. But field stations present challenges too – earning the trust of the local community is essential, as is checking your sleeping bag for snakes. Field stations therefore, as Rohini Balakrishnan says, offer crucial life lessons.

Karthik Ramaswamy takes a look at an experiment on the campus of IISc by Shubha Bhat who has set up a few birdbaths in her yard. These watering holes attract dozens of birds, both resident and migrant, which she spies on through her strategically located kitchen window.

Nithyanand Rao writes about how an alumnus of IISc and former faculty, V Ramachandran, led the team that investigated the crash of Air India Kanishka in 1985, finding that it was caused by a bomb.

Sudhi Oberoi talks to another IISc alumnus, Mandyam Srinivasan, about the remarkable navigational abilities of bees.

And as always, there's plenty more to read.

Please write to us with your feedback at connect@apc.iisc.ernet.in

Why do Ecologists Need Field Stations?

Deepika S

A peek into the challenges of working in the wild

“Field stations are absolutely crucial to the success of ecological research,” says Professor Rohini Balakrishnan, head of the Centre for Ecological Sciences (CES). They form so vital a part of ecologists’ work that Kartik Shanker, Associate Professor at CES, says they have “internalised it”. “They are just so much a part of our lives that it’s really hard for any of us to construct answers to questions like, ‘What do field stations mean to you?’” he says. “It’s like asking, ‘What do bathrooms mean to you?’”

IISc staff with visitors at the Mudumalai field station in Tamil Nadu (Photo: Nachiketh Sharma)

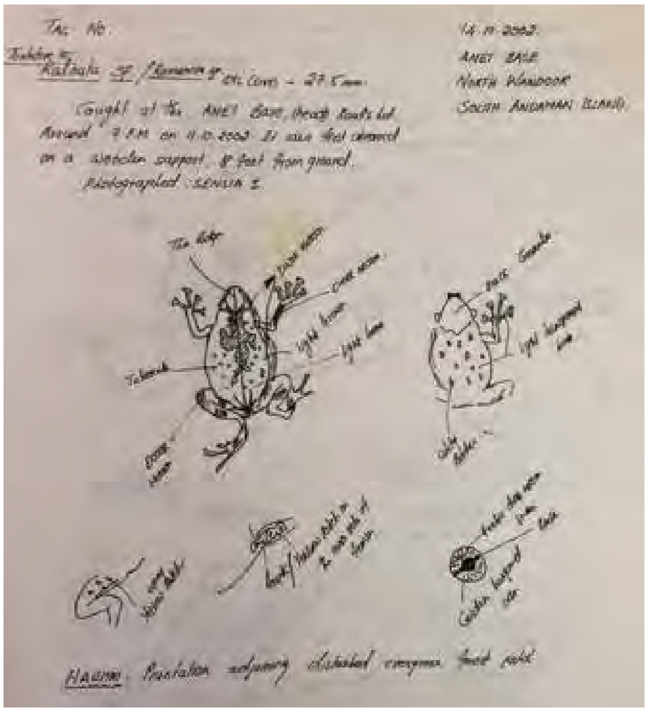
“They are just so much a part of our lives that it’s really hard for any of us to construct answers to questions like, ‘What do field stations mean to you?’” he says. “It’s like asking, ‘What do bathrooms mean to you?’”

At their most basic, field stations provide ecologists with a base to which they can return for food and boarding while gathering data in the wild. But they can serve different functions for different kinds of field biologists. For biogeographers answering broader questions about the distribution and evolution of species, field stations may serve as refuges for brief periods of time as their work involves being constantly on the move to collect samples over vast areas. On the other hand, for behavioural ecologists who spend long periods of time – weeks, months, or even years – anchored in a particular area to observe the species they’re studying, they can be a second home.

Field stations vary widely in size and purpose: they can be set up for short-term projects or long-term ones, with full-time or part-time staff, have minimal facilities limited to providing food and shelter or be equipped with more such as Internet, transport and skilled local trackers and field assistants. They can be as large as a cluster of buildings in the forests of Mudumalai acquired on lease over decades or as tiny as a hut on the outskirts of a Nicobari village, hired for just a week.

Left: Work desk at a base camp in the Nilgiris, Tamil Nadu. Right: Field base at Agasthyamalai in the Western Ghats (Photos: SP Vijayakumar)

During a discussion at his cabin, SP Vijayakumar, a biogeographer and postdoc at CES, leans over to a low cupboard and pulls out his field diaries, some from over 15 years ago, containing neat, meticulously recorded information. They hold clues to the kind of work he does as well as the role of field stations in it:



A page from one of SP Vijayakumar's field diaries (Photo: Deepika S)

they have maps that he had drawn for himself, sizes and weights of different frog specimens, their colours and patterns, geographical coordinates from which these specimens were collected, and other observations.

Vijayakumar's fieldwork typically involves moving from one location to another in quick succession in order to collect a wide range of samples, and his definition of a field station is a somewhat loose one – he considers even temporary shelters or huts in which he's spent a night or two his field stations. They're where he retreats to immediately after gathering data to process his samples. That usually means photographing and euthanising the animals, freezing them in time by 'fixing' them in formaldehyde, storing them in alcohol and taking copious notes before moving on in search of more data.

But not all ecologists need a field station in order to carry out their fieldwork: Bharti Dharapuram, a student at Shanker's lab, collects samples of intertidal marine snails from different places along India's coastline. "I take the department vehicle and drive down the coast, stopping at mangroves and rocky beaches to collect samples and staying over at hotels," she says. Unlike many other biogeographers sampling in forests who often have to spend several days in a location and usually stay at Forest Department guest houses, she says, her work involves sampling at multiple locations while travelling large distances within the same day.

Fieldwork, warts and all

Field stations are vital because for many scientists, they facilitate fieldwork, which comes with a rather long and complicated list of challenges. Take for instance the research done by Aswathy Nair, a fourth-year PhD student who studies behaviour in a species of katydids (of the same order as crickets and grasshoppers) in people's backyards in a village called Kadari near Kudremukh National Park. As the katydids live only for a few months in a year, Nair's field season is only from January until around May, leaving her with little time for field research.

Researchers work at the Mudumalai field station (Photo: Sandeep Pulla)

Added to that are the complications of working in an open environment, subject to changes and interruptions that are impossible to control. Tracking an individual to gather data is a tricky business when you consider that within the short window available, the species Nair studies calls less frequently during the full moon phase, can be eaten by predators, or the area in which she works may be affected by human activity. Amidst the stress of gathering data in the field, having a smoothly running field station to stay at can reduce the burden on scientists, allowing them to focus on their work.

The field station at Kadari near Kudremukh National Park (Photo: Harish Prakash)

> "You are an outsider inflicting a level of intrusion into spaces that belong to other people. It is very important to have at least acceptance, if not support, from the local community and the police"

Field stations, which Balakrishnan describes as "minefields to navigate" because they involve so many elements over which a scientist can have no control, including managing additional (often locally employed) staff for the upkeep of the station, can also be a prism for the socio-political pressures under which fieldwork is carried out. "In India it is culturally not very acceptable to pitch a tent and camp for fieldwork," Balakrishnan points out.

"And in forest reserves it is not allowed. A better option is to rent a house and be part of the local social system, though it's a very big challenge: you are an outsider inflicting a level of intrusion into spaces that belong to other people. It is very important to have at least acceptance, if not support, from the local community and the police," she says.

Local conditions can directly affect an ecologist's work: political turmoil in a region can cut off access to field sites, holding up research. As researchers at CES will attest, even with the necessary permits in place, there's always the possibility of running into trouble with police and Forest Department officials. Or depending on which part of the country you're in (especially if you're driving a Department vehicle with a "Govt of India" sticker on it), Naxals. Local suspicion towards researchers can also lead to scary scenarios: Nair recounts how a fellow student working at Kudremukh was once accused of stealing a family's chickens as his field site was near their home. That's on the milder side – in 2009, Aniruddha Datta-Roy, then a PhD student at CES, and a fellow researcher faced a terrifying ordeal in which they were confronted by a group of men with swords and knives near Fatehpur in Rajasthan. The men threatened to kill them, believing they were involved in kidnapping goats from their village.

Politics and society aside, working outdoors comes with its own dangers. In 2004, at the sea turtle monitoring camp in Galathea in Great Nicobar, several researchers working on the beach were killed in the tsunami. Vijayakumar says solemnly that research in the Western Ghats involves risking one's life, though danger in the field is widespread – "It can be something as small as a mosquito in the islands or an elephant on the mainland." But he laughs about how he woke up one morning while on an expedition to find three snakes snuggling with him in his sleeping bag, and was relieved to see they weren't kraits, which can be deadly.

Ravi Jambhekar, a student at CES who studies butterflies, giggles as he talks about an incident that occurred some years ago while he worked in the Andamans on a lonely task doing research for the Zoological Survey of India. He rented paying guest accommodation in Port Blair that doubled up as his field station, where he contracted chikungunya during an outbreak in his neighbourhood.

After a few days of high fever, he woke up a few times in the middle of the night to a shaking bed. He began to believe there were spirits in the room (local stories about the Andamans being a place of ghosts had perhaps taken hold of his fevered mind). Hours later, waking at dawn, Jambhekar found he couldn't sit up: there seemed to be "some wood" in his way. By then, he was certain he had died and been buried in a coffin, and wondered what to do next. It took several more minutes before he realised he was, in fact, still alive, and had simply rolled off and under his bed.

"He was certain he had died and been buried in a coffin, and wondered what to do next"

Eventually, he learned there had been an earthquake that night. He says it was after that solitary stint in Port Blair that he realised how important human interaction can be while out in the field.

Left: A makeshift structure forms a base camp on Trinket Island, Nicobar. Right: Field base at Muthikulam, Kerala (Photos: SP Vijayakumar)

"It's not that we're completely alone," says Samira Agnihotri, a postdoc at NIAS and former IISc student who studies birdsong in the region around BR Hills in Karnataka. She points out that at her field station, there are field assistants, local residents and staff to interact with, and seems grateful for the opportunity that her work gives her to build friendships outside the confines of her own economic class and urban background.

Despite the challenges that staying at or managing a field station presents, Balakrishnan is quick to add that she would still pick it any day over being confined to a lab.

"I send all students, even if they are going to be doing largely lab work, for at least one stint in the field," she says. "We are in ivory towers. But socio-politico-economic pressures are the conditions under which you have to manage to carry out your work. You still have to uphold the high standards of your science – you need to have sufficient sample sizes, be rigorous about data, and need to follow all the rules of ethics. For me, the field stations are very important in actually understanding how to negotiate your way through life, in addition to science."

CES and Indian field stations

CES has six permanent field stations: in Masinagudi, near Tamil Nadu's Mudumalai forest, set up by Professor Raman Sukumar and in Kumta, Karnataka set up by Dr TV Ramachandra, both around three decades old; in Kadari near Kudremukh National Park, set up by Balakrishnan in the 90s; in Bhimashankar, Maharashtra run by Professor Renee M Borges, and in Lakshadweep and Rushikulya in Orissa, run in collaboration with Dakshin Foundation (of which Shanker is a founder trustee).

In 1975, even before CES was set up, its founder-Chairperson Madhav Gadgil ran a field station in Dandeli, which in 1980 shifted to Sirsi, Karnataka. At the time, only one other field station was being run by IISc (one at Bandipur Tiger Reserve from 1974-79, under what was then the Centre for Theoretical Studies, where Gadgil worked). "The only other institution in India seriously involved in setting up field stations was the Bombay Natural History Society," says Gadgil. The Sirsi station changed hands when Gadgil retired in 2004, and has recently closed. But CES has played a large role in setting up field stations in India, and with recent developments, this is set to expand significantly.

The field station on the premises of Swapnagandha Resort in Goa, where Ravi Jambhekar currently works (Photo: Ravi Jambhekar)

> “Socio-politico-economic pressures are the conditions under which you have to manage to carry out your work”

The first field station to be set up in India with the aim of supporting research by the broader community was the Andaman and Nicobar Environment Team (ANET). It was founded by herpetologist Romulus Whitaker’s Madras Crocodile Bank Trust in the early 1990s. In 2005, Whitaker set up the Agumbe Rainforest Research Station on the same model. Most Indian field stations are set up to further the work of individuals, a group of researchers, or that of a particular institution, says Shanker. Only a few attempt a broader approach like ANET but achieve this on a smaller scale, he says.

In December 2015 at the climate change conference CoP21 in Paris, the Indian Ministry of Environment and Forests announced a new programme called Indian Long Term Ecological Observatories (I-LTEO).

These observatories are meant to be set up to study the effects of climate change in eight biomes across the country, for which Rs 40 crore has been set aside. Importantly, CES will host the coordinate cell for this programme.

“[CES] will ensure that the various projects being carried out by multi-disciplinary research groups across the eight sites are synergised. It is expected to host the central database and provide scientific guidance to groups for cross-theme analyses where needed,” says Sukumar. “The LTEO project is an opportunity to build regional capacity for ecological research and for the younger generation of ecologists in the country to be assured of long-term support.”

Shubha Bhat enjoys hanging out with her flock

Karthik Ramaswamy

Shubha Bhat's early attempts to provide thirsty birds with water have now evolved into a sophisticated enterprise that draws dozens of species, both resident and migrant, to her yard

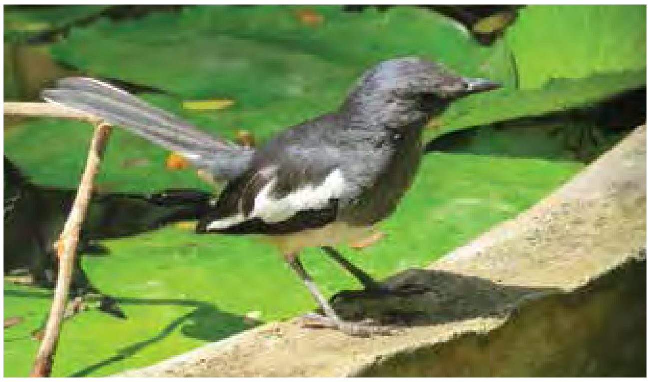
Photo: Karthik Ramaswamy

When Shubha Bhat got married 18 years ago, she found herself living in Bangalore. But life in the big city was starkly different from what she was used to in her village near Karkala in Karnataka, nestled in the Western Ghats. Here, in the midst of this bustling metropolis, she yearned for the wilderness that she grew up with. "When I came here, I had no place where I could go around. I spent my time indoors watching National Geographic. I missed nature," she recalls. Fortunately for her, it was not long before she moved to the wooded campus of the IISc, where her husband, Navakanta Bhat, works as a researcher.

Water for the thirsty

Despite being in the heart of the city, IISc's campus is home to an extraordinary diversity of plant and animal life. "I started thinking about how these animals get water," says Bhat. "So I kept a small earthen pot [filled with water] outside my house." But she didn't have much luck in luring any thirsty critters to her pot. A few years later, she and her husband relocated to another house in the campus, where she persisted with her experiment.

The change of house brought a change of fortune. First came the dogs; and it didn't take long for crows to arrive. This house had a bigger yard, and also had a strategically located window in the kitchen through which she could spy on visitors to her garden.



The oriental magpie-robin, a common sight (Photo: Shubha Bhat)

Frequent Fliers

Word got around quickly about the new watering hole in town. Other birds followed: common mynas, jungle mynas, rock pigeons, spotted doves, Asian koels, red-whiskered bulbuls, greater coucals, and magpie-robins. Some would drink water, while others enjoyed a quick shower. Even mongooses began to make regular pit stops at her garden to take a gulp.

Working the garden

The early success encouraged Bhat to attempt new experiments. She added more pots, including three big cement baths and a hanging earthen pot. All along, she also worked on her garden to make it more attractive to birds.

Bhat even introduced a few fish – guppies, kois and mollies – into the larger pots to keep in check the mosquitoes which were breeding in them. This had an unexpected consequence: kingfishers started to frequent her garden to dine on the fish.

More experiments

However, Bhat was unable to entice many other birds, especially smaller ones that she knew were around on campus, to her garden. "I felt that my birdbaths may not be safe for them because they are too deep," she says. So she put bamboo twigs with small branches that rose out of the birdbaths on which small birds perch, grew creepers adjoining the pots to make them feel safer, and added aquatic plants on which they could rest." Her efforts bore fruit immediately.

This had an unexpected consequence: kingfishers started to frequent her garden to dine on the fish

The aquatic plants make small birds like these oriental white eyes more likely to pay a visit (Photo: Shubha Bhat)

Clay figurines guarding one of Bhat's birdbaths (Photo: Karthik Ramaswamy)

But what proved to be a game changer was an observation Bhat made one day immediately after a storm. "I saw a tailor bird bathing using the droplets of water on a leaf. So I started watering the leaves of my *Ixora* bush every day," she reveals. Her effort paid rich dividends – it brought sunbirds, flycatchers, flowerpeckers, tailorbirds, warblers and other smaller birds by the dozens.

A purple-rumped sunbird basking after an Ixora leaf bath (Photo: Shubha Bhat)

Bhat's keen eyes noticed another similar behaviour that birds like orioles and starlings indulged in: they would use the morning dew captured by the leaves of trees to take a "dew bath". She tried to replicate this by sprinkling water on the leaves of her mulberry tree. And it worked. Now these birds too could no longer resist the lure of her garden. It also helped Bhat that, by then, IISc had started providing recycled water for use in the gardens. She was now able to sprinkle water on all her plants at least twice a day, which she continues to do religiously. Some days though, she is more generous. "If I hear some calls, I'll go out and water the bush, and immediately, they'll come down," she says.

Yet another rare sighting – the ultramarine flycatcher (Photo: Shubha Bhat)

Rare visitors

Bhat has so far seen over 60 species of birds in her garden. In less than a couple of years after she started her experiments with birdbaths, her garden also became a rest stop for some rare visitors, including a few from far-off lands. "On 8 October 2013, at about 12.30 pm, I saw a bird with an unusual flight. I knew that I hadn't seen this bird before. I went through my bird books and realised that it was the Kashmir flycatcher, a visitor from the Himalayas which had never been sighted in Karnataka before!" she says. "I've also seen other rare birds like Tickell's thrush and ultramarine flycatcher, which are migrants from the north. Many of the rare birds I've seen are warblers: green warbler, Hume's warbler, yellow-browed warbler, and Tytler's warbler."

Interesting behaviours

What Bhat finds most exciting is to be able to see the intriguing behaviours of different bird species when they swing by to bathe or drink water. One of the first things she noticed was how a crow – her favourite bird as a child – would dip its dry chapatti in water before consuming its meal. "Then he would bathe in it, drenching himself," she says with a laugh.

"Each bird is different and each bird takes a bath differently. For instance, the coucal would come to the same place on the left side of the rim of the pot, walk in a semi-circle to the right side of the rim, and finally dive into the water for a swim. On the other hand, the kite, which I never expected to see, would sit in the birdbath

The black kite uses the waterbath as a bath tub (Photo: Shubha Bhat)

like he's sitting in his bath tub, cooling himself. And the Blyth's reed warbler would sit on the perch, dip his head in water and sprinkle it all over himself," she explains.

Bhat's evangelism

Bhat's infectious enthusiasm for this rewarding hobby has caught on among a few of her friends, both inside and outside the main campus of IISc. She is however keen that more people in cities do their bit to help birds with water, especially during the summers, and she insists that it doesn't take much for one to make a start.

"People can keep, even if it is in their balconies, just a bowl of water, with maybe a small plant next to it. Ideally it should be a native species that can hold water in its leaves and that has branches for birds to perch on," she suggests.

Mandyam Srinivasan reveals how honeybees find their way home

Sudhi Oberoi

And how flight behaviour of bees and birds is revolutionising robotics

Photo: Karthik Ramaswamy

Mandyam Srinivasan is a professor of visual neuroscience at the Queensland Brain Institute and the School of Information Technology and Electrical Engineering of the University of Queensland. Famous for his distinctive studies on the visual systems of bees and, more recently, birds as well, Srinivasan is the recipient of the [Australian] Prime Minister's Prize for Science and a Fellow of the Australian Academy of Science and Royal Society. Srinivasan's studies on the navigational behaviour of bees have had profound impact on technological applications, such as autonomous robots and aerial vehicles.

and do whatever they need to, to get to the food. So you can train them and explore various questions because they come to you again and again in search of food.

> Traditional honeybees are very interesting because they have good colour vision and are trained easily

Honeybees in an experimental setup at Srinivasan's lab (Photo: Marie Dacke)

You graduated with a Master's degree from IISc in Applied Electronics and Servo Mechanics. Then you changed fields, studying "vision animals". Did IISc contribute to that transition?

IISc got me interested in engineering-based inquiry. The nice thing about IISc was that it was not just a teaching institution; it was also a research-based institution. It taught me to ask questions that you normally would not think of asking, and to build equipment, and design experiments to try and answer those questions. But I must say that the stimulus to do all this came from my ME thesis supervisor, BL Deekshatulu, as well as MAL Thathachar.

How did you end up studying vision in honeybees? And you now also address similar questions in birds…

I didn't quite choose to study bees myself: I joined in a department in Switzerland where they were working with bees – the Italian honeybee – and that sort of fascinated me and I decided to stick with it. Traditional honeybees are very interesting because they have good colour vision and are trained easily. They are programmed to go look for food and learn over time,

With the birds it was more circumstance and the fact that when I started studying birds, I was living in Australia. The Budgerigar, native to Australia, is easily domesticated, easy to train and maintain. It's a cruising bird, not a hovering bird. So it seemed perfect for our experiments.

How do bees navigate from point A to B and back?

There are two types of navigation: short-term navigation and long-range navigation. Long-range navigation is something that a lot of people are interested in and are working on. They study birds, for example, those that are sensitive to magnetic fields and use them to navigate. Some birds seem to use the sun or polarised light in the sky as a compass, like bees do. How they measure distance traveled is not very well known. However, our own research focuses on short-term navigation, specifically, guidance-based navigation: going through an obstacle course, or landing or avoiding an obstacle. Moment-to-moment navigation is what we are looking at.

Initially, it seems like bees learn what direction to fly in and how far to fly. Then they simply reverse that signal to fly back. But it is actually when they go many many times back and forth that they start to learn more about the landmarks they encounter along the way and they tend to rely more on the landmarks for navigation. So if you move a landmark near the food source then they will go searching for the landmark.

> Some birds seem to use the sun or polarised light in the sky as a compass, like bees do

They will then rely less on their odometric signal (that helps them gauge distance travelled from hive to food source), and more on landmarks that help identify the goal. If the landmark is displaced very far away, then they will be like, 'What is happening? I have traveled a long distance and I still haven't found the food. Something is wrong.' Then they will start to look around and come back to where their odometer told them the right spot was. Bees have this back up system, but their waiting depends on the level of experience they have. Once they have learnt a particular route to a food source they will go back and forth along the same route. This has been studied more carefully with ants, because you can watch them more closely and easily as they are not flying.

If a honeybee goes out and discovers a patch of flowers for nectar, what direction would it take to return to the hive?

Exactly the opposite, with a 180-degree turn. It just reverses the vector. To find the flower, it built up a sort of a vector; so what it is doing as it is flying looking for food is incrementally breaking up that trajectory into small straight line segments and adding these small vectors to get a resultant vector for the whole journey. Any time it decides to go home it has got that resultant vector, which is reversed by 180 degrees in order to return home.

Why would one expect honeybees, whose lifespan is very short, to do such intense learning?

Well, it is even more important to learn for an animal with a short lifespan because they do not have much time to do what they need to do. You have to learn quickly. For example, today's rewarding nectar-bountiful flower in a particular location could dry out in three or four days. And then something new will bloom. So the bees have to constantly be on the lookout and learn new locations for new flowers. Quite often, when a bee visits a given flower several times, even before that flower starts to dry out, it starts to look for its next possible site in anticipation of the current source drying out.

They need to do all this because their working life outside the hive is only about three weeks. Bees live for about six weeks in total. The first few weeks are spent inside the hive, tending and nursing to the younger ones. The last three weeks are spent as a forager. I suppose the colony requirement is that they forage as much as they can at that time. So they have to be agile, and learn new things.

What is the difference between obtaining information when one is stationary and when one is moving?

A lot! Maybe in our case it is not that different because we have stereo vision. Even sitting in a chair like this [pointing at the chair], I have a sense of the three-dimensional structure of the world because I can tell how far away you are, but that is because my eyes are far apart and I can pick up distance cues from stereo vision.

The Budgerigar, native to Australia (Photo: Partha Bhagavatula)

But if I had just one eye, I could not use stereo and that is exactly what insects are like. Then the only way I can see how far away you are is actually for me to move along some straight line and then by measuring how rapidly your image is moving, and, by comparing that with how my eye is moving, I can work out how far away you are. So it is a very active way of seeing and is called active vision where you have to do something to get the image. You cannot extract the information by sitting in one spot.

Is there a difference in navigation behaviour among different species of birds and bees?

That probably hasn't been studied a lot. There is still a lot to be looked at. Certainly I suppose that bees that have very short range navigational needs would not need to learn the navigational skills that migrating birds use to travel between continents. The thing that they find with some of these forest-dwelling sting-less bees in South America, and I think they have them in Australia as well (I don't know if they are here in India) – they are able to signal directions in three dimensions, not just two dimensions because often the food source can be in a forest, and they may need fly high up. So they have all sorts of elaborate acoustic signals which they emit during the dance, which they also use to communicate height.

That is something we have not yet looked at in many of these species; we just look at the visual aspects of the dance but we are not using microphones to pick up the vibrations, which may even be used to transmit information about the colour of a flower. We don't know so far whether they do this or not, but there could be lots of other codes that are airborne or transmitted acoustically that we again don't know of. In fact, the bee dance is also done in the darkness of the hive, so there is no visual communication there and it is mostly molecules of air vibrating. Other bees follow the dancing bee, and pick up the vibration of particles of air. And then of course a lot of substrate acoustic communication happens where they press their buzzing abdomens to the floor of the honeycomb. People are just starting to look at that.

> With insights from insect navigation these studies have already been applied in development of autonomous aerial vehicles and robots

What are some of the most exciting applications of these studies?

There's a movie called *The Eye in the Sky* – they send a tiny remote-controlled winged robot that goes inside a building and sits on the ceiling or something, and picks up information about terrorists who are plotting their next attack in that building. So this device has vision as well as acoustic information that is being transmitted back to some ground station. Stealth can be used for both good and bad purposes. In some sort of disaster situation, where for example you might be looking for injured people, it would be useful to have something which can travel to small spaces that does not rely on GPS. With insights from insect navigation these studies have already been applied in development of autonomous aerial vehicles and robots.

REMEMBERING RAJESWARI CHATTERJEE, IISc'S FIRST WOMAN ENGINEER

Sridevi Venkatesan and
Subhayan Sahu*

Rajeswari Chatterjee (Photo courtesy:
Creative Commons License/Wikimedia Commons)

It was the year 1953, and IISc had just appointed Rajeswari Chatterjee – who had arrived in India from the US after her PhD from the University of Michigan – as a faculty member. Chatterjee, the first woman engineer at IISc, joined the Department of Electrical Communication Engineering (ECE), where her husband, SK Chatterjee, was already working. Along with him, she set up India's first microwave engineering research lab. Microwave research was in its early days, but had developed rapidly during the recently concluded World War II. Together, they introduced courses in microwave technology and satellite communication in the 1960s, and were the first to teach this subject in India. Grants were not plentiful at the time, and they built their lab from scratch, making the instruments and components required for their research using indigenous resources. In a career spanning about 30 years, Chatterjee pioneered research in microwave engineering, wrote several textbooks, mentored many students who went on to have successful careers; she finally retired as the chairperson of ECE in 1981. Her contributions to microwave research are still used in RADAR technology and defense applications by DRDO, and her legacy lives on through the work of her numerous students spread all around the world.

But Chatterjee's tryst with IISc actually started much earlier, in 1943, when she joined the Institute as a research scholar in SP Chakravarty's lab at the Department of Electrical Technology, after completing her BSc (Hons) and MSc in Mathematics and Physics from Central College, Bangalore. At the time, there were only a handful of women pursuing a career in science. Chatterjee, however, was encouraged by her family, especially her grandmother, to pursue higher studies. In her few years as a researcher in Chakravarty's lab, Chatterjee worked on electronics, specializing in ultra-high frequency measurements.

> In a career spanning about 30 years, Chatterjee pioneered research in microwave engineering, wrote several textbooks, mentored many students who went on to have successful careers; she finally retired as the chairperson of ECE in 1981

In the 1930s and the early 1940s, IISc did have a few women scholars, but their paths were anything but rosy. CV Raman, who served as the Director of IISc from 1933 to 1937, was averse to the idea of having women students. He famously refused to admit Kamala Sohonie into IISc when she applied for a Master's course in 1933. He eventually took her on as a research associate, but only after she convinced him of her exceptionalism. She later went on to do her doctoral work in Cambridge, and became a celebrated biochemist.

Later Raman changed his stance, even admitting three research students to his own research group – Lalitha Doraiswamy, Anna Mani and Sunanda Bai. Though all of them went on to pursue doctoral research, none of them received a PhD. Lalitha Doraiswamy, who married S Chandrasekhar (the future Nobel Laureate), decided against pursuing research. Sunanda Bai ended her life under mysterious circumstances, while Anna Mani went on to become a well-known meteorologist.

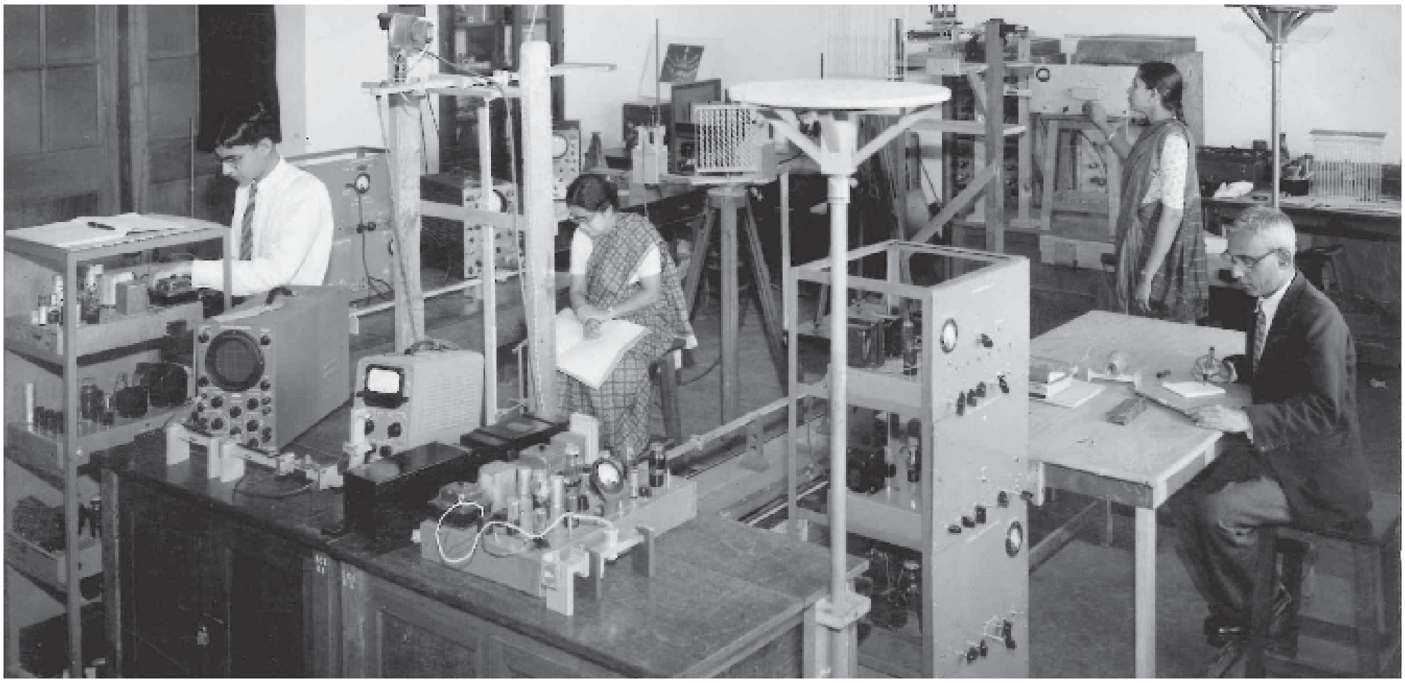
During this period – between 1945 and 1947 – there were also efforts on the part of the interim government in Delhi, which was slowly taking over the reins of power, to encourage the pursuit of science in the country. A scientific committee was set up, consisting of some of India's best-known scientists, such as Meghnad Saha, SS Bhatnagar, JC Ghosh, KS Krishnan and Homi Bhabha. They prompted the interim government to start a scholarship programme for talented Indian students in science and engineering – both men and women – who wanted to pursue research in countries like USA, Britain and Canada. In fact, in 1945, Anna Mani was one of the first recipients of this scholarship, and she went to London for research in physics.

Female students in IISc c. 1945. From left to right: Rajeswari (ECE), Roshan Irani (Inorganic Chemistry), Prima (Fermentation Technology), Mariam George (Biochemistry), Violet D'Souza (Fermentation Technology) (Photo courtesy: Archives and Publications Cell, IISc)

In 1946, Chatterjee too won the scholarship and secured admission for graduate studies in the Department of Electrical Engineering at the University of Michigan, USA. In June 1947, young Chatterjee travelled on board a troopship to go to the US. It was rare for women in those days to travel abroad for studies, but Chatterjee was undaunted and enjoyed her journey, as she recounts in her autobiography, *A Thousand Streams*.

After her return to India, she was back in IISc, but now as a faculty member. Here, she had to fight her way to the top in a male dominated field. BS Sonde, a student and later a colleague of Chatterjee, recollects how everyone respected her analytical skills and admired the way she was able to explain even difficult concepts to students in the classroom. The Chatterjees were very supportive of their students, and students were always welcome at their home. They helped them not only in their educational pursuits, but also with personal problems. Dr TS Vedavathy, who joined Chatterjee's lab as a student in 1968 and eventually became her colleague, reminisces about the support she received from her mentor throughout her graduate life. Chatterjee's strict demeanour toughened young Vedavathy during her days as a doctoral student. Vedavathy recollects an incident from 1971. She had lost her father three days earlier, when Chatterjee prescribed 'work therapy', and urged her to teach an ME class! Though at the time this seemed harsh, she says that she realised later how it helped her overcome her grief.

> It is perhaps a testament to Chatterjee's mentorship and brilliance that so many of her students have also had illustrious careers, both in India and abroad



Chatterjee and her husband working in the lab along with their students, Dhanalakshmi and Ramanujam (Photo courtesy: Indira Chatterjee)

Chatterjee's research was focused mostly on passive microwave devices – specifically, guided and radiated wave devices. Her work is still relevant, especially in the field of defence technology. Her authoritative book, *Antenna Theory and Practice,* is still widely read. It is perhaps a testament to her mentorship and brilliance that so many of her students have also had illustrious careers, both in India and abroad. Besides Sonde and Vedavathy, another student Anand Kumar went on to become a faculty member at ECE; and like their mentor, Sonde and Kumar also headed ECE. Other students she mentored also shone. One of them was RP Shenoy, a former director of the Electronics and Radar Development Establishment, a unit under DRDO, and a Padma Shri recipient who was considered the 'RADAR Pitamaha of India'. Another student, KG Narayanan, went on to become the Director of the Aeronautical Development Establishment, also a DRDO research facility.

The Institution of Electronic and Radio Engineers

This is to certify that

The J. C. Bose Premium for 1965

has been awarded to

for the paper

"Dielectric Loaded Waveguides - A Review of Theoretical Solutions."

15th December 1966

President

Secretary

Certificate from The Institution of Electrical and Radio Engineers to the Chatterjees for their research paper in 1965 (Photo courtesy: Indira Chatterjee)

Rajeshwari Chattopadhyay, also a student of SK Chatterjee, who herself became a successful researcher, remembers how there were always more female students in the microwave research lab, perhaps because the Chatterjees felt that female students were more sincere and worked harder. According to her, a great source of support through Chatterjee's life was her husband. Sonde recalls the Chatterjees were "both wedded to work", and led simple lives until the end. SK Chatterjee died in 1994. But Rajeswari Chatterjee continued to lead an active life. Chattopadhyay remembers how, even in her 80s, she travelled alone to the US to visit her daughter, a professor at the University of Nevada. In 2010, days after her last solo trip to visit her daughter, she collapsed in her house in Malleswaram, and breathed her last on being taken to the hospital.

Chatterjee at her residence in 2009 (Photo courtesy: Vikas Kamat)

**Sridevi Venkatesan and Subhayan Sahu are fourth year undergraduate students at IISc*

SWAY WITH SCIENCE

Bitasta Das*

*Bitasta Das is an Instructor in the UG programme at IISc

On 8 April 2017, undergraduate (UG) students from IISc performed Indian folk dances that communicated complex scientific ideas. The performances, which brought together the arts and sciences, were part of their humanities course Mapping India through the Folk Arts. The Saturday morning spectacle comprised six different dances, each of which was performed by a group of students majoring in either Physics, Chemistry, Biology, Mathematics, Earth & Environmental Science, or Material Science. Each of the six dances represented a ground breaking piece of research from one of these fields of study. All the photographs of the dances were shot by Sabyasachi Basu.

Bitasta Das and the students who participated in Sway with Science (Photo: Anirban Mandal)

VIRA

Plastic Eating Worms (Earth & Environmental Science)
The zestful Vira dance – a hangover from Portuguese colonisation in Daman and Diu – shows the unfettered party of the plastic molecules until mealworms introduced by scientists break their bonds and spoil the fun.

DOLLU KUNITHA

Haber Process (Chemistry) The popular drum dance of Karnataka with its typical structural patterns illustrates the exothermic and reversible formation of ammonia by combining nitrogen from the air with hydrogen derived from natural gas.

KALBELIA

Four Colour Theorem (Mathematics)
Dancers donning costumes in four different colours perform the sensuous snake charmer dance of Rajasthan to express the complex theorem that not more than four colours are required to colour the separate regions of a plane, so that no two adjacent regions have the same colour.

LAVNI

CRISPR (Biology) The energetic dance from Maharashtra, with its unique costume and choreography, shows the genome editing technology that allows permanent modification of genes within organisms, and has a wide range of applications.

KOITHU PATTU

Gravitational Waves and Universe Expansion (Physics)
This rustic farmer's harvest dance of Kerala explains how gravitational waves will allow us to explore the fascinating mysteries of the cosmos.

KOOTHU

Material Properties and Microscopy (Material Science)
The high-octane street folk dance form (Dappan) Koothu of Tamil Nadu shows techniques from materials science which probe and map the surface and sub-surface structure of a material.

Photo: Karthik Ramaswamy

KANISHKA CRASH, 1985: HOW METALLURGY HELPED EXPOSE A TERRORIST ATTACK

Nithyanand Rao

Former IISc metallurgist V Ramachandran helped establish that a mid-air explosion brought down the plane

A piece of wreckage from the crash of Air India Kanishka being placed on the deck of *Kreuzturm* (Photo courtesy: V Ramachandran)

V Ramachandran recognised the fragment from a stanchion, one of the structural elements used to support the fuselage of the aeroplane. But it didn't look normal: the aluminium tube had fractured and curled inwards by almost a full circle. He knew then that the piece might yield clinching evidence of the fate that had befallen Emperor Kanishka, Air India's Boeing 747, on 23 June 1985. He stored the piece carefully when he returned to his quarters on the ship *Kreuzturm* amidst the Atlantic Ocean, off the coast of Ireland.

> Three appeared to have survived the free fall from 31,000 feet, only to drown in the deep waters of the Atlantic

Kanishka had taken off from Montreal, Canada and was to stop over in London en route to New Delhi. As the plane entered Irish airspace, it was being tracked on radar from the Air Traffic Control at Shannon, on the west coast of Ireland. Two other planes, flying at well-separated altitudes one above the other, overlapped with Kanishka on the radar screen. Expecting to see the three planes separated again after a few seconds, the radar operators instead saw only two. Air India Flight 182, with 329 people on board, had vanished from the sky.

Soon, their worst fears were confirmed as passing ships spotted floating wreckage about a hundred miles from the coast. Of the 329 victims, bodies of only 131 were found. Some of them had had their clothes ripped off. From the postmortem examination which revealed flail injuries, it became evident that they had fallen from a great height. The plane must have disintegrated in mid-air and suffered a rapid decompression, for some had their eardrums ruptured. Some of the victims showed symptoms of hypoxia, exposed as they were to the thin atmosphere lacking oxygen. Three appeared to have survived the free fall from 31,000 feet, only to drown in the deep waters of the Atlantic.

To investigate the crash, the Government of India appointed a Court of Inquiry led by BN Kirpal, a judge of the Delhi High Court. Ramachandran, a metallurgist at the National Aerospace Laboratories (NAL), Bangalore, was named one of the assessors of the Court of Inquiry. Ramachandran had done his D.IISc in metallurgy in 1955, before serving as faculty in the Department of Metallurgy – now the Department of Materials Engineering – from 1956 to 1966. He went abroad for his PhD and joined NAL in its Materials Science Division in 1972. As a prominent member of the Failure Analysis and Accident Investigation Group at NAL, he had led inquiries into accidents before. But he knew they faced a much greater challenge with Kanishka because the wreckage was on the ocean floor and not all in one place, and therefore could not all be examined.

Ramachandran and others first examined the flotsam that had drifted across the ocean – seat cushions, pieces of the overhead luggage bins, hand baggages, life vests, floor panels – but found nothing to establish why the plane fell from the sky. The rest of the wreckage was spread over an area of 15 square miles on the ocean floor, 6,700 feet deep. In it somewhere were the two black boxes (the Cockpit Voice Recorder and Digital Flight Data Recorder) from the plane. To recover them, Scarab, a submersible vehicle used to lay cables on the ocean floor, was pressed into service, operated from a French ship. Scarab was equipped with sonar, and video and still cameras; it also had arms with which to handle pieces of wreckage it came across. With it, investigators retrieved the black boxes and found that their recordings were normal but stopped abruptly, as though due to a power failure. This was not enough to conclusively establish the reason for the crash – they would have to go back for the rest of the wreckage to understand what happened.

"That was not going to be an easy task," Ramachandran, now 85, told me. We were sitting at his home in Bangalore more than three decades later, with photographs from the time spread out on a table.

Using Scarab, the crew of *John Cabot*, a Canadian Coast Guard ship, photographed and video-recorded the pieces of wreckage they found on the ocean floor. Four hundred different pieces of wreckage were identified and their geographical coordinates noted to prepare a wreckage distribution map. Then, a priority list of items to be salvaged was made. A crew led by Ramachandran went back to retrieve about 30 chosen pieces in October of that year, for what turned out to be a one-month, round-the-clock operation.

A part of the floor structure of Kanishka being recovered from the ocean floor
(Photo courtesy: V Ramachandran)

"But in case of operational constraints," says Ramachandran, "I was given the authority to make on-the-spot decisions during the salvage operations." As Kirpal later wrote in a letter to Roddam Narasimha, another old IISc hand, who was the Director of NAL at the time, "The only interest Dr V Ramachandran appeared to have was to do his work to perfection."

"The only interest Dr V Ramachandran appeared to have," wrote Kirpal, "was to do his work to perfection"

The salvage team needed a second ship because *John Cabot* did not have heavy-duty cranes and could not accommodate all the pieces of the Boeing 747, given the number and size and weight of them. So *Kreuzturm*, a bigger ship with larger deck space, was engaged. But this meant that Ramachandran and three others had to shuttle each day in a small boat between *Kreuzturm*, where their quarters were, and *John Cabot*, where Scarab was operated from. Travelling on the boat was not without peril in the choppy waters of the Atlantic. "If I fell overboard," Ramachandran told me, "I would not have drowned because of the life jacket, but the sharks of the Atlantic would have had a south Indian meal." His own appetite had disappeared but that, he remembers, did not make him feel fatigued.

Ramachandran oversaw the salvage operation and was on board *John Cabot* as it carried Scarab to the spot from where a piece of wreckage was to be recovered. The crew operating Scarab would send it down to the ocean floor, a process that took three hours. Scarab would then attach one or more grips and a 10,000-ft long Kevlar cable to the piece and attach a brightly coloured floating buoy at the other end of the cable to mark the spot. Then, *Kreuzturm* would arrive to lift the piece with its 5-tonne crane. "To retrieve one piece of wreckage," Ramachandran says, "the two ships had to work in unison for a total of about 25 hours." It was expensive too: about $30,000 per ship per day.

After a piece was recovered, it had to be inspected and documented immediately. Ramachandran had a microscope on board for initial examination of some of the fragments. Because the wreckage had been on the ocean floor for about four months by then, some of it had acquired salt crystals which had to be washed off with a jet of fresh water. Then it was dried and treated with corrosion-inhibiting compounds. The wreckage was later transported to the Bhabha Atomic Research Centre and the Naval Chemical and Metallurgical Laboratory, both in Mumbai. With the help of scientists there and his NAL colleagues RV Krishnan, also an IISc alumnus, and S Radhakrishnan, Ramachandran planned and organised the metallurgical examination of the Kanishka wreckage using Scanning Electron Microscopy and X-ray imaging.

Examining the wreckage of an aircraft to understand what caused its crash is difficult because of the subsequent damage caused by the crash. But if you know what to examine and how to examine it, fragments of the wreckage – a small fraction of them – carry unique signatures.

If you know what to examine and how to examine it, fragments of the wreckage – a small fraction of them – carry unique signatures

Ramachandran and others shuttling between the ships *John Cabot* and *Kreuzturm*
(Photo Courtesy: V Ramachandran)

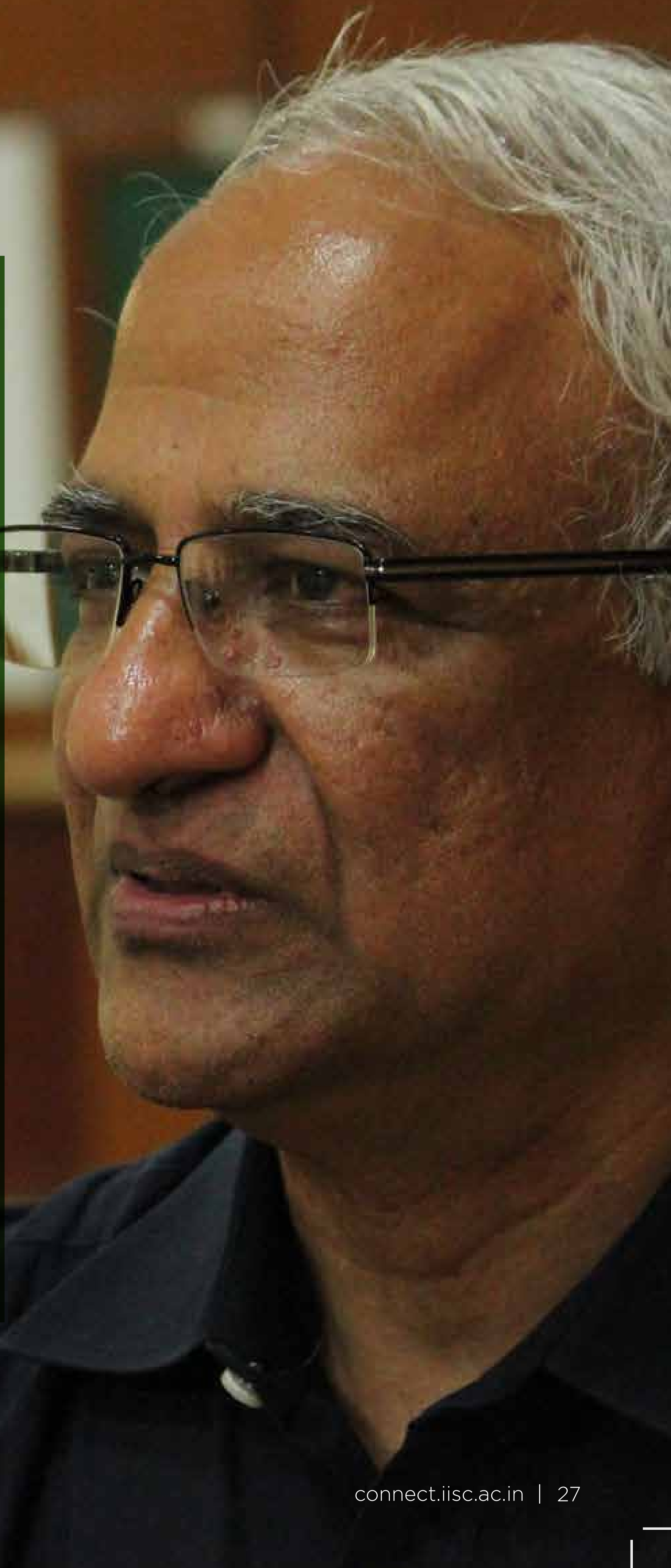
Bottom skin of the front cargo hold showed evidence of explosive deformation and fracture (Photo courtesy: V Ramachandran)

Ramachandran had already, at the time of recovery, observed a number of dents and impact marks on the underside of the cabin floor towards the front of the plane, suggesting shrapnel penetration. Further, this bottom skin of the front cargo compartment was severely mangled, with holes and tears at numerous places. The holes were often surrounded by petals and curls of the metal. The fracture edges had another feature – sharp spikes resembling the teeth of a comb, a distinct signature of explosive deformation and fracture. Further, the slopes of the edges of some of the fractured fragments reversed frequently, a feature known as reverse slant, that is also a signature of explosive fracture. Some of the sheet metal fragments indicated fracture in a plane parallel to their surface, with the sheet losing a part of its thickness. This phenomenon, called spalling, can only be caused by shock waves.

There was another crucial piece of evidence – the stantion. A square tube of aluminium from the forward cargo hold of the plane, it was one of the fragments of metal that came along with a large piece of wreckage retrieved from the ocean floor. When Ramachandran and his team examined the microstructure of the piece, they observed a feature known as deformation twins. Under usual rates of strain, planes of the aluminium crystal merely slip past each other. Under very high rates of strain, however, aluminium deforms by twinning – parallel bands appear in the microstructure, cutting across its grains. Deformation twins were also observed in the microstructure of the fragments that exhibited spikes. "These twins form in aluminium only under high-rate deformation conditions, as in explosions," says Ramachandran. Confirmation of this arrived from explosion experiments that were carried out.

The conclusion was clear: Kanishka had been brought down by a bomb. In their report submitted in December 1985, Ramachandran's team noted that an explosion in the forward cargo hold of Kanishka would account for all the features observed in the salvaged fragments. Other investigators put together pieces of the puzzle that confirmed this, concluding that the bombing was a terror attack by Sikh separatist militants. (In February 2017, Canada released Inderjit Singh Reyat, the only person who was convicted for the bombing in the subsequent investigation.) A cascade of failures – such as a violation of rules regarding transfer of luggage from one flight to another and a malfunctioning airport X-ray machine – led to the bomb being undetected.

Ramachandran vividly remembers the tragic consequences of these failures, especially the scenes at the Regional Hospital in Cork, Ireland, a coastal town that functioned as the control centre for the salvage operations. The gymnasium at the hospital had to be converted to a makeshift mortuary to receive the large number of dead bodies. Relatives of the victims visited the seaside to pay their last respects to their dear ones and immersed rose petals and wreaths in the sea. The residents of Cork lent their shoulders to the grieving relatives of the victims. "The victims included 30 children," Ramachandran says. And among the wreckage found floating across the sea, he remembers, were children's toys.



MAKING BUILDINGS ENERGY EFFICIENT: LESSONS FROM THE MECHANICAL ENGINEERING AUDITORIUM

Karthik Ramaswamy

Inaugurated in 2013, the auditorium in the Mechanical Engineering Department also serves as a classroom. What makes it unique is its design – energy efficient, yet sensitive to human comfort. The driving force behind this initiative was Jaywant Arakeri, Professor, and former Chairperson of the Department. He spoke to *Connect* about the thinking that went into the design of the auditorium, and the science behind it. Here are excerpts from the interview.

Photo: Nithyanand Rao

How and why did you get involved in this project?

I was the Chairperson at the time it was initiated; the last bit was completed under the next Chairperson, Prof Narasimhan. We wanted a room which is, as far as possible, naturally ventilated and naturally lit. I also had an interest in it because I work in fluid mechanics and heat transfer. And we had been doing some work on thermal design and human comfort. I was also keen on making the design environmentally sustainable. But the many inputs that went into the design came as a result of discussions among the Department's faculty members, Profs Satish and Bobji, and Dharuman, who were part of the core team. And whenever required, we consulted other faculty members like Prof Gurumoorthy, for aesthetics, and Prof Sonti, for acoustics.

This hall has no air-conditioning. Yet, right now, it is quite comfortable even though it is the middle of the day during peak summer.

Yes. To understand how to make a room comfortable from a thermal viewpoint, we need to understand two things: one, the surrounding climate, and two, issues related to human comfort. In Bangalore, except for March and April, we have very comfortable temperatures. And even during these months, night time temperatures go below 25°C. So we can use this diurnal variation in temperature, and "store the low temperatures" in the nights. That's the reason we decided to have thermal mass in the form of thick walls instead of using fabric or some board which are good for acoustics, but don't store "cold".

> To understand how to make a room comfortable from a thermal viewpoint, we need to understand two things: one, the surrounding climate, and two, issues related to human comfort

The other important thing is thermal comfort. Our core body temperature is around 37°C. When it gets hot, we lose heat to maintain this body temperature in different ways: convection, radiation, evaporation through perspiration, and to a small extent, conduction to the surface that one is in contact with. If the ambient temperature is about 26°C, there's no problem. If it is slightly higher, one way of ensuring comfort is through fans. In a place with moderate climate, the breeze from fans carries away the heat from the body. So we decided to use fans – we have many wall-mounted fans all over. Ideally we would've liked to have some low-noise large fans. But due to time constraints, we got these.

In a place like Rajasthan which is hot and dry, we could use a desert cooler [desert coolers cool the air through evaporation of water]. But if both the temperature and humidity are high, then you would need an AC.

There are many exhaust fans in the auditorium. Could you explain the role of these fans?

In an auditorium or a classroom environment, human heat load is important. Each of us dissipates around 100 W of heat. If there are 100 people in the audience, then we generate about 10 kW of heat! This heat needs to be removed.

Exhaust fans fitted all around the auditorium suck rising hot air out of the room. Also, notice light seeping in from some of the translucent panels in the ceiling (Photo: Karthik Ramaswamy)

There are two exhaust systems here. One is on the roof. It has turbo ventilators whose turbines are rotated by the wind, and it sucks the air from inside. The other is small, low-noise exhaust fans. As hot air rises, some of it will be sent out through these exhaust fans [pointing at a panel of exhaust fans that are placed high up on the wall all around the auditorium] and some of it will go up into the turbo ventilators.

What about the lighting?

Lighting was not so much of an issue because we have plenty of windows which ensured both good lighting as well as good ventilation. If you notice, some of those [pointing to the ceiling panels] are translucent. That allows some light to come through as well.

And the acoustical design?

Initially when we went to a consulting engineer, he said that we would need to use some kind of soft material on the walls and carpets on the floor [deployed to absorb sound and improve the quality of acoustics]. But we didn't want that because of the reason I already mentioned. Fabric and carpets also collect dust and fungus.

Curved tiles help scatter sound, thus preventing echoes
(Photo: Karthik Ramaswamy)

I once happened to go to the new building of the Aerospace Engineering Department. I met the Chairman and saw one of the classrooms. It was a regular classroom with plain walls. But they were complaining that they had a lot of echo problems. Luckily, at around that time, someone told me about BECIL [Broadcast Engineering Consultants India Ltd], a public sector undertaking that is into sound engineering. We spoke to the Manager [Narasimha Swamy] about our requirements. He had a very scientific approach. During the discussion, we asked him whether some sort of waviness in the tiles would help scatter the sound waves and prevent echoes. He said, "Yeah, it should work." Then we thought, "Why not use the tiles with curves that have the right wavelength?" The wavelength of a sound wave with a frequency of 600 Hz is about half a metre. So if the wavelength of the undulation [in the tiles] is right, then the scattering will be appropriate. Any sound in the frequency range relevant to speech just bounces off and gets scattered. So we bought these tiles (usually used for decorative purposes on compound walls) with a wavy pattern. They are thick and have small perforations which allow the sound to get absorbed and get scattered, and not cause reverberations.

So if the wavelength of the undulation [in the tiles] is right, then the scattering will be appropriate

What would your advice be to people in the IISc community as well those from outside?

One of the best designs is the Vidhana Soudha [seat of Karnataka's legislature]. On the outside, there's a corridor that allows diffused light to come in, but keeps away direct sunlight. Our own Materials Engineering building – built long back – has a similar design. The current building designs that you see in India are probably the worst. For instance, it doesn't make sense to use so much glass for the climatic conditions that we have. Glass is good for colder climates where you want to trap heat inside. In places like Bangalore, we should avoid glass and can also do away with air-conditioning, unless you're building a lab or something like that. It's more about using common sense and being sensitized to these issues. You have to be willing to spend some time on the design, and believe in it.

The corridor of Bangalore's Vidhana Soudha keeps direct light away, only letting diffused light into the building (Photo Courtesy: Bikashrd/Creative Commons License/Wikimedia Commons)

Photo: KG Haridasan

ANNAPOORNI RANGARAJAN IS ON A QUEST TO UNDERSTAND HOW BREAST CANCER SPREADS

Deepika S

Learning what activates cancer stem cells, which lead to metastasis, can hold the key to fighting other cancers too.

Annapoorni Rangarajan, Associate Professor at the Department for Molecular Reproduction and Developmental Genetics, was bitten by what she calls the "cancer keeda" over two decades ago as a Master's student at Nagpur University. "What really interested me was how a normal cell in our body could convert to a cancer cell," she says. "It's not so altered that the body's immune system rejects it. At the same time, it's different, and it's out of control. So what goes wrong?"

In 2004, armed with a PhD from the National Centre for Biological Sciences and having completed her post-doctral study at the Whitehead Institute for Biomedical Research in the US, she moved to IISc at a significant time: oral and cervical cancers were the highest-occurring ones in India, but in cities, breast cancer posed a large problem, threatening to overtake cervical cancer (it is now the leading cause of cancer deaths among Indian women).

> Rangarajan moved to IISc in 2004, a significant time for the epidemiology of cancer in India: oral and cervical cancers were the highest-occurring ones in India, but in cities, breast cancer posed a large problem

It was also an important period in terms of how cancer biologists had begun to understand the disease: in 2003, scientists at the University of Michigan Comprehensive

Cancer Centre identified breast cancer stem cells for the first time, and the fields of stem cell research and cancer research were starting to overlap. A tiny subpopulation of cells, among normal cells as well as cancer cells, were found to show stem cell-like properties (namely, the ability to develop into different cell types and divide to produce more stem cells), and were able to live and grow even after detaching from the substratum.

In an ordinary cell, this detachment leads to cell death. It is hypothesised that cancer stem cells, however, are able to survive in suspension and travel through blood vessels to a different part of the body to form a new tumour. Such spreading of cancer in the body – known as metastasis – is responsible for an overwhelmingly large number of cancer deaths, and that was where Rangarajan's focus on cancer research came in.

Spreading of cancer in the body – known as metastasis – is responsible for an overwhelmingly large number of cancer deaths, and that was where Rangarajan's focus on cancer research came in

"My [question] when I started my lab at IISc was, can I isolate these cancer stem cells, and learn the molecular mechanisms for how they grow in an anchorage-independent fashion?" she says. "It is the only kind of cell that can re-create a tumour, and is also, to an extent, drug-resistant as it survives chemotherapy. Fundamentally, can I understand the stem-like properties in them? And therapeutically, can I find out new mechanisms through which we can target them?"

When Rangarajan started out as an independent researcher, she says, "I did not want to deal with cell lines, which is what every biology lab was doing at the time." (If we know of cancer cell lines in popular culture today, perhaps it's because of the infamous HeLa cell line, named after Henrietta Lacks, whose cancer cells were taken in 1951 and cultured without her knowledge or consent – now the subject of a recent movie starring Oprah Winfrey.) Instead, Rangarajan collaborated with the Kidwai Memorial Institute of Oncology in Bengaluru to obtain breast tissue biopsies and isolate the cancer cells for further study.

As a tumour grows, its Trojan Horse-like stem cells go into a hibernation of sorts, cutting down on nutrients and energy use to save them for later. Stresses that lead to depletion of energy activate a protein within cells called AMP-activated protein kinase or AMPK. The first "eureka moment" in her laboratory, says Rangarajan, was when they identified matrix detachment as a form of stress that super-activates AMPK. The second such moment was establishing that inhibiting AMPK prevented the growth of mammospheres, or clumps of breast cancer cells. Recent work in her lab reveals that once it is activated by stress, AMPK combines the "axis of evil" in terms of drug resistance: it makes the cells more drug resistant in suspension, transforms its shape to penetrate and exit blood vessels, and enhances its stem cell-like qualities so that it travels through the body until it latches onto a new organ and forms another tumour.

In 2015, in an innovative step taken with Kaushik Chatterjee, Associate Professor at the Materials Research Centre, porous 3D scaffolds were created on which they could grow breast cancer cells that mimicked tumour growth in humans far better than the existing 2D plates, and was cheaper than using animal models. Currently, they are developing patient-specific 3D models of tumours which they plan to use for drug screening.

Targeting AMPK seemed to hold the key to achieving this. While chemotherapy kills the bulk of cancer cells, it actually appears to enrich cancer stem cells, which can cause a relapse later on, Rangarajan says. "In the absence of AMPK, commonly used chemotherapeutic drugs like doxorubicin can target and kill cells far better. Inhibition of AMPK, in combination with existing chemotherapeutic drugs, is probably an effective option." Currently, her team is collaborating with HS Atreya, Professor at the NMR Research Centre, to make peptide inhibitors for AMPK. "It will be a good 10 years before it enters the market," she says.

Inhibition of AMPK, in combination with existing chemotherapeutic drugs, is probably an effective option

Rangarajan's work on the role of AMPK in breast cancer is especially significant as AMPK plays a role in other epithelial cancers; learning how to inhibit AMPK could mean advances in treatment for other kinds of cancer as well.

Currently, Rangarajan is studying the link AMPK might provide between diabetes and breast cancer. A widely used anti-diabetic drug, metformin, is also used to treat cancer, but activates AMPK in the bargain. "What if you treat a patient for diabetes but place them at a higher risk of developing cancer that spreads? And if you have a patient who's got both, what kind of treatment and strategies should we predict for them?" They're big questions, with important implications for healthcare in India and the world. "They're in our next Five Year Plan," she jokes.

Open Day 2017 (Photo: IISc Photography Club)

A ‘GREEN’ OPEN DAY AND OTHER EFFORTS TOWARDS A ZERO-WASTE CAMPUS

Bhama Sridharan*

*Bhama Sridharan is one of the driving forces behind the activities of IFF.

Spring Mela 2017 (Photo courtesy: Bhama Sridharan)

IISc Families and Friends (IFF) is a forum created to provide a platform for voluntary initiatives to work towards improving the quality of life for all those associated with IISc. A major endeavour of this organisation, started in early 2015, is to work for a "clean and green IISc", which entails reusing and recycling all solid waste produced by the campus residents in a responsible manner.

IFF also brings the campus community together by organising fairs and festivals at regular intervals, the latest of which was the Spring Mela held on 16 April. Home-made food and chaat stalls, arts and crafts stalls, live music and dance performances, games and on-the-spot competitions are the highlights of these events. A major achievement at these events is that waste is managed by following a number of guidelines: people are encouraged to bring their own cutlery (plates, spoons and cups), and if they can't, food is served in arecanut leaf plates that are composted along with food waste. Using plates made of thermocol, plastic or lined with aluminum foil is strictly prohibited.

IFF has invested in 400 steel spoons and cups so that plastic spoons and paper cups are not used. Paper cups are a hazard to the environment: they are difficult to recycle (because of their plastic resin waterproof coating), result in loss of trees and add to greenhouse gases, and are bad for our health as we ingest this plastic coating when we drink hot liquids from them. The Spring Mela was the fourth such programme to be conducted that followed all these protocols, and was a huge success with over 400 people taking part. At the Diwali Street Art festival last year, with waste being similarly managed, the members of IFF took an oath to cut down on firecrackers, which are detrimental to the environment, use children in their manufacture, and are a nightmare for the numerous animals on campus.

The biggest challenge IFF has taken up so far is to make IISc's Open Day a green one. Every year on this day, a huge amount of trash is generated by the thousands of visitors who throng the campus. This year, it was held on 4 March, and saw about 22,000 visitors. IFF's goal was to ensure that all the trash generated on Open Day doesn't end up in landfills; paper, plastic and tetra-packs should be recycled and food waste composted. This implies segregation of waste at source, not an easy task when that many people visit the campus. But IFF also saw this as an opportunity to educate them about waste segregation and recycling. This ambitious plan would work only with the full support of the administration, along with voluntary help from students, staff and residents of the campus.

Makeshift bins for segregated waste (Photo courtesy: Bhama Sridharan)

To achieve this, plenty of steps were taken. At all help desks, dustbins were provided for segregation at source and properly labeled for plastic, paper, and food waste. Banners were put up explaining waste segregation. Green volunteers (comprising students, staff and campus residents) instructed visitors on how to use the dustbins properly. Only reusable steel glasses were kept at the water stations with a poster showing why no paper cups would be used.

Strict notices were given to all restaurants (like Prakruti and Nesara) on campus specifying that food should be served in arecanut leaf plates. Labelled dustbins for different kinds of waste had to be provided near these places. The use of plastics was minimised as far as possible and thermocol packaging was not used, even for take-outs.

Student volunteers oversaw waste management in and around their departments, made sure the labelled dustbins were provided and took care to see that visitors used the bins properly on Open Day. Many IFF volunteers were in constant touch with the students and chairpersons of the departments to make sure this happened.

IISc Alumni Association also sponsored t-shirts with the message "Reduce-Reuse-Recycle". All the volunteers (including faculty, students, spouses and campus residents) sported these t-shirts to spread the message. At the end of the day, all the segregated waste was transported to the Solid Waste Management Initiative by IISc (SWaMII) centre – started by the Centre for Infrastructure, Sustainable Transportation and Urban Planning (CiSTUP) – which composted the food waste on campus. Hard plastics, paper and laminated plastics were channelled for recycling through ITC's WOW (Wealth out of Waste) programme. Eventually all paper was sent by ITC to their paper recycling unit in Coimbatore, hard plastics were given to recyclers in Bangalore and the low-value laminated plastics that cannot be recycled were sent by ITC to the ACC cement plant in Gulbarga.

All the planning and hard work yielded positive results: enormous quantities of waste were recycled and composted (3,100 kg of wet waste, 540 kg of dry waste), which would have otherwise ended up in landfills. The campus was clean at the end of the day; it didn't look like a place that had just hosted a huge science party for thousands of people.

But perhaps the most heartening activity that IFF volunteers embarked upon on this day was to use the event as a teaching moment: they were able to educate the many busloads of children and young adults about the importance of waste management and why it is important to segregate waste at the source.

Besides organising festivals and dealing with solid waste segregation on these days, IFF volunteers have been working with SWaMII (Solid Waste Management Initiative by IISc) on a door-to-door campaign educating people about the importance of segregation at source. Now, the segregated garbage pickup by SWaMII has been extended to all the staff quarters and to 31 departments. IISc also has an agreement signed with Sembramky Environmental Management to take care of sanitary waste.

Volunteer efforts were key to successfully coordinating waste segregation (Photo courtesy: Bhama Sridharan)

Organic photovoltaic cells made at IISc were tested in the harsh environs of the world's southernmost continent

The Organic Photovoltaic Cells from IISc (Photo: Charulata Somal)

THIS RENEWABLE ENERGY TECH TRAVELLED ALL THE WAY FROM IISc TO ANTARCTICA

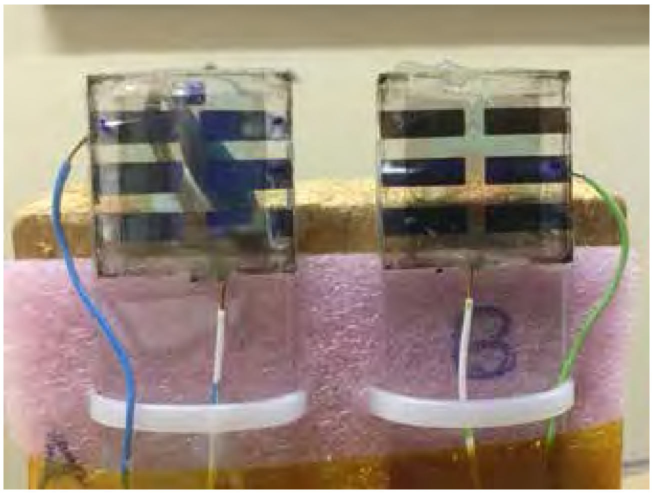
> The OPVs were sent to Antarctica as part of the International Antarctica Expedition (IAE) 2017 organised by '2041'

Sudhi Oberoi

"Things were not going well, but he [Monto Mani, Associate Professor, Centre for Sustainable Technologies] did not let go. He went around arranging for the packaging, got me out of bed at 10 pm, and got me and my students to the lab to test the cell and [other] settings," exclaims Praveen C Ramamurthy, Associate Professor at the Department of Materials Engineering, about his colleague's tenacity in ensuring that the Organic Photovoltaic Cells (OPVs) they developed at IISc made a successful trip to the South Pole, where they were tested.

The OPVs developed at IISc were sent to Antarctica as part of the International Antarctica Expedition (IAE) 2017 organised by '2041', an organisation founded and led by polar explorer and sustainability enthusiast, Robert Swan. The cells were carried to the Union Base camp, 80° South and tested by Charulata Somal, an IAS officer and Chief Executive Officer of Kodagu Zilla Panchayat, Karnataka, also a passionate advocate of environment issues and climate change. "Since our expedition was focused on renewable energy, technology from NASA and other companies was being tested. I wanted to [carry] some Indian technology too," says Somal, who got in touch with IISc to enquire about the possibility of testing a device from here in the extreme environs of Antarctica.

Somal's offer enticed both Ramamurthy and Mani. They had a device in the works, which they wanted tested in demanding environmental conditions, but preparing it for the harsh environs of Antarctica was going to be a challenge. With less than a week to go before Somal's expedition, the duo got to work.



Two OPV Cells mounted on a wooden block, sandwiched between glass layers held together by flexible silicon adhesives to tolerate extreme temperatures (Photo: Sudhi Oberoi)

Construction of the Cells

OPVs use an organic polymer to absorb light and convert it into electricity. These cells require almost 1,000 times less energy for manufacturing than silicon-based solar cells, are lighter, more pliable and work well in regions with diffused sunlight.

The OPVs carried to Antarctica from IISc were designed, synthesised and fabricated at Ramamurthy's lab. Their cells, now in the fourth generation of development, have a novel architecture that facilitates maximal light absorption and current passage, making them function more efficiently. According to Varun Adiga, a student involved in fabrication of the cell, "[the] making of the device was not as challenging as optimising each layer of the cell to ensure that [all] the contacts were in place."

But before the cells could be carried to and tested in Antarctica, they had to be first tested in the lab, which was done by Mani's team. Several cells cracked. What proved to be the Achilles' heel was the encapsulation step: a process that provides protection to the cell and enables ease of data recording. This step requires sandwiching the cells between a layer of glass and ensuring that the contacts, electrodes and sensors are all held in place, a challenge that Mani took head on.

When a standard cell is tested in the lab, all contacts are usually fastened using crocodile clips or pogo pins. But Mani and his team knew that clips would not survive Antarctica! Therefore, the team decided to provide a second layer of protection. "We got some really flexible silicon adhesives to press the whole cell between two glasses and use that pressure to hold the electrodes in place" explains Mani. The cells were then mounted on a wooden block and a simple ice-cream bag (a bag to keep instrumentation safe from low temperatures) acted as a portable mini-weather station. The station included a data logger to measure voltage, current, ambient temperature and humidity. Recounting the many methods that the team looked for to prevent the instruments from freezing dead, Mani says, "We did look at many ideas to get the instruments to function at sub-zero temperatures, including a heated box powered by a portable battery bank, but these were getting too complicated and heavy. Something simpler [like the ice-cream bag] was required."

"[The] making of the device was not as challenging as optimising each layer of the cell to ensure that [all] the contacts were in place"

The cells, though made to withstand -20°C, were tested at room temperature in the lab, where they logged an operational efficiency of 6-7%, a good number for OPVs. Recalling her experience of testing the cells before they were sent to Antarctica, Khadija Kanwal Khanum, a post-doctoral fellow in Ramamurthy's lab, says, "We [she and Mani] were both testing the device and had to hold the cells in our hands without disturbing it for about a minute. We have many setups in lab, but this experiment was one of a kind."

Expedition to Antarctica

Once the device was ready, Mani flew to Jaipur where he handed over the experimental setup to Somal; he also

IAS officer Charulata Somal and polar explorer Robert Swan along with the cells from IISc (Photo: Charulata Somal)

Ramamurthy (standing second from left) and Mani (standing third from left)
with their happy team and OPV cells (Photo: Sudhi Oberoi)

explained to her about how to operate the two cells.

On reaching Antarctica, Somal found that both cells worked, much to her delight. She was able to record data for two hours; she made all the measurements and also took down detailed notes of sunlight conditions. The main objective of the exercise had been accomplished.

After experiments in Antarctica, the cells however went on their own little unexpected expedition! On the return journey, the bag carrying the cells was misplaced by the airline. Much to everyone's relief, it was eventually traced and brought home safely after a month's travel through many continents.

Performance and Future

Back at IISc, Mani and Ramamurthy have now been able to analyse the data from the cells. However, they had to forego data from one of the cells which was corrupted because of mishandling. The cell that survived the harsh conditions of the South Pole recorded an efficiency of 2%. Ramamurthy attributes the low efficiency to temperature cycling, but is pleasantly surprised that the cells turned out to be "robust even after the harsh exposure and the bumpy ride."

One of the findings of the analysis is counterintuitive. "The efficiency is actually going up with decrease in temperature," remarks Mani on the data obtained from one of the cells. But he is glad that the cells survived the test of extreme conditions, which is precisely the application they were designed for. Mani explains why OPVs hold much promise for the future – they require significantly less energy than the commercial silicon counterparts, making them an environmentally friendly alternative better suited to low temperature and low light conditions. However, he adds that issues of stability and performance still remain.

From an explorer's perspective, Somal feels that the cells have a lot of potential and are a good solution to "keep warm in extreme conditions, especially during white outs, high winds, [and in regions of] indirect solar radiation."

Anjula Gurtoo, Associate Professor, Department of Management Studies, not involved in the study, says, "The climate change impacts of Antarctic explorations are immense as they use conventional energy for heating, radio [and] lighting. These cells can change that and slow down the use of conventional energy in small consumption areas like [various sensors], radio and lighting." The research team agrees with her and believes that niche applications stand to gain most from this technology.

Ramamurthy and Mani have now been invited by the "2041" team to test different applications of the same technology at the South Pole by end of this year. What started as a fun exploratory experiment has now opened up a serious research avenue with exciting possibilities.

Photo: Karthik Ramaswamy

SUBBIAH ARUNACHALAM, “MR OPEN ACCESS”, TELLS US WHY POLICY RESEARCH IS IMPORTANT

Nithyanand Rao

Subbiah Arunachalam is a visiting scientist at the DST Centre for Policy Research, IISc. Arunachalam started out as a researcher in chemistry, then became an editor of scientific journals, but eventually turned to his interest in information science. He is known for his work in scientometrics and for his advocacy of open access to knowledge. Arunachalam spoke to *Connect* about information science, science policy and research in India.

You've been described as an information scientist. What is information science?

There are two streams of information science, and they differ as much as chalk and cheese. The first is where I belong – handling information and knowledge for the benefit of others. The purpose is to present to the users accurate and timely data to satisfy their specific needs so they benefit from it. The users could be professors, farmers, workmen, children, college students, the lay public, just about anybody. Information science of this kind goes beyond librarianship in that some of us, influenced by the work of Derek de Solla Price, Robert K Merton and Eugene Garfield, analyse knowledge production and use scholarly literature to study the history and sociology of science.

The second kind of information science – the major kind – is a lot more technical and mathematical and deals with the transmission, reception, storage and retrieval of information based on the statistical analysis of communication between humans or machines. It was pioneered by Claude Shannon and Warren Weaver, and is a part of communication engineering although researchers in other areas use it too.

Could you tell us about your work and research interests?

I watch what scientists do and try to quantify India's contribution to research in specific fields and answer questions such as, "Are we doing research relevant to our needs?" I also like to see how knowledge produced by scholars leads to further knowledge – knowledge begetting knowledge.

> I watch what scientists do and try to quantify India's contribution to research in specific fields and answer questions such as "Are we doing research relevant to our needs?"

Another facet of my work concerns information useful for local communities – villagers, fishermen, farmers, etc. I was a volunteer for 12 years with the MS Swaminathan Research Foundation in Chennai where I experimented successfully with cross-cultural knowledge exchange through travelling workshops for development workers from Africa, Latin America and Asia. So the work I do can have some relevance to academic and public libraries, scholarly communication and development work.

You said you like to study how knowledge begets knowledge. Is that broadly the field of scientometrics?

That is one major aspect of scientometrics and it is called bibliometrics. It is the study of how knowledge spreads and is exchanged – what Newton referred to as seeing further by standing upon the shoulders of giants – as reflected by references in research publications. This can provide insights into the social, cultural, and cognitive structures latent in the practice of science.

Tell us about the research at the DST-CPR here at IISc.

The CPR at IISc is one of five such centres set up by the DST, each with a different focus area. Ideally, what is required is a very large set up, a whole group of people who can address the relation between the nation's needs and science and technology. Here at the IISc DST-CPR, at the moment, we are addressing certain limited but useful issues, one by one. We have published a couple of papers on practical issues and the third is getting ready. I believe they will have some impact. One of them is about why Indian researchers should shun the practice of paying publication charges to journals. Another is on why every researcher in India should have a unique author identifier. The third is about misuse of impact factors and other citation-based indicators by our regulatory bodies and funding agencies. We are also looking at ranking of academic institutions.

Evaluating return on investment is part of policy research and many funding agencies bring out periodic reports. It began with the National Science Board, USA, which in 1973 brought out the first of its biennial *Science & Engineering Indicators*. In India, the DST produces annual S&T reports for the nation. The work of DST-CPR, using literature data in conjunction with data on investments on R&D, personnel deployed, etc., to develop science indicators, will be useful for such reports.

Do you think science policy in India over the years has been adequately informed by policy research?

Mostly. A number of scientists have helped, right from Mr Nehru's time – people such as AV Hill and PMS Blackett. In the early years after Independence, Nehru's government sought the advice of scientists like PC Mahalanobis and Vikram Sarabhai and this tradition continues to this day, perhaps with a diminished intensity. Currently, Rajagopala Chidambaram is the Principal Scientific Advisor to the Government. All these people are professional research scientists who have spent most of their time in laboratories before they moved into advisory roles. They need the support of a new breed of people who can look into maximizing the socio-economic benefits of science.

Policy research is important because poor advice will lead to poor policies. Unless we're well equipped to handle the relation between science and economy, and science and society, it is difficult to provide the best policy choices.

What was your earliest engagement with science policy?

In 1982, *The New York Times* quoted passages from a provocative article I wrote for *Science Today* in 1976, titled "Why is Indian science mediocre?" The NYT write-up had juxtaposed my statement "If science is an enterprise aiming at the creation of new knowledge, we in India seem to have failed miserably in this enterprise," with a summary of Mrs Gandhi's speech at the Annual Meeting of the Indian Science Congress acclaiming India's scientific achievements. I was summoned to explain. That was my earliest engagement with science policy.

Another of your interests has been advocacy of open access.

Yes, indeed. Some people even refer to me as "Mr Open Access, India!" I am an advocate of inter-operable open access repositories and open science.

If knowledge in the sciences, including social sciences, is locked up in subscription journals, only those who subscribe to those journals can access it. Unless all the knowledge you need is freely available, your ability to further advance knowledge is limited. If all knowledge is available to all, chances of seeing more knowledge produced are very high. That is the raison d'être for open access.

> Unless all the knowledge you need is freely available, your ability to further advance knowledge is limited

There was resistance in the beginning but now even journal publishers who opposed initially are ready to come on board; but they also want to retain their profits and they're trying to find models [for it]. Open access is now an accepted idea. According to a 2013 study funded by the European Commission, more than 50% of what is produced in S&T is available in the open in some form or the other. It's remarkable – all within the last 20 years. Major funders such as the Wellcome Trust and the Bill and Melinda Gates Foundation are supporters of open access.

In India, journals published by the various Councils and Academies and some private publishers are open access. However, many Indian researchers publish in toll-access journals. But there is a way by which they can make them open access – they can make the post-prints available, which we're persuading them to do. IISc has a repository; indeed, it was the first to be set up in the country and one of the earliest in the world, but the faculty and students don't seem to be taking it seriously. Similarly, although the DST, DBT and CSIR mandate that research funded by them should be published open access, researchers don't take it seriously and these agencies don't enforce it. Science policy is not just about tabling reports before committees; it is also about persuading decision-making bodies to adopt certain policies and take action.

Do you think the emphasis on publishing in journals with high impact factors, which also tend to be toll-access, is one reason why open access isn't yet the norm?

Not necessarily. There is a large number of people who want to publish in high impact factor journals, such as *Nature*, *Science*, *Cell,* and *New England Journal of Medicine*. But these journals have set the bar very high. Not many Indians are writing papers which can be published in such high impact factor journals. That is the truth. There are a few who can – by all means let them do that. For instance, in 2016, there were only 22 papers in *Nature*, 14 in *Science* and 3 in *Cell* with at least one author from an Indian address. You can see that if you go to *Web of Science.*

You have been coming to IISc and Bangalore for many years now…

I came here as a student in 1969. Ever since, I've been coming here like a pilgrim. I was a visiting fellow for three months when NCSI [National Centre for Science Information] was here and I used SCI [Science Citation Index] on CD-ROM to gather data for one of our earliest papers on S&T in India.

Another attraction is the Indian Academy of Sciences. In 1973, the Academy invited me to join them to edit their journals and subsequently be the Secretary. I was there for two years, but what an eventful two years that turned out to be. I helped the Academy reorganise their journal publishing programme; founded *Pramana*, the physics journal. I also persuaded the ageing Academy to enlarge its Fellowship to truly reflect the large number of bright scientists deserving to be elected.

Yet another link to Bangalore is a vibrant group of bright young people who go by the name "The Centre for Internet & Society". I like talking to scientists and thinkers and keep in touch with them to learn what they're doing. Even in Chennai, where I live, I go to Matscience [The Institute of Mathematical Sciences] often.

Photo: Karthik Ramaswamy

“I Realised that Only Chemistry Permitted Endless Creativity”

Rohini Krishnamurthy

Ashoka G Samuelson is a professor at the Department of Inorganic and Physical Chemistry, IISc. He joined the Institute after completing his PhD from Cornell University, USA, in 1983. His research is centred on understanding how a chemical reaction proceeds before it reaches the product. More recently, his team has been exploring the applications of metallic complexes, particularly copper complexes, with suitable ligands in treating cancer.

On 30 March 2017, Samuelson delivered an Institute Colloquium, after which he sat down with *Connect* to talk about his journey as a chemist.

When did you realise you wanted to become a chemist? What drew you to this field?

After my Pre-University degree, I had to make a choice for my Bachelor’s. I tried my best to move away from chemistry; I did not want to be labelled as someone who became a chemist due to parental influence. But I realised that only chemistry permitted endless creativity. It is still true. Chemistry is a creative science.

Can you tell us about your life as a PhD student at Cornell University? What did you work on?

I worked on a physical organometallic chemistry problem. Physical organic chemistry is still my first love. Much of my work still involves understanding reactions through the use of isotopes. However, that part of my research is more involved and would be difficult for a general audience to follow. The papers read like detective stories where we try to figure out the path taken by the molecules during a reaction.

How you set up your lab after taking charge?

Slowly, and with great difficulty! It took some time to obtain a research grant. In those days, the funding agencies did not have the same magnanimity they have now. We set up a lab to handle air and moisture sensitive compounds, but could not get sufficient funds to import a dry-box.

You've been associated with IISc for the last 34 years. How would you describe this journey?

This has been a wonderful experience in my life. I would not trade my position here with a position in any other institution in India or even abroad. The academic atmosphere in our department is wonderful. It would take several pages to describe this journey.

How different is it teaching undergraduate students as compared to teaching PhD students?

I have been teaching undergraduates [UG] for only the past three years. The experience has been improving. The challenge is to convince them that learning the concepts you are trying to teach would have a lasting value even if they are not going to be working in the area of chemistry associated with the course. So I try to teach the logic behind various studies and try to do case histories as well so that the basic principle of scientific research is understood. UG students are more easily excited compared to PhD students. After going through a Master's programme, there is very little energy left for studying! But then generalisations are difficult.

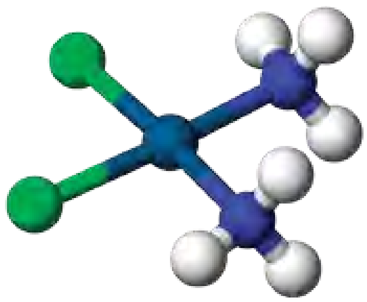
So I try to teach the logic behind various studies and try to do case histories as well so that the basic principle of scientific research is understood

You started your research here by studying copper complexes. Can you tell us why you chose copper (I) complexes over other metal complexes and also throw some light on other areas of research?

We studied copper (I) complexes for two reasons – its role in speeding up reactions and carbon dioxide capture. Palladium (0) is an excellent catalyst and we hoped copper (I) could mimic palladium (0) as they have similar electron counts. And we achieved moderate success in this field. We were also interested in looking at how copper (I) could mimic the role of nickel (0), a carbon dioxide activator, as nickel (0) also has the same electron count.

Another metal complex we used to capture carbon dioxide was titanium tetraisopropoxide. It doesn't react spontaneously, but in the presence of one molecule of water, carbon dioxide capture does occur. But the efficiency wasn't that good as two titanium tetraisopropoxide molecules were required to capture one molecule of carbon dioxide.

We also worked on understanding on how two copper atoms come close together [a phenomenon called cuprophilicity] despite repulsion from the filled 3*d* orbitals of each copper (I) atom. During the course of our research, we realised that copper complexes which are soft cations can form more stable complexes in the presence of both hard and soft ligands [referred to as the optimisation principle], which goes against the widely believed principle – soft cations bound to soft ligands would only like to bind soft ligands rather than hard ligands [maximisation principle]. Working on copper complexes turned out to be like working in a gold mine.



An example of a metallic complex, Cisplatin-platinum bound to its ligand (Image courtesy: Benjah-bmm27/Creative Commons License/Wikimedia Commons)

In your talk, you made a mention of the scientific debate on cuprophilicity. Can you explain that?

Gold atoms can come close together, otherwise called aurophilicity, because there is an inherent mixing of 6*s* and 5*d* orbitals, bringing the metal atoms together. This is on expected lines. But what came as a surprise was the fact that the copper-copper distance was found to be short in several complexes. There were two conflicting views based on this. One group believed that ligands were responsible for the short distances and another group was of the opinion that metals were making a difference.

So we studied factors that promote short distances. We understood that the ligand was inducing short distances between two copper complexes. Ligands are capable of removing electron density from metals, thereby reducing repulsion and bringing the metal atoms together. It took us about 15 years to arrive at this conclusion systematically and definitively.

Did you experience any eureka moment while working in the lab? Can you tell us about it?

We have had many eureka moments. The identification of orthocarbonates as a product in the carbon disulphide reaction was a startling discovery and our first eureka moment. This was made while we were trying to develop reactions that can capture carbon dioxide. We used carbon disulphide as a model reaction with copper aryloxides. Orthocarbonates were relevant in the 1980s because they were used to make polycarbonates that are widely used in making CDs. Our method of making orthocarbonates was rather convenient as opposed to the earlier more complicated methods. Back then, we didn't realise the value of orthocarbonates. Later, GE plastics patented a method of conversion of orthocarbonates to polycarbonates and cited our paper as well.

We were the first ones to show the difference in reactivity between two extremes ends of the *d* block elements. We originally studied copper (*d* block element) which is on the right side of the periodic table and also looked at the left side of the *d* block elements like titanium and zirconium with the help of my students, Rajashekar Ghosh and Akshai Kumar. We were surprised to see the reactivity between the two ends were indeed very different. The difference can be attributed to differences in electron count. The nucleophilicity of the coordinated alkoxide goes up for metals with high electron density while for metals with few electrons; the reactivity is the exact opposite.

The fact that copper (I) prefers hard ligands to soft ligands was another eureka moment too.

Apart from its role in catalysis, do organometallic complexes have any other applications?

These complexes are used increasingly in medicine and in making new materials.

In your talk, you spoke about the utility of another metallic complex, ruthenium half-sandwich complex, in reducing the harmful effects of a drug used to treat blood cancer. How did you go about this?

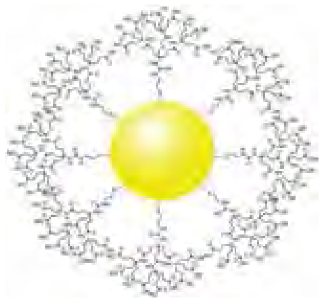
6 Thioguanine (TG) is used to treat Acute Myeloid Leukemia (AML). Unfortunately, use of 6 TG can lead to skin cancer if the patient is exposed to UVA radiations from the sun. One ends up with skin cancer while treating blood cancer. My student, Raja Mitra, used 6-TG with a ruthenium half-sandwich complex to carry the active molecule to the cancer cell. We used NMR [Nuclear Magnetic Resonance] and mass spectrometry to look for photochemical products that are normally formed when 6 TG undergoes oxidation. Ruthenium (Ru) complexes with 6-TG did not show any such products. This has two advantages. One is that it is transported more efficiently to the cancer cell and another unexpected effect is that it is less reactive to sunlight. We think the use of Ru (6-TG) complex might be useful. But it has to be shown that is more active and less damaging than 6 TG in vivo. A lot more research is required. The Office of Intellectual Property and Technology Licensing (IP TeL) from IISc has contacted several companies. A start-up company will be testing this complex and taking this forward.

You are now focussing on using copper complexes to study anti-cancer activity. Why did you choose Cu (II) over Cu (I)?

We started our research by testing copper (I) complexes but copper (I) is not suitable for the targeted delivery work. copper (II) complexes are better suited due to their stability in an aqueous environment; they also have ligands which we can easily attach to macromolecules.

You spoke about triple targeted therapy to reduce tumour burden. Can you explain this?

We explored copper complexes for targeted delivery to reduce tumour size. We used a combined approach of gold nanoparticles carrying metallic complexes and decorated with vitamins. Cancer cells have more receptors for vitamins than normal cells; we used biotin to enable targetted delivery of the drug conjugate. Glutathione (GSH) cleaves disulphide bonds. So we used a disulphide linker with the drug conjugate as the GSH concentration is higher in cancer cells thereby leading to release of the complex from the conjugate. We collaborated with Kumaravel Somasundaram, Professor, Department of Microbiology and Cell Biology, to test this on mice. The results were encouraging as treated mice showed tumour size reduction by 75%.



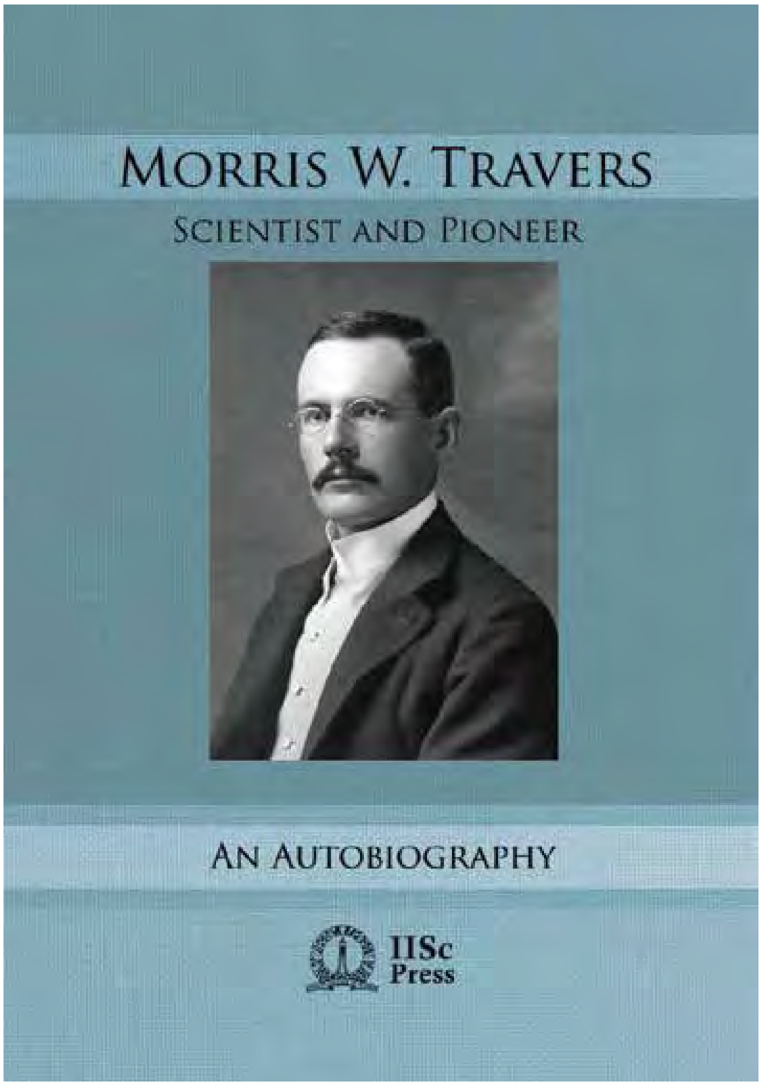
Gold Nanoparticles (Image courtesy: Tae Joon Cho/Creative Commons License/ Wikimedia Commons)

After the success you've obtained with copper complexes in mice, what is your next plan of action?

The targeting efficiency has to be improved as we realised that the addition of biotin to the drug complex was only 5-10 % more efficient than the drug without biotin. This is something that we are hoping to explore. One of my students is working on a different method to increase biotin concentration on the drug conjugate to increase the efficiency. I would like to hand over the problem to younger colleagues on this campus or elsewhere because it would take a long time.

What advice would you give to budding chemists?

Ask the right questions! Sounds easy, but framing right questions are tough, especially in today's context. I believe one should have two types of research going on. One based on the tough long-term goals and the other based on topical problems which will find acceptance in today's journal system which relies on catchwords and hype. Unlike most new institutions, IISc should support open-ended problems. Personally, I am in favour of old style freedom to do research without pressure. However, one also has to move with the times.



THE LIFE AND TIMES OF MORRIS TRAVERS, IISc'S FIRST DIRECTOR

Rohini Krishnamurthy

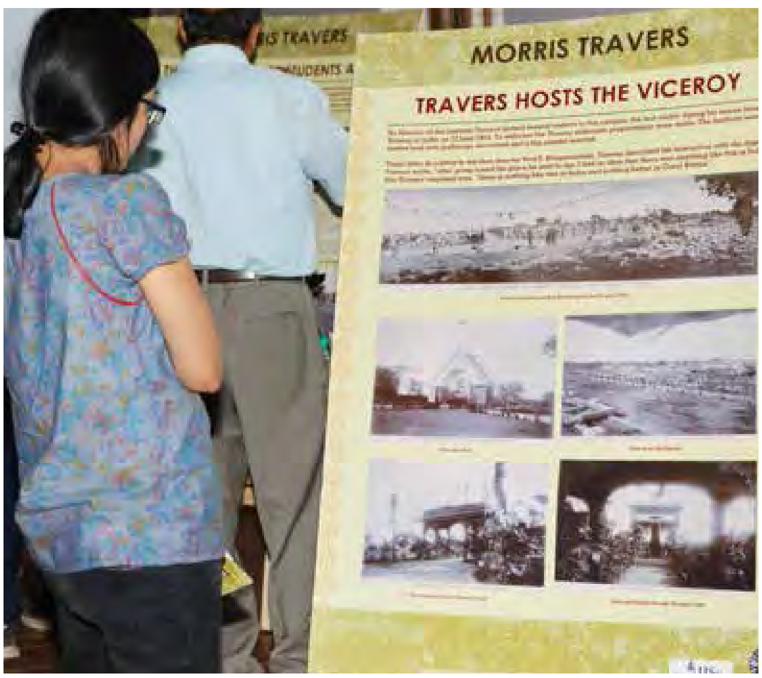
The autobiography of IISc's first Director Morris W Travers, published by IIScPress, was released on 20 February 2017 by historian Ramachandra Guha and IISc's former Director P Balaram. The current Director, Anurag Kumar, was also present.

A student of Nobel Laureate Sir William Ramsay, Travers was a British chemist who discovered three missing elements in the periodic table during his stint at the University College London. The discovery of these elements krypton, xenon and neon earned him the nickname 'Rare Gas Travers'. Eight years later, Travers was appointed the first Director of the newly set-up institute of scientific research, the first of its kind in India.

Travers arrived in India in 1906, and assumed charge as the Director of the Institute at the young age of 34. His journey from London to India from being a chemist to the role of an administrator and an institution builder at the University of Bristol, UK is chronicled in his autobiography *Morris W Travers: Scientist and Pioneer.*

Besides carrying a detailed account of Travers' early life in England, his stay in India, and life after IISc, this book incorporates letters that Travers wrote and received, giving us a peek into his personal life. It also has a section dedicated to his work on borohydrates at the Institute which paved the way for future research in this field.

The autobiography has been edited by Travers' grandsons, David MW Travers and John R Ainslie, who visited IISc during its centenary celebrations in 2009. Based on suggestions made by Balaram, they obtained Travers's handwritten manuscript from the University College London Library. Later, GK Ananthasuresh (then Chair, IIScPress and Professor, Mechanical Engineering) was instrumental in bringing the book to life as an edited autobiography. The effort was coordinated by Kavitha Harish from the Archives and Publications Cell (APC).



An exhibition curated by Sowmithri Ranganathan (APC), Morris Travers and IISc: The Road Traversed, was displayed after the launch.
Image courtesy: IIScPress

ABSTRACTS

IISc Photography Club

The vivid colours on this rock surface by the seaside at Gokarna, Karnataka are from the algae growing across it.