Connect

WITH THE INDIAN INSTITUTE OF SCIENCE

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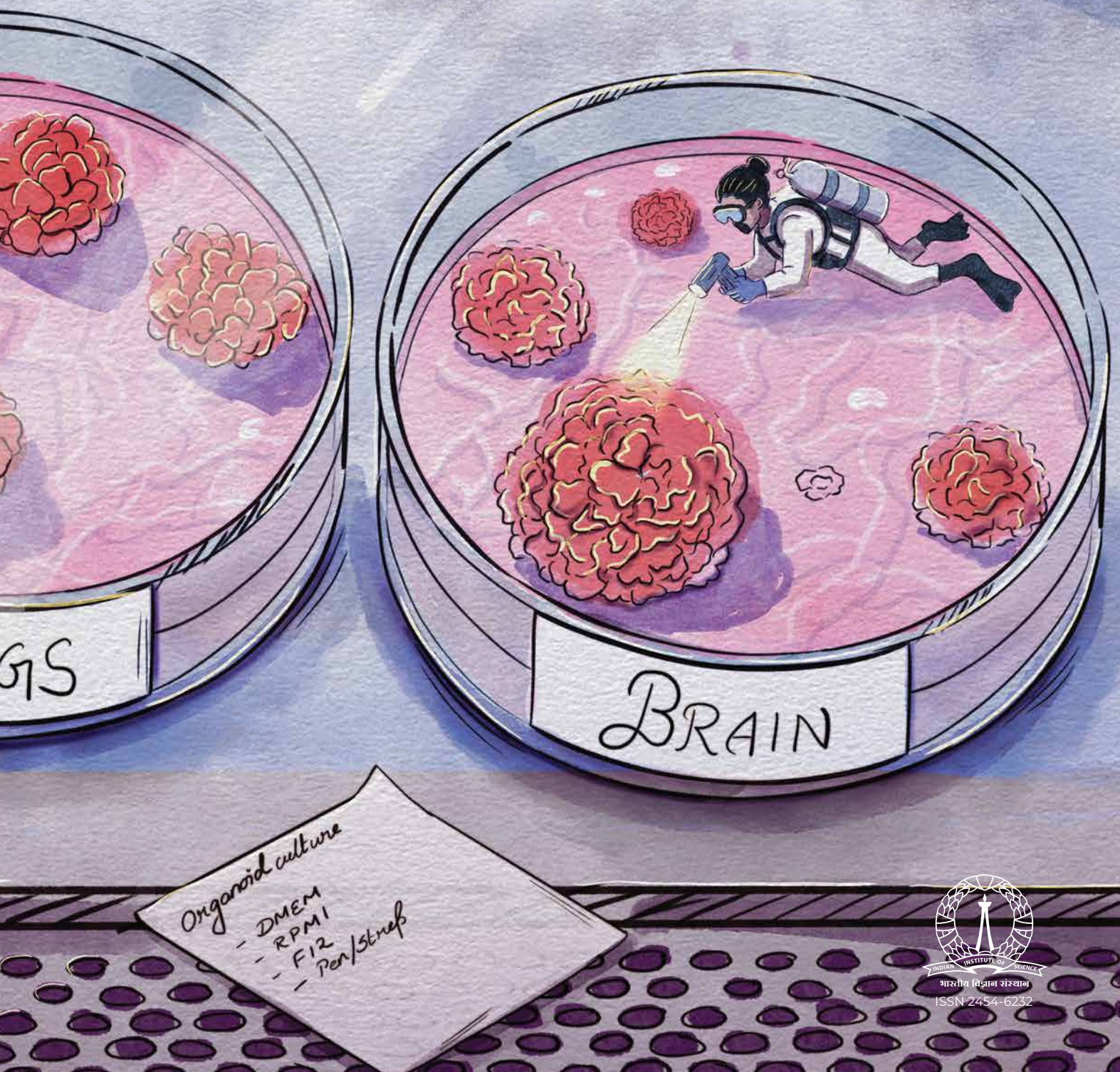
Nature's pigment makers

Organ Mimics
Lab-grown miniatures

Ocean as Archive
Ancient climate clues



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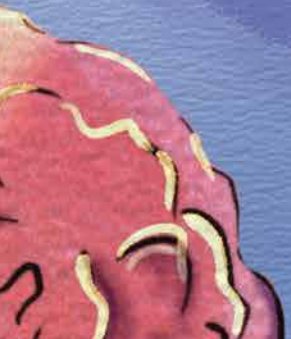
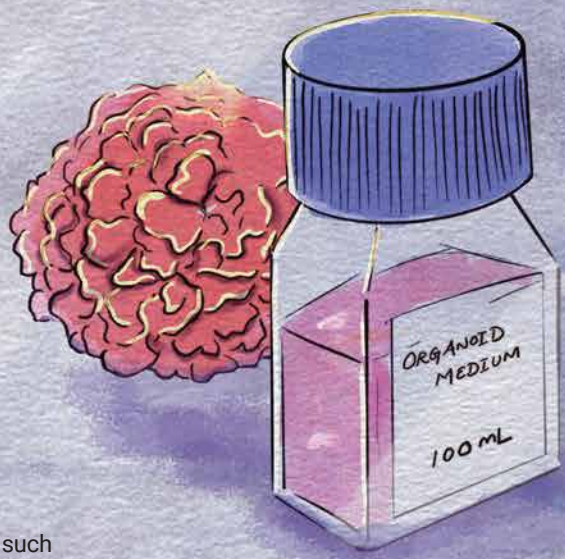


EDITORIAL



For centuries, scientists have sought to demystify disease and the human body. Model organisms like mice and monkeys have provided a lot of clues, but they don't give us the full picture. What if we could instead create replicas of human organs? Organoids – made from human stem cells – can mimic tissues and organs as diverse as neurons and cancer cells, providing us deeper and more meaningful insights into how diseases develop and how our body responds to treatments. Our cover story traces scientists' efforts to develop such organoids, and what challenges lie along the way.

In other stories, we explore how fungal pigments colour the natural and human world, why spintronics could be a gamechanger for modern computing, and how underwater fossils help scientists piece together our climatic past. A student writes about the twists and turns of her PhD experiment on cancer, while another explores how researchers are turning to DIY to customise equipment and cut costs.

On campus, we spent a day with the charming campus post van as it chugged along leafy lanes, delivering mail just like old times. We also asked students about persistent myths about IISc that they would like to put to rest.

Rounding out the issue are two in-depth interviews. We spoke with alumnus Murthy Gudipati whose work at NASA's Jet Propulsion Laboratory spans planets, ice in space, and the origin of life itself. We also sat down with former Sports Officer CP Poonacha for a nostalgic conversation about his time on IISc grounds.

As always, don't miss our crossword and a fun competition on the last page.

Happy reading!

Team Connect

Abinaya Kalyanasundaram (Coordinator), Ashmita Gupta, Bitasta Das, Kavi Bharathi R, Ranjini Raghunath, Rohini Subrahmanyam, Sandeep Menon

Contributing Writers

Amrapali Datta, Devansh Jhawar, Shreya Vashista, Kavitha Harish, Mihir Prakash Kapse

Contact

Email: connect.ooc@iisc.ac.in

Phone: 91-80-2293 2066

Address: Office of Communications, Indian Institute of Science, Bangalore 560 012

Website: http://connect.iisc.ac.in

Design: Magnetyz

Cover illustration: Gayathri R

Printer: Sri Sudhindra Offset Process

Post on Wheels

- Bitasta Das

Photo: Bitasta Das

A ride-along with the campus mail van

The campus mail van on Gulmohar Marg

Picture a typical morning at the Indian Institute of Science in the early 1980s. Three attenders set out on bicycles, each assigned to a different part of the sprawling campus. Their task is to collect the day's mail. They stop at departments and offices along their route, gathering letters, handwritten notes, official messages, and bills that need to be sent across the Institute.

This was the time before electronic communication had entered everyday life in India. Emails and mobile phones were still years away; messages moved physically, carried from one place to another by people and paper. By noon, after covering their respective routes, the three cyclists reach a common meeting point. During lunch hour, they sit together, sorting and exchanging the bundles of mail.

After lunch, they set off on their bicycles once again and retrace their paths across the campus. This time, their bags are filled with letters to be delivered. One by one, envelopes reach their destinations – offices, laboratories and faculty rooms – carrying news, instructions, and everyday exchanges from one corner of the Institute to another.

These bicycle rounds were the predecessors of the present-day campus mail van, which continues to perform the same essential duty at the Institute.

The campus mail van is a customised Tata Ace especially designed to carry internal mail across the institute. The vehicle has been modified to accommodate 85 metal mailboxes, each clearly labelled with the name of a department or office. These boxes function as individual collection points for campus mail. Each mailbox remains locked, and the keys are kept with the respective departments. Staff members open their department's box to collect the mail addressed to them. When documents need to be sent to another part of the campus, such as letters, posters, bills, or official papers, they are posted through the mail slot of the box labelled for the relevant department or office. As the van makes its rounds across the campus, it collects these items and delivers them to their destinations.

The campus mail van makes two rounds of the Institute every day, following the same route each time. Each round covers about 22 kilometres. V Thimmaiah, who has been driving the van for several years, explains that both the route and timing are fixed. "Every day, the van begins its first round at 9.30 am from the Contract Management Cell on Amra Marg and follows a set route across the campus," he says.

The campus mail van makes two rounds of the Institute every day, following the same route each time

The van travels a long circuit through all the campus lanes, covering the departments, offices, and guest houses. A minimum of 50-60 pieces of correspondence are delivered across the campus every day.

At lunchtime, the van halts at the Central Stores for about an hour. It then begins the second round of the day at 2 pm, covering the same route once again. The double trip ensures that if someone wants to send a response to the mail they received in the morning, they do not have to wait until the next day. At night, the van is parked under the portico at the Challakere Campus office.

The campus mail van is maintained by the Contract Management Cell, formerly known as Unit 3. Vasanthan AA, the Assistant Registrar who heads the cell, says this is a unique facility at IISc and that hardly any other institute has such a long-standing, continuously operating internal mail system. He believes the mail van has become an integral part of IISc's system and culture.

"We maintain an Excel sheet and record the number of documents posted every day," he explains. "Every month, we conduct an audit to review how many mails were transported. To date, not even a single mail has been lost. It is the most trusted mode of communication on campus." Vasanthan points out that the van drivers have been instructed not to exceed the campus speed limit of 20 km per hour. "If someone misses the van and still wants to post a letter, they often get another chance," he says. "Because the van moves slowly, people can easily catch up and drop their mail."

The internal mail delivery system was started during the tenure of Deputy Registrar Captain Venkatesh in the early 1980s. Ravi R, former Office Supervisor of Unit 3, was associated with the mail service since its inception. He recalls that in the early 1980s, the Institute realised that having each department send its own staff to

Photo: Bitasta Das

V Thimmaiah, the seniormost driver of the campus mail van

deliver mail across the campus was a waste of time and resources. To address this, a centralised delivery system was introduced. The three cycling attenders arrangement worked well for some time. However, as the Institute expanded and the number of departments and centres increased, delivering mail by bicycle became impractical.

The Institute then introduced a three-wheeler auto rickshaw for the purpose. A few years later, as the campus continued to grow, this, too, proved inadequate. The next solution was a Bajaj vehicle with a trailer attached, which was used for several years. But this vehicle had its limitations as well. "After the Institute's underpass was built, the vehicle did not have enough power to climb through it," Ravi recalls. Finally, the present vehicle was deployed in 2011, and it has been running smoothly ever since. "The vehicles kept changing, but the process of mail delivery continued uninterrupted," he says.

Moving at an unhurried pace, the campus mail van chugs through the lanes of the Institute. Inside the rows of metal boxes are all kinds of documents – official letters, circulars, bills, notices, newsletters, posters, greeting cards and magazines that keep the Institute vibrant. Rani Amma, the Office Attender at the Centre for Society and Policy (CSP), has been collecting the centre's mail for many years. She waits for the mail van to arrive at the CSP gate at 12.30 pm. Rani recollects that the mail van has been arriving at the same time for several years.

"It is a useful service of the Institute, since I do not own a vehicle, I would have to walk a lot to deliver the documents, if the mail van were not there. On some days, when I am busy with other tasks, I simply call the driver and say, 'Anna, please wait a little longer,' or they ask me to come to the nearest stop to collect the mail. They are very understanding," she adds.

Thimmaiah is the oldest of the seven drivers who drive the van on a rotation basis. He has been cleaning the van every morning before the trip starts for the past 15 years. Though a monotonous routine, he considers it "god's work". "On rainy days, we stop under a shed since there is a danger of the documents getting damaged; we do not take the chance," he says.

'Many new departments come to me with requests that I add their mailboxes to the van. It is a sign of prestige to have a dedicated box in the iconic mail van'

Despite the faster, digital modes of communication available today, the campus mail van continues to remain popular on campus. "Many new departments come to me with requests that I add their mailboxes to the van. It is a sign of prestige to have a dedicated box in the iconic mail van. In this age of digital communication, a physical copy has become even more personalised and special," Vasanthan explains.

For almost five decades, the mail delivery system has been woven into the rhythms of campus life. The van stands as an enduring symbol of IISc's living history. In an age defined by instant messages, emails and rapid exchanges of information, the quiet journey of the campus mail van across the leafy avenues of the IISc campus offers a gentle contrast. Its slow and steady movement reminds us that communication does not always have to be instantaneous to be effective.

(Edited by Sandeep Menon)

Photo: Bitasta Das

Rani Amma, collecting the day's mail

Life in a Dish

- Rohini Subrahmanyam

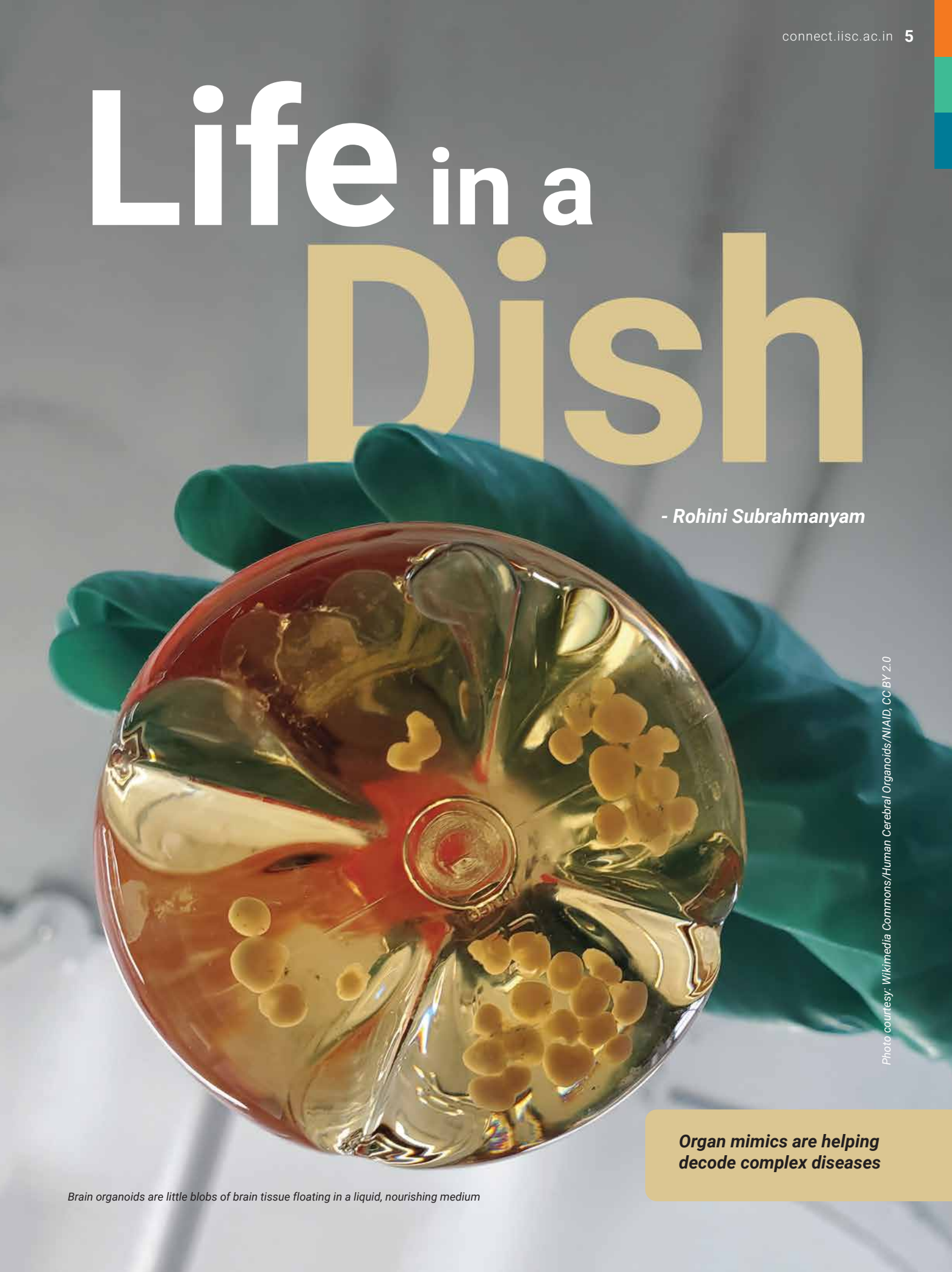


Photo courtesy: Wikimedia Commons/Human Cerebral Organoids/NIAID, CC BY 2.0

Organ mimics are helping decode complex diseases

Brain organoids are little blobs of brain tissue floating in a liquid, nourishing medium

On the lab bench, inside a Petri dish nestled between two metal coils, sits an unassuming glob of jelly. But this is no ordinary jelly – it is a squishy gel filled with magnetic particles and cells from the human lung.

Once the power switches on, magnetic currents pass between the two coils, swirling the particles about and stretching the gel out the tiniest bit. When the power's off, the gel relaxes. Turn the power on and off at a certain frequency, and you've got a gel that stretches and relaxes, back and forth, back and forth, almost rhythmically. "It's trying to mimic a portion of your lung tissue as you breathe," explains Kaushik Chatterjee, Professor at the Department of Bioengineering (BE) and Department of Materials Engineering, IISc.

In a science fiction-esque endeavour, researchers like Kaushik are trying to mimic the functioning of human organs in the lab. The "breathing" jelly that his lab is working on is supposed to simulate the action of the human lung. Some researchers are making brain organoids, which are tiny, living blobs of brain cells floating about in a dish. Others are creating solid tumours in the lab by 3D-printing gel-like structures with breast cancer cells, or using patient-derived cells to make gallbladder cancer organoids.

Such organ mimics are helping these scientists demystify complex diseases, from cancer and lung fibrosis to TB and schizophrenia. With labs worldwide increasingly cutting down on the use of animal models, such organ mimics offer an attractive alternative. "From the USFDA to Indian drug regulators, everybody's pushing hard for alternatives to animal testing," says Kaushik.

Organ mimics are helping these scientists demystify complex diseases, from cancer and lung fibrosis to TB and schizophrenia

Another reason to switch from animal models to organoids is that they are easier to manipulate. "If I want to modify a gene, or knock it down and go for high-throughput analysis, [it] is not possible using animal models," says Dwijit GuhaSarkar, Lead Scientist in the Organoid Laboratory at the Tata Translational Research Centre (TTCRC), Kolkata. High throughput experiments include modifying many genes at once or testing hundreds of drug molecules at a time in a biological system. More importantly, it would be ethically wrong to sacrifice animal models at these scales.

The other issue is that what works in animals doesn't always work in humans. "So many drugs that seem to be working well in animal models then fail in human trials, and that further slows down discovery," he adds.

Plus, some diseases like TB, lung fibrosis, gallbladder cancer, and schizophrenia affect humans and animals very differently. Lung fibrosis – a condition in which lungs get filled with dense, fibrous structures that can literally choke people to death – is irreversible in humans, even with medical intervention. But in mice, once the drug that induces fibrosis is removed, the mice's lungs spontaneously revert to normal. Complex human brain disorders like schizophrenia are pretty much impossible to study in mice models.

"[A] human is not a mouse," says Rachit Agarwal, Associate Professor in BE. "We need to mimic humans better, whether it's digitally or through some organoid systems."

Brain blobs

One of the earliest scientists to build a brain organoid was Madeline Lancaster, currently a Group Leader at the MRC Laboratory of Molecular Biology in Cambridge, UK.

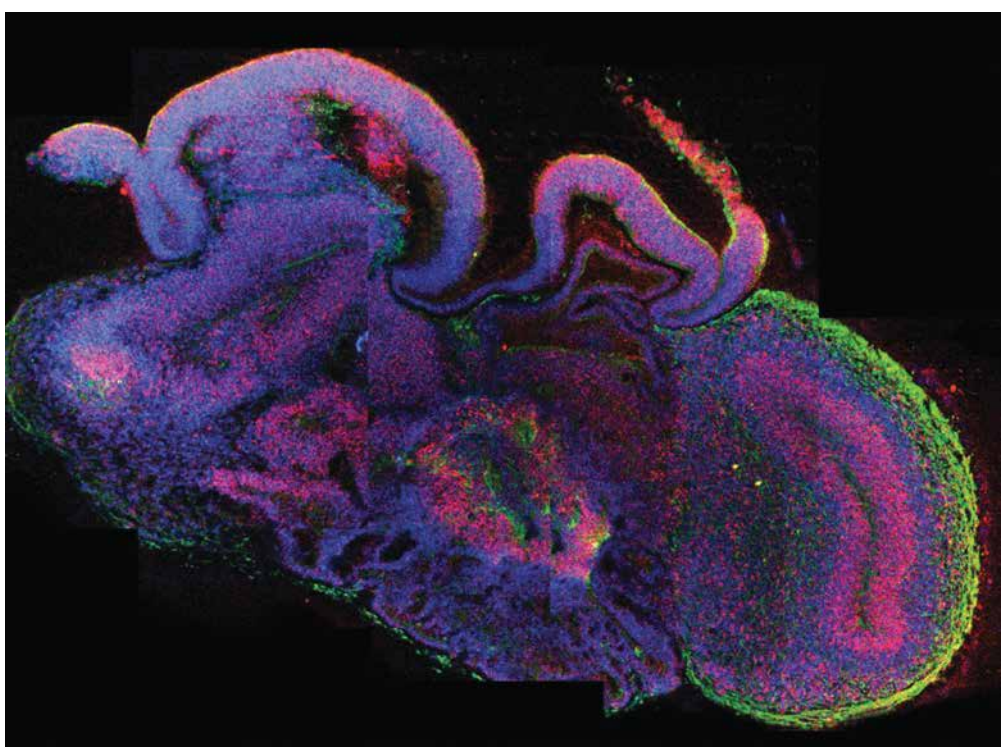


Image courtesy: Wikimedia Commons/Madeline Lancaster/IMBA

Cerebral organoids made by Madeline Lancaster in 2013, with neurons (green) and neural stem cells (red)

In 2013, her team used skin cells from a patient with microcephaly – a condition that leads to shrunken heads and abnormally developed brains in babies – and turned them into stem cells. They then converted the stem cells into neurons and used those to develop cerebral organoids, representing the outermost squiggly part of the human brain called the cerebral cortex. She and her colleagues then compared these patient-derived organoids to organoids made using skin cells from a healthy donor and found that the former could, to some degree, mimic microcephaly. "Amazingly, the [patient-derived] organoids were smaller, and had fewer neurons," says Madeline, in a 2016 TEDx talk.

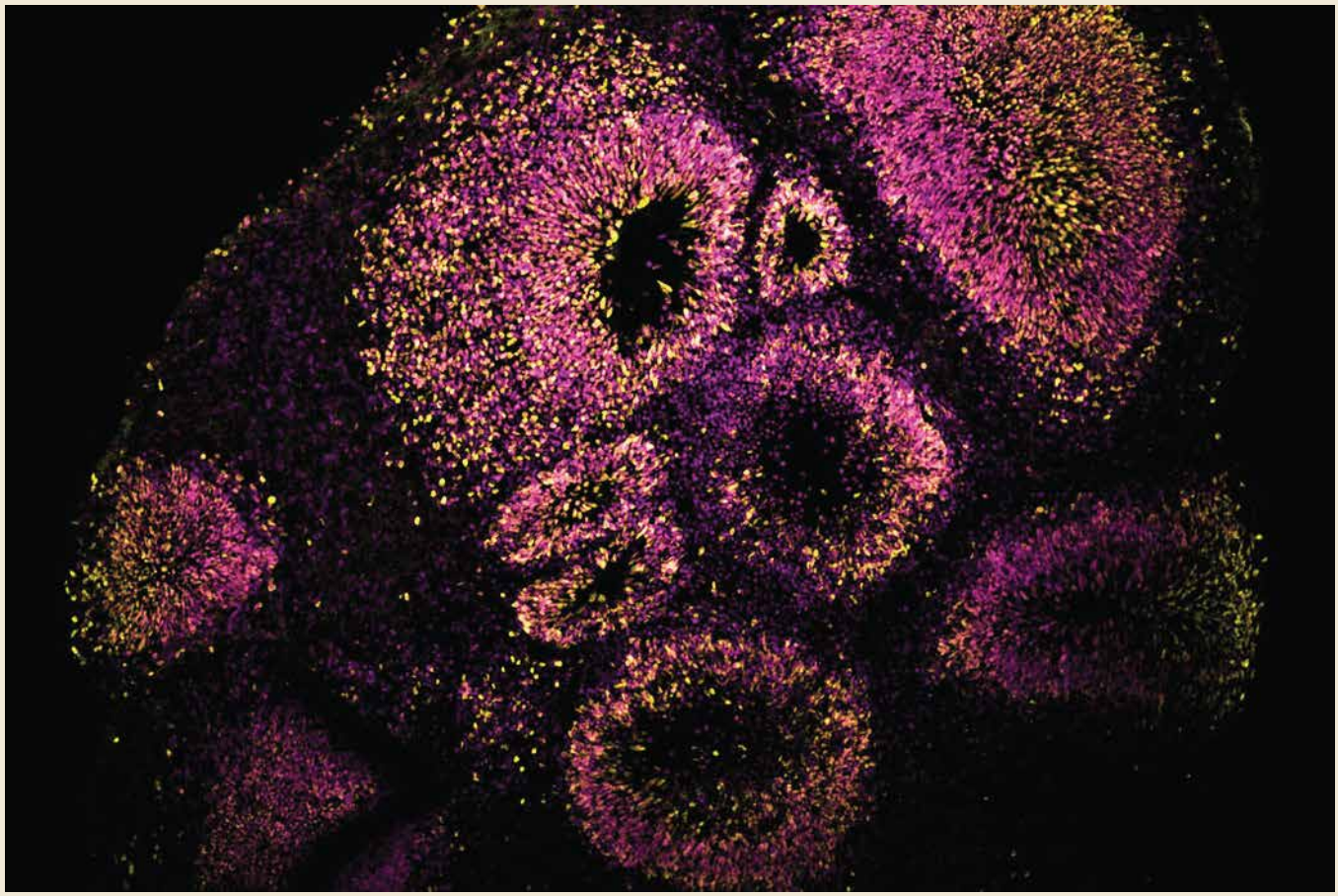


Image courtesy: Kruttika Phalnikar, Muralidharan lab @BRIC-inStem

50 day-old cortical organoids have their neural stem cells (yellow) arranged in a rosette-like structure

Brain organoids are basically little balls of tissue floating about in a Petri dish or flask filled with a nourishing liquid. But they offer a way for scientists to chip away at one of the most complex organs, "particularly when you want to look at human-specific aspects and also probably capture the genetics of [a] disease," says Bhavana Muralidharan, Associate Professor at BRIC-inStem, Bengaluru.

A typical starting material for such organoids is human embryonic stem cells (ESCs); extracted from a structure called the inner cell mass in very early stage foetuses, these cells can be turned into almost any other type of cell.

Human induced pluripotent stem cells (iPSCs), like the ones Madeline employed, can also be used. These are adult human skin or blood cells that have been "induced" to become stem cells using specific molecules called Yamanaka factors. iPSCs or ESCs are then treated with a targeted cocktail of chemicals, which gently coax them into becoming neurons. If the chemicals and media conditions are just right, these neurons then self-organise into 3D clumps called organoids.

To dig deeper into how the brain functions, scientists have gone a step further and created assembloids – organoids of different brain regions fused together

Researchers can create organoids of specific brain parts as well, like the cerebral cortex, or the entire front part called the forebrain. It all depends on how you nudge the stem cells towards a particular fate – some researchers like Bhavana use a set of molecules that push them into forming smooth cortical spheres. Others don't use any molecules at all; the media that the cells are submerged in turns them into popcorn-like forebrain organoids. Such organoids can help scientists study how the neurons move around and organise themselves in the developing human cortex.

To dig deeper into how the brain functions, scientists have gone a step further and created assembloids, which are organoids of different brain regions fused together. "When you want to look at circuitry, looking at one region of the brain is not enough," explains Bhavana.

As part of the Accelerator programme for Discovery in Brain disorders using Stem cells (ADBS), now the Center for Brain and Mind, a joint center between the National Centre for Biological Sciences (NCBS) and BRIC-inStem that works with patient families having a history of mental illness, Bhavana has access to iPSCs from people with schizophrenia. She is using these cells to make assembloids and study the neuronal network secreting dopamine in them. Dopamine is a mood-and-movement-regulating chemical, and its release is usually hampered in people with schizophrenia. "You can use these patient samples to come up with a very nice human in vitro disease model," says Bhavana. Such a model can help explore potential mechanisms underlying any clinical symptoms, she

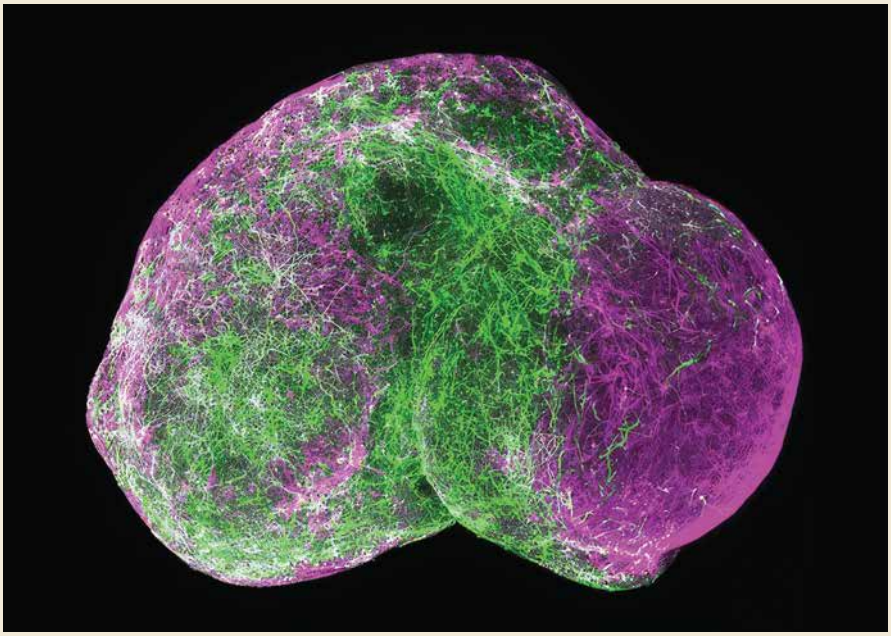


Image courtesy: Wikimedia Commons/Pasca Lab, Stanford University

A brain assembloid made of fused organoids representing the cortex and the subpallium, using which researchers can study how inhibitory neurons (green) migrate between the two brain regions

adds. Some dopamine-related schizophrenia symptoms are hallucinations, an inability to experience pleasure (anhedonia), and social withdrawal.

The three brain regions that Bhavana is studying jointly using assembloids are the striatum – a part of the brain that has many dopamine-releasing neurons – the cortex, and the midbrain. Her plan is to first check whether the dopamine neurons are formed correctly in the assembloid. Then, she wants to explore if and how the dopamine circuitry or the connectivity between these three regions is messed up.

Assembloids are the brainchild of Sergiu Pasca, Professor at Stanford University. In 2017, he published a paper showing how his lab fused a cortical organoid with that of the subpallium – a brain region below the cortex that's involved in foetal development. Once the organoids merged, Sergiu and his team found that inhibitory neurons called interneurons hop across from the subpallium to the cortex and make new connections with the cortical neurons. It almost resembled what happens in the developing foetal brain.

Sergiu's team also made assembloids using cells from young patients with Timothy Syndrome, a rare genetic disorder that leads to autism, epilepsy, and cardiac dysfunction. When they compared the two assembloids, the interneuron jumps were messed up in the ones derived from patients with the syndrome – the distances were shorter and the interneurons failed to connect with cortical neurons.

In 2020, Sergiu's team described the fusion of not two, but three organoids – representing a part of the cortex, the spinal cord, and skeletal muscles. When they passed an electrical impulse through the cortical organoid, the muscle portion twitched, indicating that the three blobs had connected.

With such intertwined assembloids, scientists can study complex brain disorders in which the connections between neurons are affected, like autism spectrum disorders, Parkinson's disease or Alzheimer's disease, and even obsessive compulsive and bipolar disorders. Once scientists can figure out what circuits may be messed up in these conditions, they can use assembloids to test drugs that might fix the problem, at least at a molecular level. "For instance, we may see that some receptors [are] getting affected. So, can we now look at small molecules to either accentuate or to down-regulate that receptor?" says Bhavana. "That's where we want to go with this eventually."

"Brainy" organoids

In 2022, scientists at the Australian company Cortical Labs taught neurons in a dish to play the computer game *Pong*. They wired the neurons to electrodes, which were in turn connected to a computer running the video game. With the right kind of stimulation, the neurons eventually learned to fire electrical signals that could – via the electrodes – manipulate the game's controls and play it. More recently, the company taught mouse brain organoids how to balance a pole on a virtual moving cart and play the video game *Doom* (which is more complicated than *Pong*) – sparking conversations about "organoid intelligence".

Researchers are also growing brain organoids that last long – Harvard professor Paola Arlotta has organoids in her lab that have been rocking away in the incubator for seven years (the rocking helps better distribute oxygen in the culture medium). These organoids express similar genes as one would find in a kindergartener's neurons of that age.

The race to build increasingly mature and complex brain organoids has raised concerns over the ethics of growing human brain tissue. Some scientists are worried that the little lumps may eventually become sentient and "suffer" the way humans do, but others counter that "human-like" consciousness – a complex phenomenon that scientists have still not understood – is too remote a possibility in organoids. But issues still remain. "The recognition of possible sentience in honey bees, whose brain size is smaller than some of the more complex organoids in terms of sheer number of cells, grounds the rationale for a continuous monitoring of how size and complexity track with emerging properties," write a team of researchers and bioethicists in a 2025 policy forum article in *Science*.

But maintaining organoids in a dish for long is tricky. Unlike the human brain, organoids don't have arteries filled with fresh oxygenated blood growing inside them. As the blobs get bigger, their cores get cut off from oxygen supply and they start dying out. One solution is to slice up the organoids, open them up to give them some oxygen, and then let them grow back into a sphere, Bhavana says.

"Organoids and assembloids are not full replicas of the human brain, they are not brains in a jar or mini-brains, they are not a stepping stone to some Frankenstein monster," clarifies Sergiu in a 2022 TED talk. "But using them, we can create avatars of a patient's brain development."

Cancer in a dish

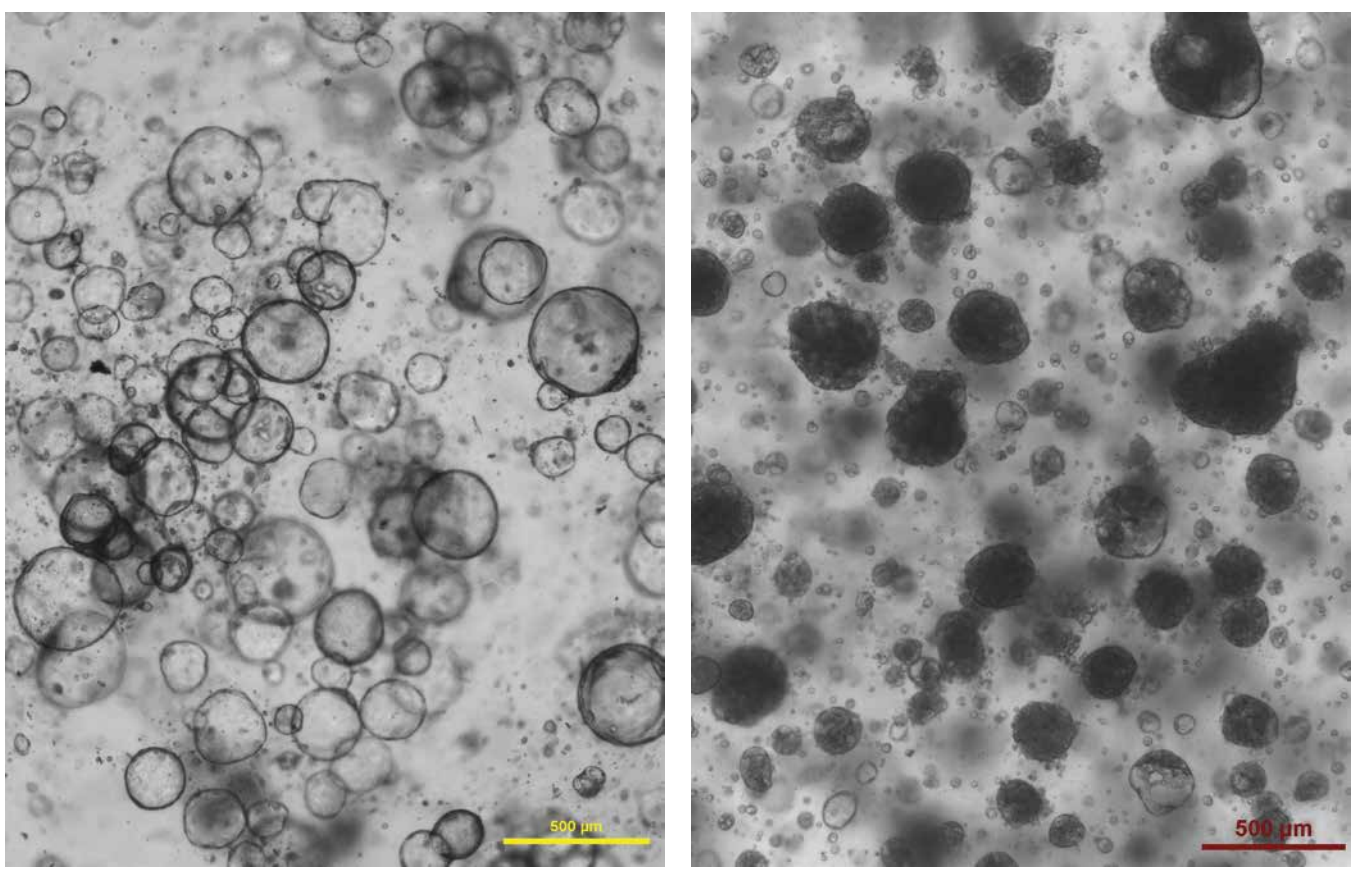
At the bustling Tata Medical Centre (TMC) in Kolkata, within which TTCRC sits, making cancer organoids is a multi-departmental affair. With the help of a dedicated clinical coordinator, Dwijit and his team, called SOLi3d, first keep track of patients undergoing surgery for gallbladder cancer or cancers in neighbouring organs. The surgeon then passes the dissected tissue onto the pathologist, who decides how much of the gallbladder can be spared for research (the first priority is diagnosis). After ensuring that they have the patient and their family's consent, Dwijit and his team use the cells from the tissue to make gallbladder cancer organoids, which they then store in a biobank. As they are living organoids, researchers can use them whenever they need for experiments – be it DNA or protein analysis or drug testing. "It's a lot of coordination between the surgery team, the pathology team, the banking team, and the research lab," Dwijit explains.

A 3D organoid version of a tumour is as close as one could get to an actual tumour, making it easier to assess which drugs could treat it

Every year, TMC sees 300 patients diagnosed with gallbladder cancer, Dwijit says, and most of them have very poor outcomes. Even though it is a globally rare cancer, it has a high prevalence in the north and northeast of India, particularly around the Himalayan region and the Gangetic belt. Because it is uncommon in the West, gallbladder cancer is somewhat neglected. It is also a silent cancer that can sneak up on people at an advanced stage, making treatment difficult.

Scientists believe that one trigger for gallbladder cancer is chronic inflammation. To investigate this, Dwijit is also growing organoids from patients whose gallbladders are under various stages of inflammation. The idea is to check if and how an inflamed gallbladder eventually ends up becoming cancerous. "Our interest is to study the progression of the disease," says Dwijit. "So, we are not just growing organoids from cancer patients, we are growing organoids from all different disease states of the gallbladder."

A 3D organoid version of a tumour is as close as one could get to an actual tumour, making it easier to assess which drugs could treat it. The cells are seeded in a dense matrix of proteins, sugars, lipids, and small molecules that



Images courtesy: Dwijit GuhaSarkar

Gall bladder organoids (left) and gall bladder cancer organoids (right) can help researchers understand how healthy gall bladders turn cancerous

resembles the extracellular matrix (ECM) inside the human body – the network of supporting proteins surrounding cells. Just like human tumours grow with the help of chemical cues from their ECM, 3D cancer organoids also respond to molecules from their surrounding matrix as they develop – making them structurally similar to their counterparts in the body.

In addition to gallbladder cancer, Dwijit is interested in using organoids to study breast cancer variants, like triple negative breast cancer (TNBC) – which has no targeted treatment yet – and HER-2 enriched breast cancer – which is extremely expensive to treat. He hopes to develop new, inexpensive drugs and repurpose more affordable, already existing drugs to treat these rare, aggressive cancers.

Using patient-derived cancer organoids can also help us understand how different people respond to the same drugs. "In principle, one can do personalised medicine," says Kaushik.

At IISc, Kaushik is also studying breast cancers – he uses gels made up of long chains of repeating molecules called polymers. The cancer cell lines are mixed with these gels and printed onto a 3D scaffold, and the resulting structures can mimic both healthy breast tissue and a breast tumour.

Digital doubles

Picture this scene that sounds straight out of a sci-fi movie: A digital hologram of the heart is shimmering above a patient in an operating theatre and doctors are carefully scanning the hologram to determine the best course of action.

Whilst the medical world is not quite swiping at holograms yet, researchers have been able to use computational modelling to recreate the structure and function of some organs, essentially creating a digital duplicate. In a *New England Journal of Medicine* study from April 2026, researchers worked with 10 patients who had recently suffered a heart attack and had developed a condition that caused their lower heart chambers to beat too fast while pumping blood. Using MRI scans, the researchers digitally recreated 3D versions of the patients' hearts and then used computer simulations to model how electrical signals will zip through the heart's muscles. This way, before surgery, they could precisely predict how to operate on and remove the muscles generating the errant electrical activity, which would help correct their heartbeat. This helped reduce the surgery time from three hours to roughly 30 minutes.

Scientists at the University of Liverpool in the UK have also digitally recreated the retina for in-silico drug trials. Others at Wayne State University in Detroit, USA, have modelled the placenta to study issues that could arise during pregnancy. The ultimate goal is to make a whole-body "digital twin", "a personal guinea pig for testing out medicines", writes Jessica Hamzelou in an *MIT Technology Review* feature. Predictably, the prospect of human digital doubles has raised concerns over patient autonomy and who will own such highly personalised data.

Depending on the ratios of the polymers that they use, and how cross-linked they are, the gel-like material can be stiff or soft. "As a materials lab, we can make various kinds of materials or modify them," says Kaushik. "We can tune, say, the stiffness of a material to match the mechanical properties of the tissue – for example, if you want a slightly softer gel to mimic the breast tissue versus a slightly stiffer gel to mimic the breast tumour."

In collaboration with Annapoorni Rangarajan, Professor at the Department of Developmental Biology and Genetics, Kaushik's team mixed cancer cells from patients with a polymer gel and bioprinted 3D spheres that mimicked a breast tumour. After growing the spheres in the lab and checking if the cells were viable, Kaushik and his team confirmed that standard chemotherapeutic drugs worked well against the tumours.

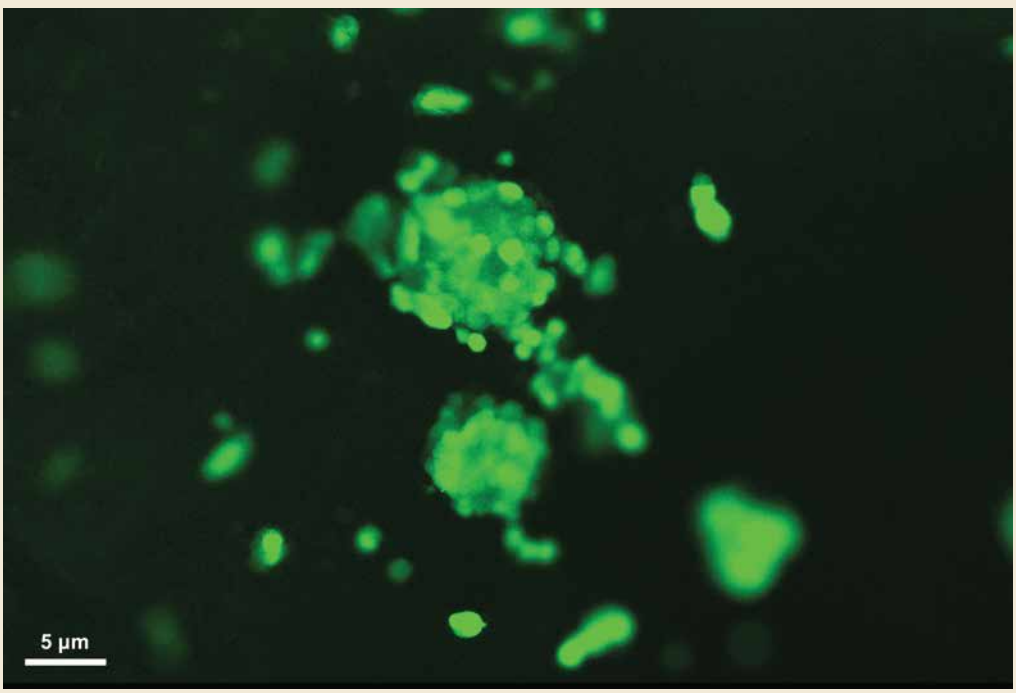


Image courtesy: Souvik Debnath

Breast cancer cells (live ones are green) form spheroids in a 3D bioprinted hydrogel

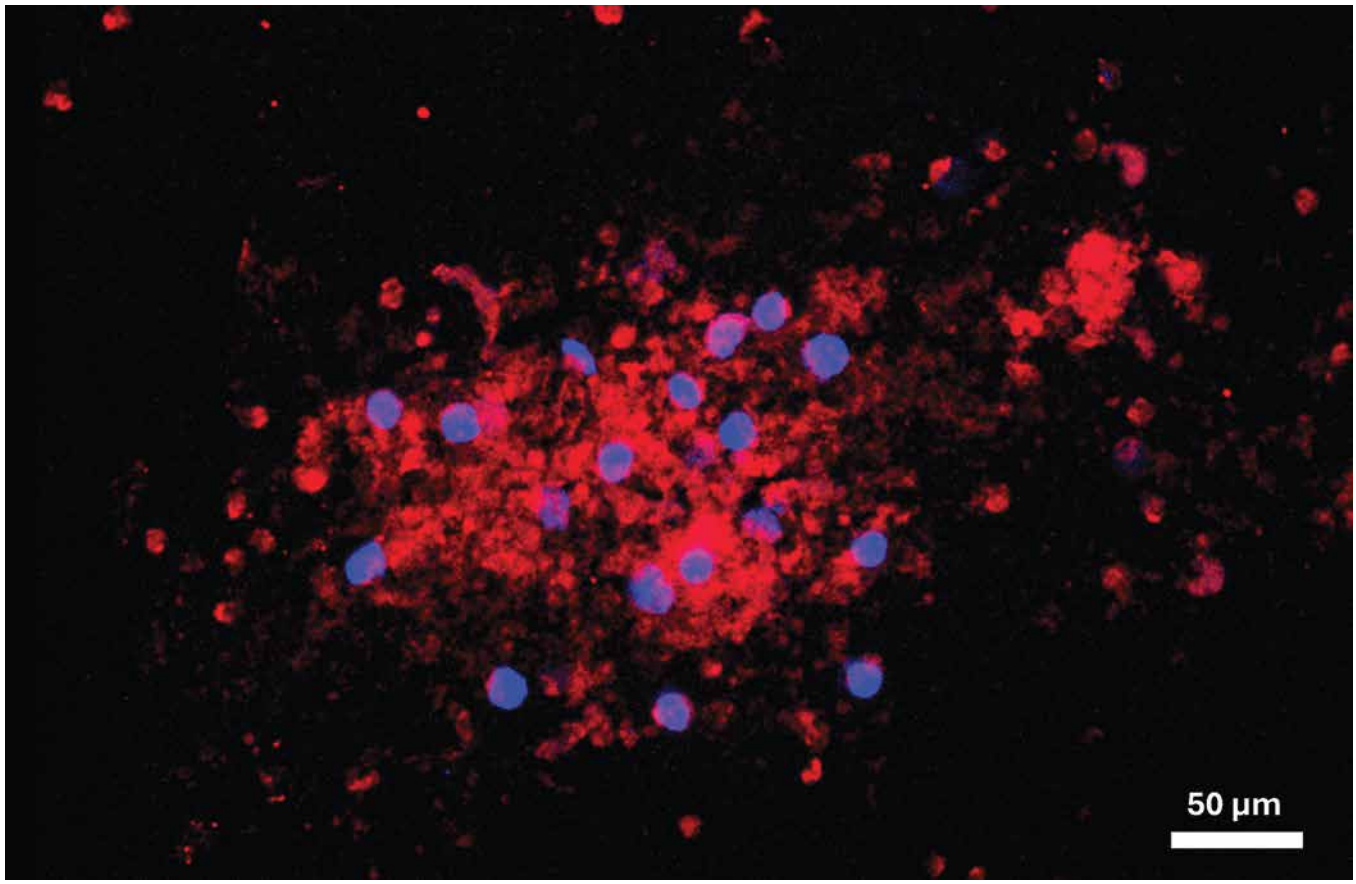


Image courtesy: Vijaya Vaishnavi V

The initial TB-infected immune cells (with blue nuclei) can grow into granulomas (red) in the artificial lung

One can also mix the cells and the gel together to form "bioink", and then use a 3D bioprinter to squeeze the material out layer by layer, Kaushik says. If you had two types of "ink", one with cancer epithelial cells (specialised cells lining the tumour surface) and another with immune cells, you could bioprint them as layers to see how the former invades the latter. With new bioprinting technologies, one can even create channels within the material. "So, if I make a tube-like structure, I can perfuse it [with a fluid or blood] and you can think of it as a blood vessel in a breast tumor," says Kaushik.

The ultimate goal is to replicate the tumour and its environment as closely as possible. "The idea would be to mimic the architecture, the biophysical properties, and the active biomechanical forces," Kaushik adds.

Lungs in the lab

When TB bacteria attack humans, immune cells are the first to respond. As the bacteria break down the cells' defences, the immune cells send out alarms, calling out for more of their kind. But the incoming cells only end up becoming more fodder for the invaders. As more and more immune cells flood in to try and quell the disease, they start amassing around parts of the lung. These clumps of immune cells eventually grow to a millimetre or even up to a centimetre in size, becoming what are called TB granulomas. They are what show up as "nodes" in a chest X-ray when someone is tested for TB, says Rachit.

By carefully selecting which polymers to use, the team created an artificial biomaterial quite similar to the lung in composition, mechanical properties, and softness

But studying TB in mouse lung models is tricky because the bacterial species that infects humans does not infect other mammals. Primates could work, but studying and maintaining them is expensive and challenging. And, as Rachit says, they are still not human.

Since Rachit and his team came from a materials-based background, they wondered if they could use that to develop an organoid that is more human-relevant. "If we are able to do so, then we can open up several lines of inquiry into understanding and designing therapy against the disease," Rachit says.

Lung tissue is made up of long chains of proteins and sugars called proteoglycans and biological polymers, one of them being collagen. By carefully selecting which polymers to use, the team created an artificial biomaterial quite similar to the lung in composition, mechanical properties, and softness. "This gives us the initial matrix where we can play [out] this battle between the bacteria and the immune cells," Rachit explains.

In this artificial lung, Rachit and his team have mimicked the process of how the granuloma forms over several days. So far, their granuloma organoid has grown to about half a millimetre long in size, about five to ten times that of what previous research groups have reported. They also found that some

drugs that are prescribed to TB patients work well against the granulomas they grow.

TB bacteria are present in approximately one in four people worldwide, but they remain latent (dormant) in most of them. However, if people with latent TB bacteria end up taking immunosuppressant drugs, then the weakened immune system can end up triggering the bacteria into action. Not all cytokine blockers – drugs that suppress the immune system – re-activate TB bacteria. Rachit and his team also want to use their artificial granuloma to find out which of them do.

"The granuloma is quite a tight structure, so often a lot of drugs don't penetrate inside and don't work very well. Because this is an in vitro setup, we can test how deep the drug has been able to go and what the concentration profiles are. Those are the things that we are building this model towards," says Rachit. "But right now, the major focus has been to characterise and be confidently able to say that this indeed mimics human granuloma and how well it is able to mimic it."

Granulomas are not the only enemies in the battle to breathe. Sometimes, continuous exposure to pollutants can cause lung tissue to become very thick and stiff. Known as lung fibrosis, this irreversible process can lead to extensive damage, scarring, and breathing difficulties.

In collaboration with Deepak Saini, Professor in the Department of Developmental Biology and Genetics, IISc, Kaushik is keen to use lung mimics to study fibrosis. The idea, he says, would be to mix human lung cell lines with polymeric gels that mimic the lung tissue, add molecules to induce fibrosis, and then use the artificial lung-fibrosis system to test drugs.

Kaushik's lab has also been studying the effects of air pollution on lung cells. They first bioprinted a gel containing connective tissue cells called fibroblasts. Then, they added lung epithelial cells onto the gel mixture. Using a holder, this gel-cell mixture was then suspended at a slightly elevated level in a Petri dish filled with media. This way, the fibroblasts were submerged inside the media, while the epithelial cells were just at the right level to be at the air-liquid interface, on the air side. To simulate dust, the team sprayed silica particles over the epithelial cells, and found that the cells immediately became irritated. The cells also started producing surfactants to protect the cell surface.

The more realistic organoids are, the more complicated they become

Compared to a classic cell culture setup where one would grow the lung epithelial cells in a flat Petri dish, this setup is much closer to actual human physiology, Kaushik says. His goal is to test what happens to the cells upon prolonged exposure to these silica particles, and to check if fibrosis can be induced, and reversed. "These could be good ways to study lung pathophysiology and also look at drug treatments," he adds.

Closer to reality

Despite these exciting advances, at this point in time, an organ or tumour-mimic will never truly behave exactly like its counterpart in the human body. "In the body, the brain is connected to every organ, your lungs are connected [and supplying oxygen] to every organ," Rachit says. "When you isolate an organ like that, there is no crosstalk that is happening with the rest of the organs, which obviously is not the way the human [body] works." Therefore, some of the results we find using organoids will eventually need to be validated in an animal model or using clinical trials, he adds.

We also still need an animal to understand what a drug does to the body as a whole, Dwijit says, which is why he believes that we cannot completely phase out animal models at this point. "[But] can we reduce the number of animals used in research?" he says. "Because, for certain questions, we probably do not need a living system." An organoid or organ mimic would be helpful at the preliminary stages of testing whether a drug works or not, before taking confirmed candidates to an animal model or a full-blown clinical trial. "They're good isolated systems to be able to start to make one's research more relevant to humans," Rachit says.

Scientists at Stanford University have already achieved one holy grail – growing liver and heart organoids with a blood vessel (vascular) network inside. Vascularised tissue in the lab brings us closer to better therapeutics, as mimicking blood flow is crucial to take organoids closer to the actual organ. Researchers have also managed to grow blood vessels in skin, lung, gut, and pancreatic islet organoids.

There is, however, a trade-off to making organoids more realistic. The more realistic they are, the more complicated they become, which means that not only are they more challenging to grow, but reproducing them is also tricky. Depending on the application, scientists need to straddle the line between simple but physiologically less relevant organoids and ones that are more complex but definitely more physiologically relevant. While screening multiple drugs to see which one is more effective, for example, a simple organoid may help scientists get reproducible results faster. But a more intricate organ-mimic can help scientists figure out the finer details of how a specific drug might affect an organ.

Which is why the quest to develop the ideal organoid is ongoing. Back in his lab at IISc, Kaushik has found that the lung epithelial cells in his jello grow more when they are dynamically stretched by the magnetic field, as opposed to when they stay still. As the gel "breathes", its lung cells grow better.

For now, they are only able to keep the experiment going for a few minutes per day for a couple of days, because the gel heats up quickly. "It's like exercising, you exercise it for a little bit," says Kaushik. "The cells seem to respond to that and they do seem to do better."

(Edited by Ranjini Raghunath)

'Life on Earth is so Precious'

- *Interview by Abinaya Kalyanasundaram*

Growing up in rural Andhra Pradesh, Murthy Gudipati sometimes slept in fields looking up at the stars. A few decades later, he now studies them as an astrophysicist and planetary scientist at NASA's Jet Propulsion Laboratory (JPL) in Pasadena. An IISc alumnus from the 1987 batch, he studies the evolution of different kinds of ice in the universe, and the surfaces and atmospheres of solar system bodies and exoplanets. He also serves as Co-Investigator and Investigation Scientist in NASA's Europa Clipper mission. He speaks to CONNECT about what ice in deep space can tell us about the origins of life, and why he feels education might be humanity's best bet for survival.

Photo courtesy: Murthy Gudipati

Murthy Gudipati among poppy fields during a hike in California

Where did you grow up, and what was your childhood like?

I grew up in a small village in rural Andhra Pradesh, with a population of barely 200. There was plenty of access to nature, and I would climb all kinds of trees to pick fruit, take care of cows and buffaloes, and help in our peanut fields.

I'd sleep in the fields at night during harvest season. With no light pollution in those days, the sky was full of dots ... stars. For school, I would walk about four and a half miles one way, which took about two hours. I enjoyed that. It gave me ample time to fantasise, contemplate, and talk to myself.

Chemistry is a difficult subject, but if teachers make you think rather than memorise, you realise the logic behind it

That's a beautiful memory. Is that how you got drawn to science?

I was drawn to the natural sciences as early as grade six. I probably started learning, subconsciously, during my walks – wondering why the sun rises around the same time and other such thoughts. I used to try to calculate how much I would have to walk based on the angle of the sun to the horizon (*laughs*).

Someone suggested I study economics and civics in college, to get a bank job, but I wanted to study mathematics, physics, chemistry, and natural sciences.

And then you specifically decided on chemistry.

That was actually influenced by my teachers. During my Bachelor's at the SRR and CVR Government College in Vijayawada, I had excellent physics, chemistry, and mathematics teachers. Among them, our chemistry lecturer was outstanding. Chemistry is a difficult subject, but if teachers explain it in simple terms and make you think rather than memorise, you realise the logic behind it.

I also used to spend significant time at the UGC Library at the college, reading about quantum mechanics and theoretical chemistry, which deepened my interest.

How was your Master's degree experience?

In those days, as a village boy, there was not much access to information. An unfortunate thing for people, even today, is not the lack of passion or motivation, but the lack of information.

By sheer luck, while visiting the local library in Vijayawada, I came across an advertisement from the University of Hyderabad (UH) for MSc admission interviews that included a travel allowance, so I applied for that. Hundreds of students wrote the entrance exam; I thought I wouldn't have any chance to get through. But that evening, I found out I was one of the 25 pre-selected. After the oral interview, I travelled back to Vijayawada and a few weeks later, I received a telegram informing me that I was selected. I was jumping with excitement. I went from one bank to another seeking a loan, and finally, one bank offered a study loan, and I joined the UH for a Master's in chemistry.

I had fantastic teachers there – Prof Govardhan Mehta, who later became the director of IISc, and Prof D Balasubramanian, who became the director of the Centre for Cellular and Molecular Biology (CCMB). In my third or fourth semester, I worked on a project in theoretical chemistry with Prof Eluvathingal Jemmis, who later retired as a professor at IISc and was the founding director of IISER Trivandrum. I was his first student.

My time at the UH strengthened my interest and my passion for chemistry, though physics, too, was always at the back of my mind.

How did you choose IISc for a PhD?

I actually wanted to go to the USA for a PhD, but my mom would be alone; my father died very early in my childhood. So, I decided to do a PhD in India.

I first interviewed at the Tata Institute of Fundamental Research (TIFR), and two days later at IISc. I travelled by train in the general compartment; it took one and a half days from Mumbai to Bangalore! I attended two interviews – one at the Department of Organic Chemistry and one at the Molecular Biophysics Unit (MBU). I got selected in both. I chose Organic Chemistry and worked with Prof K Venkatesan, with whom I had a great mentor-mentee relationship.

I began researching X-ray crystallography. Prof Ramamurthy, a photochemist, came on as my co-advisor. That was the beginning of my PhD career. I had the best five years of my life at IISc. When you go to an institution in your formative years, it contributes in shaping you. I was 21 when I joined, and about 26-27 when I left. That's a critical time.

Your post-PhD journey seems like a trip across the world – you moved to Texas, then Germany and are now at NASA JPL.

Yes, I decided to move away from crystallography; India already had too many crystallographers. So I went to Austin, Texas, to work on low-temperature spectroscopy and chemistry.

During my postdoc, I worked with a German student who became my girlfriend and, later, my wife. I moved to Cologne, Germany, to do habilitation, which is like a tenure-track position, in low-temperature spectroscopy. I completed that in 1998 and was looking for faculty positions.

Photo courtesy: Murthy Gudipati

Murthy Gudipati (right) with his PhD advisor Prof K Venkatesan (left) and Nobel laureate Dorothy Hodgkin (centre) during her visit to IISc in 1984

Around that time, I met a NASA scientist, Louis Allamandola, at a Gordon Research Conference. The work I was doing in low-temperature spectroscopy focused on aromatic molecules called polycyclic aromatic hydrocarbons (PAHs), and he happened to be the one who proposed that these molecules are ambivalent in interstellar space.

I later visited him at NASA Ames Research Centre for a summer, during which we worked on an interesting project. A prevalent molecule in space is water ... but water exists mostly as ice because the temperatures are so cold. What happens if the water and the PAHs are co-trapped to become ice?

Those three months opened up a new area of research in optical spectroscopy of water ice. I decided to move to the USA to the University of Maryland, College Park and the Stanford Research Institute. Lou and I continued our collaboration on PAHs in ice. After a few years, I moved to the NASA Jet Propulsion Laboratory, a part of Caltech, to focus more on planetary sciences, ice, and other materials in planetary environments.

Europa Clipper is not a mission to find life ... only to examine if conditions for life are present

What kind of insights can ice really give us about our universe?

When we say ice, it is usually water ice, right? But it can also be any other molecule forming a solid at very low temperatures. The uniqueness of water ice is that, spectroscopically, we have observed it in every astrophysical and planetary environment where the temperature is below a certain threshold, and typically with no atmosphere (except our own Earth). Even our Moon has ice in permanently shadowed regions, in craters where sunlight never reaches.

Photo courtesy: Murthy Gudipati

Murthy Gudipati demonstrates a Celestron telescope donated to IISc in 2017, alongside former IISc Director Anurag Kumar

In the matter between stars in our galaxy, typically, it is a vacuum; we call this the interstellar medium. But there are regions with so-called molecular clouds; one of the more famous ones is the Horsehead Nebula. These are all extremely cold environments where all molecules freeze, and water is the dominant molecule in these ice grains. It is in a form called amorphous water ice, which our research has shown can support extremely complex chemistry because it is a place where the rest of the molecules in the interstellar medium are trapped. You have oxygen and hydrogen from water, carbon from carbon dioxide, nitrogen from ammonia, and sulphur – all these elements together, when subjected to radiation from galactic cosmic rays or nearby stars, even at these frigid temperatures, create almost a chemical soup. When we simulated that in the lab, we found that the building blocks of life can be synthesised there.

Among the many hypotheses on how life could have started on Earth, one is based on this. These molecular clouds, these ice grains – which already carry the chemical building blocks of life – eventually come together to form comet-like material. This happens because molecular clouds undergo gravitational collapse, where the pressure builds until a new star is born. Around that newborn star, the surrounding material – including these ice grains – gets incorporated into comet-like bodies.

Photo courtesy: Murthy Gudipati

Murthy Gudipati overlooking the Europa Clipper spacecraft being assembled in the high-bay cleanroom at NASA JPL in 2023

In our solar system, there appears to have been a gravitational instability between Jupiter and Saturn around four billion years ago. This disruption flung these small comet-like bodies across the solar system, including onto Earth and the Moon. We think that soon after this bombardment – about four billion years ago – the first form of life on Earth was detected, about 3.7 billion years ago. This is the importance of ice and its connection with life on Earth.

You are also involved in NASA's Europa Clipper mission. Can you share more about that?

Europa is one of the four big moons of Jupiter. It has twice as much water as Earth.

We want to understand how radiation affects ice on Europa and whether there is any exchange of water between its subsurface ocean and the surface through the ice crust. For example, if there were to be life, microbial life or something else, and if it gets pushed up to the surface, would it survive? How long can it survive? If it doesn't survive, what radiation-driven chemical processes would occur? These are also things we study in the lab.

The spacecraft will reach Europa in 2030, right? What are you most excited about finding?

I would be extremely excited if we could see the night side of Europa, where there is no Jupiter shine, or Ganymede (another of Jupiter's moons) shine ... when it's really, really dark ... and see whether there is any ice-glow coming off from the surface.

Jupiter's radiation, especially electrons and protons, bombards Europa heavily, day and night. Our lab work has shown that this bombardment leads to so-called electron-induced luminescence from ice. And that [glow] depends upon what kind of composition those ice regions have. For example, if the ice contains sodium chloride, it will not glow. If it has magnesium sulphate, it will glow really bright. So, if the surface of Europa is non-uniform, then different areas should glow at different intensities.

I would also like to know how thick Europa's ice crust is and whether it is uniform. Then we can consider sending ice-penetrating instruments into the ocean one day to see what it is made of.

Is it more promising to find signs of life on moons than on planets?

To find life somewhere else, we need to know what we are looking for. We have only one example – life on Earth. So, we are searching the universe with this one known example. Not because other kinds may not exist elsewhere, but because we have not yet found, either experimentally or otherwise, what that could be like.

Now, for carbon-based life, one of the most important ingredients, in addition to hydrocarbons, is water. So, we search for where liquid water is available. Mars once had liquid water, but its atmosphere is now gone, and the surface is dry. It has ice, but no liquid water. So, there might have been life, but it did not have enough time to evolve. So, the next thing that we look for is time to evolve. Other things include energy sources, minerals needed for life, and stability.

Other planets do not have these. So, we go to the moons. Of all the moons, Europa is the most important because it has liquid water inside, it has mineral-water interaction (rock-water interaction), and it has energy from an elliptical or eccentric orbit around Jupiter. Stability is also evident, as Europa has been like this for four billion years.

But Europa Clipper is not a mission to find life. It is only to examine if the conditions for life are present on Europa. If we find those conditions, the next mission can drill through the ice, enter the water, and see whether there is life. Or, if we are lucky, there might be plumes coming from deep within the ocean, and they may contain bacteria or other forms of life, so we can detect them more easily. That is a very rare chance, but that would be a jackpot.

I don't know if humanity is ready to find out about life on other planets or moons.

One thing that happened to me going into astrophysics and planetary sciences is that I realised how precious life on Earth is. And that there's no planet B for humans. We are taking life for granted. As for detecting life elsewhere in our solar system or in the universe, there is a non-zero probability. But when we find life elsewhere, it fills in that big intellectual void in human civilisation. However, I am not that optimistic that this could happen in my lifetime or in centuries to come.

Moving away from space for a bit … what motivated you to start IISc AANA and also work with the Notebook Drive initiative?

We have a responsibility to leave a better Earth for future generations. I have been thinking about how we can build a better civilisation, one more at peace with our differences. Education will help us develop logical thinking processes. If we can give every kid the ability to think, they may take a step back before resorting to violence.

So, I started a small scholarship programme, and I was also working with the Notebook Drive (a programme that promotes quality education in schools).

IISc has played such a critical role in my life. This gratitude led a few other IISc alumni and me to start the IISc Alumni Association of North America (IISc AANA) in 2000; it became incorporated as a non-profit in 2005. We have been working with directors since then, with students, and, of course, we are all doing things at an individual level. Whenever I come there, I try to mentor students.

Do you indulge in any hobbies?

I enjoy vegan cooking. Listening to music across the world. We often go hiking in the mountains. One of our three daughters, Hima, is an avid mountaineer, and she took us on a week-long trek to Annapurna Base Camp. If we have visitors, I usually take them to the Mount Wilson Observatory, where Edwin Hubble discovered that the universe is expanding back in 1929.

Wow. Visitors must really like that. Space is fascinating, and humanity's missions to understand it are even more so. Like the Voyager missions.

The interesting thing about the Voyager Mission, sent in the 1970s, is that they knew so much about the orbital mechanics of our solar system, that all the planets would be positioned such that the Voyager spacecrafts could take a gravity assist from each of them to go faster and further, while also studying them along the way.

Both Voyager spacecrafts, travelling at about 15 kilometres per second, are now entering interstellar space. Thousands or millions of years later, provided they do not collide with something, these spacecrafts could be the messengers of human civilisation to the universe and probably survive even longer than humanity.

A human-made spacecraft. Imagine … where we started and where we are … that's the beauty of it [space exploration].

(Edited by Sandeep Menon)

Photo courtesy: Murthy Gudipati

Murthy Gudipati with his daughters and a guide at the Annapurna Base Camp in Nepal

Stories from Oceans Past

- Ashmita Gupta

Photos: Anusri Saha, Sajeev Krishnan

Different species of foraminifera collected by Sambudhha Misra's lab, IISc

Chasing climate clues in underwater fossils

Around 18,000 years ago, the Earth began to thaw. Expansive ice sheets that had covered much of the northern hemisphere for tens of thousands of years began to retreat. Sea levels rose, glaciers collapsed, and the planet slowly emerged from the last ice age.

At the same time, atmospheric carbon dioxide (CO_2) increased by about 100 parts per million as the oceans released stored CO_2. The extra greenhouse gas trapped more heat, pushing the planet towards a warmer interglacial world.

But how do we know what the Earth was like back then, when we only began to record surface temperatures 150 years ago?

Fortunately for us, the planet has done a decent job of archiving chemical

signatures left by its climatic ups and downs – we just need to know where to look. Cue paleoclimate researchers. Using a wide range of 'proxies', they have managed to paint quite a vivid picture of the Earth's past.

These proxies could be tree rings, whose widths reflect how favourable a growing season was – wider rings often indicate favourable warmer, wetter conditions. Or bubbles trapped in Antarctic ice, which preserve tiny samples from ancient atmospheres. Or stalagmites in caves, whose chemistry records past rainfall patterns. Retrieving these archives often means crawling through narrow cave systems, drilling down kilometres into polar ice sheets, or sailing across oceans to collect sediments from the deep seafloor.

Of all the places that researchers search for such clues, the ocean is especially crucial. "The ocean contains far more carbon than the atmosphere," says Gavin Foster, Professor of Isotope Geochemistry at the University of Southampton. "So, if you want to understand changes in atmospheric CO_2, you have to understand what the ocean is doing."

Using a wide range of 'proxies', paleoclimate researchers have managed to paint quite a vivid picture of the Earth's past

But understanding past climate requires more than broad hints about whether conditions were warmer or colder. Many climate proxies offer only qualitative clues – suggesting, for instance, that parts of the ocean were cooler during a particular phase of the Ice Age, without revealing by how much. If one wants to know, say, how temperature responds to a given change in CO_2 concentration, we would need quantitative proxies, says Sambuddha Misra, a chemical oceanographer and Associate Professor at the Centre for Earth Sciences (CEaS), IISc.

And for these, scientists have to dig deeper – all the way down to the ocean floor.

The ocean's archive

In July 1947, the sailing vessel *Albatross* left Swedish waters bearing the newly developed Kullenberg coring machine. It returned over a year later, loaded with several 20 metre-long sediment cores collected from the seafloor at 400 sampling stations across the Atlantic, Pacific, and Indian Oceans.

Photo courtesy: Shuhao Xie/IODP JRSO

The JOIDES Resolution, a research ship operated under the International Ocean Discovery Programme (IODP), in the South China Sea, which collected several sediment cores used for palaeoclimate research

These cores contained deep-sea clay that was millions of years old – mineralogical remains from continental weathering – and countless microscopic organisms. Hidden among them were what the researchers had primarily hoped to find: the shells of foraminifera – tiny single-celled organisms that have inhabited Earth's oceans for over 500 million years, recording all of its events.

Foraminifera live both at the ocean surface (planktonic) and on the seafloor (benthic). As they grow, they build calcium carbonate shells. When they die, these shells sink and accumulate on the seafloor, forming layered records of past oceans. The kinds of species found at a location are a clue too, as some thrive in warm waters and others in colder regions. Crucially, their shells preserve chemical traces of the water they formed in – not bad for organisms smaller than a grain of sand.

For instance, the shells store oxygen in two forms: a lighter isotope (^{16}O) and a heavier one (^{18}O). The ratio between these – known as $\delta^{18}O$ – varies with temperature and global ice volume. During colder periods, when ice sheets locked away lighter oxygen, the oceans became relatively enriched with the heavier isotope. This signal was recorded on the shells as they formed.

Expeditions like that of the *Albatross* helped establish deep-sea sediments as climate archives. In the 1950s, Italian-American geologist Cesare Emiliani measured $\delta^{18}O$ in foraminifera from such cores to reconstruct a timeline of alternating warm and cold periods, revealing the rhythm of Earth's glacial and interglacial cycles for the first time.

Since then, the proxies that scientists have extracted from foraminifera go far beyond oxygen isotopes. Their shells now help researchers reconstruct past ocean temperatures, seawater acidity, carbon cycling, and even atmospheric CO_2, using traces of other impurities such as magnesium and boron locked within the calcium carbonate.

Sambuddha Misra is one of those researchers. Growing up around scientist grandparents, a chemical toolbox to play with, and an innate fascination with history, he developed an interest in paleoclimate research. Well, that and a gentle nudge from his grandmother to pursue oceanography. Years into working on marine geochemistry and paleoclimate reconstruction, his work has come to focus on extracting climate signals from minute chemical impurities locked inside marine carbonates.

"In my lab, we focus on the trace metal chemistry of carbonate samples [foraminifera and corals]," he says. "The amount of impurities in them is on a nanogram scale. We try to measure its concentration and sometimes its isotope ratio to reconstruct past conditions of seawater."

Collecting these samples is a massive logistical effort. International ocean drilling programmes send expensive, diesel-guzzling research vessels across the world's oceans, where scientists retrieve sediment cores from depths of 3,000–5,000 metres.

Back in the lab, researchers like Sambuddha and his team extract foraminifera from the cores and rigorously screen them for signs of alteration, such as dissolution, recrystallisation, or chemical exchange with surrounding seawater – a process known as diagenesis – all of which can distort the original signal.

"It is like cooking. If you cook with bad ingredients, it will never taste good," says Sambuddha.

Selected samples are then dated to determine when they were deposited. If it's a short core, they use radiocarbon methods. For longer cores, they usually match the oxygen isotopes from the shells with the Milankovitch cycles – climatic cycles that track predictable shifts in Earth's orbit around the Sun.

Foraminifera shells help researchers reconstruct past ocean temperatures, seawater acidity, carbon cycling, and even atmospheric CO_2

The team then dissolves the shells for analysis using mass spectrometry, which reveals its chemical composition for isotope analysis. From all these diverse processes emerge a set of chemical clues – temperature-sensitive ratios, pH indicators, and isotopic signatures – that must be interpreted together to reveal how the oceans have changed through time.

Chemistry into climate cues

On the other side of the world, researchers like Gavin Foster are working on similar questions.

Before Gavin stumbled upon paleoclimate research, he spent some time studying the metamorphic geology of the Nanga Parbat mountain in Pakistan in the 1990s. That is where he learned to use mass spectrometers to date rocks. Thereafter, the plasma mass spectrometer came into existence, opening up a whole new range of isotopic systems that could be measured – pushing Gavin towards more climate-based applications of isotope geochemistry.

After years in the field, Gavin got hooked on using boron isotopes in foraminifera to work out past CO2 concentrations and, from that, understand past climates and potentially predict future climates too.

Boron isotopes reveal the pH of seawater. In seawater, boron exists in two forms, and the balance between them shifts depending on the acidity. As more atmospheric CO_2 dissolves into the ocean, it forms carbonic acid and lowers seawater pH. Foraminifera incorporate boron into their shells in proportions that reflect those pH changes, allowing scientists to work backwards and estimate past atmospheric CO_2 levels.

Besides boron isotopes, other chemical signatures offer complementary insights. For instance, magnesium naturally substitutes for calcium in foraminiferal shells, and warmer waters lead to higher magnesium-to-calcium ratios.

By combining such data from proxies, scientists have pieced together how carbon moved between the ocean and atmosphere, particularly during major transitions like the end of the last ice age.

Reading between the lines

For all the insights paleoclimate research has offered, it remains an interpretive science, shaped by uncertainties, assumptions, and constantly evolving methods. Sambuddha prefers the term "uncertainty envelope" – a defined range within which interpretations are built.

Part of that uncertainty stems from the ocean itself. Seawater is chemically complex, with ions constantly interacting and shifting behaviour. Even salinity is not constant through time. During the last ice age, for instance, vast amounts of water were locked in ice sheets, leaving the oceans about 5% saltier.

Such shifts influence how the proxies behave. Scientists must account for background changes in sea level, salinity, and ocean chemistry alongside the signals preserved in shells. So, the results of paleoclimatic studies are usually not a single value, but rather a constrained range within which the past most likely lies. For instance, researchers may conclude that a region of the ocean was likely between 2°C and 4°C cooler during the last ice age, rather than assigning one definitive temperature value.

What's more, different proxies don't always agree.

Boron isotopes illustrate this well. In some cases, they suggest relatively stable CO_2 levels even when data from other temperature proxies indicate that the planet was significantly warmer.

This is because local conditions, such as temperature, circulation, and the movement of carbon-rich or carbon-poor waters, can reshape the signal. "The physical oceanography is overlaid on the chemical oceanography," Sambuddha says. "And we are picking out organisms influenced by both."

In one study of corals from Lakshadweep, his team was looking to assess the pH record of the Arabian Sea between 1990 and 2013. They expected a drop in seawater pH as atmospheric CO_2 rose. Instead, they observed a slight increase. The shift was driven not by global CO_2 trends, but by regional ocean dynamics linked to the El Niño–Southern Oscillation.

Such contradictions between proxies are often a clue, pointing to the layered complexity of ocean systems, where chemistry and physics are both at play.

When biology shapes the signals

Other uncertainties in paleoclimate science come from the organisms themselves. Foraminifera don't just passively record seawater chemistry; they also modify it. As Gavin explains, the shell only captures the conditions in the tiny microenvironment around the organism. "The pH that the foraminifera records is the pH in that little zone just between the foraminifera and the seawater."

Photos: Gavin Foster

Live foraminifera collected in Bermuda being measured using microelectrodes in Gavin Foster's lab. The measurements quantify the effects of life processes, such as photosynthesis, respiration, and calcification

Unlike the foraminifera studied by others, Rosalind Rickaby, Chair of Geology at the University of Oxford, focuses on coccolithophores, which are photosynthetic algae that produce about half of the open ocean's calcium carbonate. Her research explores how these organisms control mineral formation at a global scale and how their physiology adapts to changing ocean chemistry.

"The forams, by and large, are a better proxy of seawater chemistry," Rosalind acknowledges. "My organisms (coccolithophores) are very heavily overprinted, I think, by the biology of the cell – but that is a signal in its own right."

Before they form the shell, coccolithophores must transport all the elemental ingredients to the interior of the cell – selecting against uptake of elements like magnesium that inhibit calcification, or adding carbon to drive mineral formation. These processes leave their own chemical imprint on the final shell, thereby altering the signal.

Different organisms manipulate chemistry in different ways. Even within a single group, the individuals' size, growth rate, and metabolism all influence how elements are incorporated. Smaller cells, for instance, tend to grow faster, and that metabolic intensity can alter the chemistry of their shells.

Additionally, over millions of years, the organisms have evolved.

Contradictions between proxies are often a clue, pointing to the layered complexity of ocean systems

Coccolithophores, Rosalind notes, have become smaller and faster-growing over time – a shift that is visible both in their fossil record and in their geochemistry. Some foraminifera, meanwhile, have grown larger, appearing to strengthen symbiotic relationships with photosynthetic organisms to survive in increasingly nutrient-poor stratified waters.

All of this complicates what seems, at first glance, like a straightforward translation of chemistry into climate. But Rosalind notes: "We shouldn't be scared of complication. We should embrace it – it will help us create a better understanding of what these signals are truly telling us, even giving insights into past physiology."

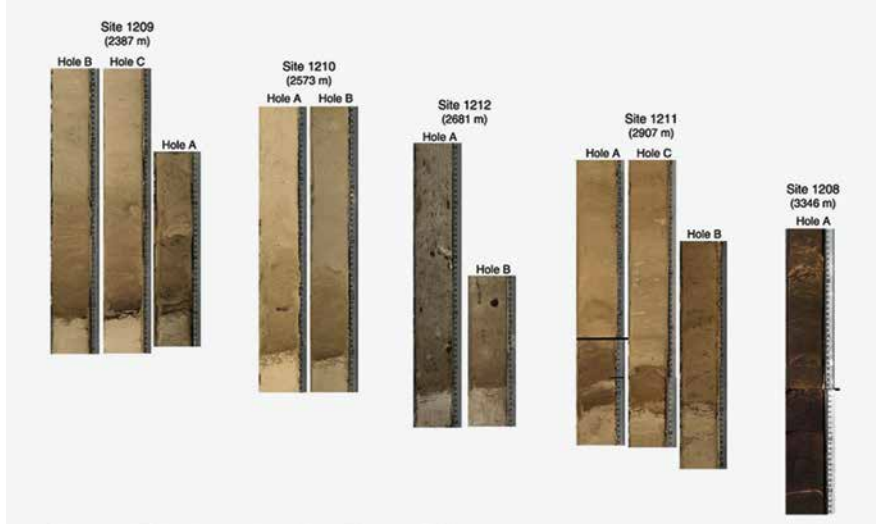


Photo courtesy: International Ocean Discovery Program

Sediment cores from Shatsky Rise, an underwater volcanic plateau in the northwest Pacific Ocean, ordered by depth. The transition from carbonate (white) to clay (brown) reflect the abrupt ocean warming during the Palaeocene–Eocene Thermal Maximum

To filter out such distortions in the proxies, scientists combine several strategies. They select samples carefully – often restricting analysis to a single species and even a narrow size range – and compare organisms that lived in different parts of the ocean. When multiple proxies point to the same conclusion, scientists gain greater confidence in the results.

"If forams that live on the surface and forams that live in the deep, as well as coccolithophores, all record the same signal," Rosalind explains, "you can be very sure that's an [accurate] environmental signal."

Why the past still matters

For Sambuddha, the lesson from palaeoclimatology is fundamental. "Through forams, scientists have uncovered [past] worlds that look radically different from our own: a time 35 million years ago when Antarctica supported rainforests, and an even earlier Earth with no permanent ice at all."

Geological records have revealed astonishing stories about our Earth's past. Greenland ice cores have shown rapid temperature rises of roughly 10–15°C over just a few decades to centuries, possibly driven by ocean circulation patterns, says Rosalind. Some records indicate that 50 million years ago, during the Eocene, global temperatures were far higher than today, with atmospheric CO_2 levels reaching around 1,200 parts per million (today's levels are around 431 ppm). Earlier still, during rapid events such as the Palaeocene–Eocene Thermal Maximum (PETM), massive injections of CO_2 into the atmosphere triggered abrupt warming and ocean acidification.

At its core, however, paleoclimate science is not just about reconstructing what the Earth once looked like – it is also about understanding what it can become.

Unlike digital climate models, which simulate possible futures, paleoclimate records capture physical evidence of how the Earth system has already responded to shifts in CO_2 levels, temperature, and ocean circulation.

These records allow scientists to assess how sensitive the Earth system truly is and test how well climate models capture that sensitivity when predicting future scenarios. "If the climate models get the Eocene climate right," Foster says, "then we have much more faith in their predictions [for future climates]."

This is crucial now more than ever, as atmospheric CO_2 levels are rising faster than at any point in human history. "The power of the geological record is that it represents actual events that happened," says Gavin. "The Earth has already run these experiments for us."

(Edited by Abinaya Kalyanasundaram, Ranjini Raghunath)

Cloudy Trail

- Devansh Jhawar

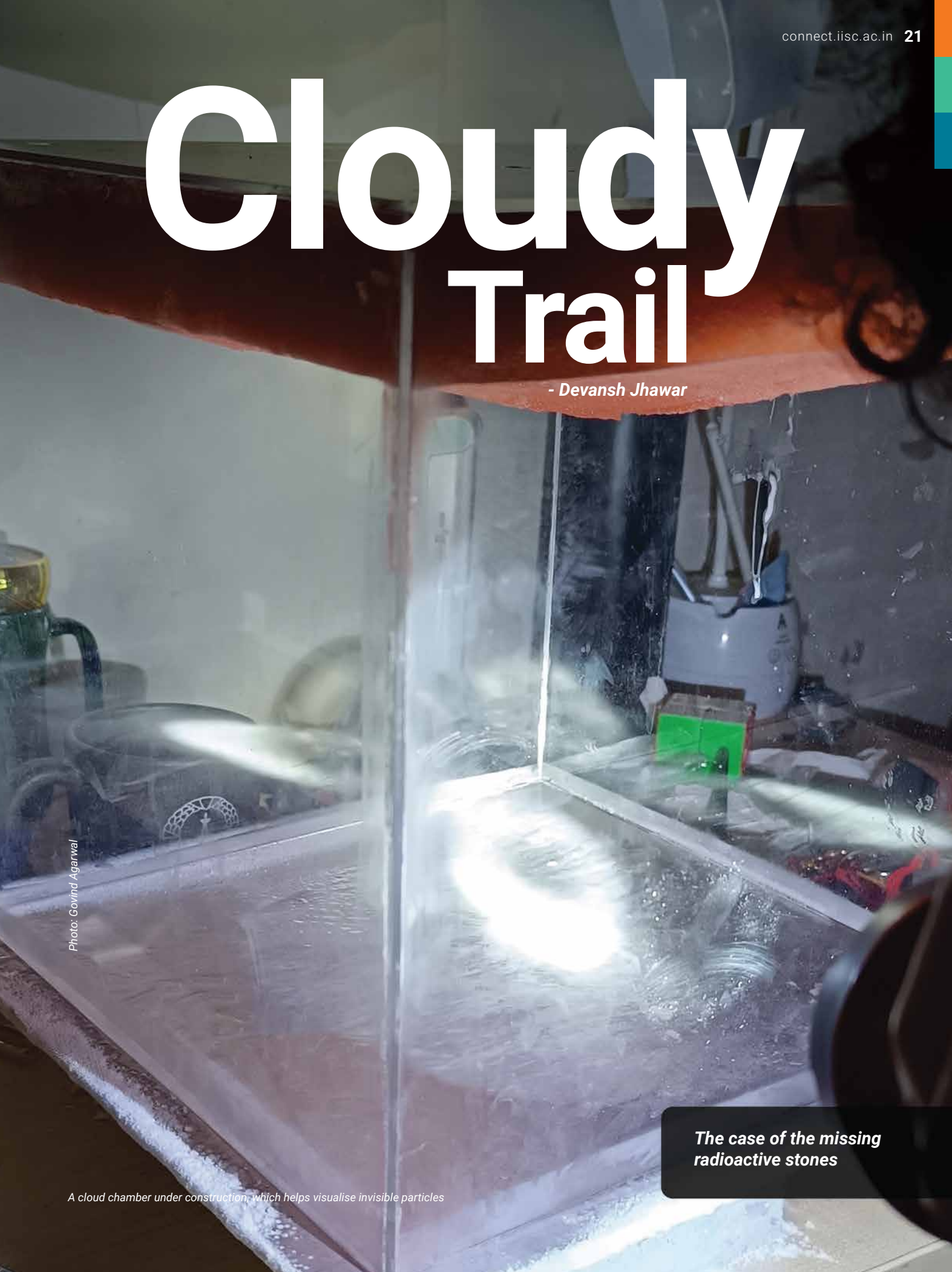


Photo: Govind Agarwal

A cloud chamber under construction, which helps visualise invisible particles

The case of the missing radioactive stones

As the last flowers cling to their trees, and the spring blossoms begin to fade on campus, the onset of summer is marked by a very special time at IISc: the arrival of Open Day.

Gates open, labs light up, and thousands of people throng the campus, marvelling at seemingly seamless demonstrations and cutting-edge science. To a visitor, everything appears to work.

The night before D-day, however, just hours before the gates open, things are not so smooth. Some demonstrations, in fact, have utterly failed. And no guarantee that they will work even by morning.

On the undergraduate side of campus, four first year physics enthusiasts – Ryan Ray, Govind Agarwal, Savio Joseph, and Dishaanth Basu – were trying something that even the Physics department, due to their previous track record, had given up on: the cloud chamber, a neat way of making invisible particles visible. Neat, of course, only if it worked.

A cloud chamber is a particle detector that helps visualise invisible paths of subatomic particles. It creates an environment of supersaturated vapour of alcohol – meaning that the vapour is very close to condensing into liquid – which interacts with energetic particles, thus ionising the vapour. The alcohol vapour rapidly condenses around these particles, leaving a cloudy, visible trail of particles.

"Now, the issue with this is that it is a very simple setup, but to actually see these particles, we need radioactive rocks that are very rare and a little hard to find," says Ryan. And so, they thought they'd get hold of some radioactive material.

How difficult could it be?

They started by asking one of their professors for help, and got referred to Sanjay*, who agreed to lend them three pieces of zircon – crystals with trace quantities of uranium in them. Those polished gemstones of zircon were extremely valuable, but the students promised the professor that they would take good care of them.

At first, *Ensemble*, the UG Physics club, was a bit sceptical about whether this experiment should be done or not. In fact, they didn't even add it to the official experiments list, because the same experiment had been done at a lot of places, and it just didn't work well at all. "But we were adamant," says Govind.

Their stubbornness didn't help. The zircons weren't radioactive enough to show significant trails of the particles. In fact, even the contingency plan that they had thought of for this exact scenario – a different radioactive source that they had bought from Amazon – also failed. More than failed, they got scammed because the source did not contain any radioactive material, despite what they were led to believe. And the product was not refundable.

Open Day was just four days away now, and so far nothing had worked. Thankfully, Sanjay had mentioned another, even more precious radioactive source – a monazite sample – that he could lend, in case the zircons didn't work. The students emailed him asking for the monazite sample, to which the professor agreed, and asked them to return the zircons.

At the time that they received a reply from the professor, Ryan and Savio were out of campus buying a few remaining items for the setup. The box of zircon samples had been left in Ryan's room.

When Govind entered the room, the box was gone.

He searched the table, looked into the drawers, under the bed, and … nothing. Panicking, Govind asked Ryan's roommate if he had any idea. The roommate didn't, but mentioned that monkeys had entered the room a while ago.

Ryan heard all of this on a call, and started freaking out. He sat on a pavement there, head in his hands, contemplating. Savio tried to comfort Ryan, saying, "Bro, what does a monkey want to do with zircons? Like, it's not a banana or something."

At this point, the only lead left was the terrace, which Ryan's room opened onto directly. They rushed back and searched the area. Just outside the window, they found the box, with one zircon sitting inside. Another lay nearby. The last one was missing.

While this was happening, the professor was waiting for the students to return the samples and collect the monazite. Yet, they continued searching for hours, looking under and above every leaf on the terrace – unfortunately, those leaves were the same colour as the sample – to no avail. A gem-grade zircon was gone.

The students were completely dejected. "For us, our complete reputation in the Institute [was] at stake, because we asked our professor to reach out to a different professor for something that he possesses," recalls Ryan. "We take it from him with the guarantee that we will keep it safe. And what will we now tell him? Even if we just tell him the truth, it's the equivalent of saying a dog ate my homework!"

All of this had gone down just two days before Open Day, and there was barely any progress made. Their only hope now was the even more precious monazite sample, but to get it from the professor, they would have to first return the zircons. And they were terrified to do that.

Somehow, the team mustered up the courage to finally go and meet the professor. They handed the box to him, waiting for the eventual scolding. But the professor seemed to have not noticed the missing zircon; he simply took the box and handed them the monazite sample. The students, unwilling to lie to him, stopped him, and narrated the entire incident nervously.

Photo: Dishaanth Basu

Long, cloudy tracks of otherwise invisible particles can be seen with the help of the monazite

**name changed*

Sanjay was quiet for a moment, taking in the sheer absurdity of the situation. To their surprise, he remarked that he'd done much worse in his undergrad days. He went on to say that they needn't have worried so much and tried so hard to retrieve the zircons, because if he lost it this way, he would have just let it go.

The students were stunned, but also incredibly relieved. In fact, Sanjay still offered the monazite sample, although with a very important caveat: if they lost the monazite too, they would be done for. The students, despite not having any other leads, declined. They didn't think it would be appropriate to ask again, not after what had just happened.

The professor just shrugged it off, and finally said that if they were unable to get any other leads, they could come over to his office anytime the next day – a day before Open Day – to collect the sample, and he would be there.

The students knew, even as they walked away, that they would have to go back and ask again anyway. At the moment, however, they were simply trying to be good samaritans.

In the hours that followed, they scrambled to find an alternate radioactive source. They scoured the internet, made calls to any remotely related vendors, and asked everyone they could for help.

Finally, in their desperation, they stumbled across an IndiaMart listing that seemed to be selling thorium oxide – a stable, radioactive powder. Govind called the number that was being displayed on the listing, and asked what concentrations they sold. The seller rebutted him, instead asking Govind the concentration that *he* wanted, promising that he would acquire it.

Now, here's the deal: a legal business selling thorium oxide cannot just provide any concentration, since the product is highly regulated by national agencies. This already set off Govind's alarms.

But the seller wasn't exactly trying to hide anything. In fact, he'd occasionally say something like "*aap samajh rahe hai na? *wink wink**" on call, constantly trying to hint that his business was not on the most legal grounds. He also refused to share any other details, like a rough idea of the cost, or anything else.

And so, by the evening before Open Day, the monazite was their only remaining option. Because dealing with an illegal business – and possibly facing a police case – wasn't exactly on the students' first-year-in-college bingo card.

At 4 pm on the day before Open Day, the students trudged back to Sanjay's office, only to find that he was not there. 5 pm came, but Sanjay still didn't. Then 6 pm, 7 pm, then 8 pm, he still wasn't there. The night before Open Day, they had no sample. They were supposed to have a mock run-through of the experiment with Ensemble that night, but the group didn't even have all the required equipment.

After dinner, they decided to try one last time at around 8.50 pm. As Ryan walked up the stairs to his office, he saw something the students hadn't seen on any of their previous attempts: the lights in his office were switched on. Eager, he ran up the stairs, and found Sanjay with two other colleagues. He told him that they needed the monazite desperately for tomorrow, and that if he gave it to them, they would protect it with their lives.

Sanjay agreed.

The students rushed back to the lab at around 9 pm, and put the sample into the chamber. They stared at the chamber, their hearts thumping loudly. It took a few minutes, but they suddenly saw wonderful trails of particles everywhere. They had somehow managed to make the experiment work at the eleventh hour.

By the next morning, on Open Day, the cloud chamber held up. Crowds gathered, asked questions, marvelled at it, and moved on to the next demonstration, without realising just how close the experiment was to not being there at all.

In the middle of the day, when it was his turn to demonstrate the experiment, Dishaanth suddenly realised that the monazite had disappeared. He decided to keep this information to himself, lest his teammates panicked.

Photo: Sameer Rajputh

From Left to Right: Govind, Savio, Dishaanth, and Ryan in front of their cloud chamber on Open Day 2026

Fifteen minutes later, Dishaanth found the monazite again. Apparently, during a demonstration, a foam layer that held the alcohol had dropped onto the monazite, which had somehow submerged itself into the sponge. But that had been enough to give Dishaanth a heart attack.

Later in the day, after the stalls had all wrapped up, Govind made his way to the department to return the monazite sample. Sanjay seemed quite happy to receive the monazite back, and also asked Govind if he could show some footage of the cloud chamber with the trails. He watched with interest, and asked if he could keep a copy of the footage to show it to his students and colleagues.

When Govind was about to leave, Sanjay casually mentioned that at the end of the day, these rocks didn't hold much value to him. At some point, he would retire, and the rocks would just remain rocks. They would serve no purpose to him.

Govind simply nodded. To think he and the team had almost lost their sanity trying to return the zircons and the monazite safely.

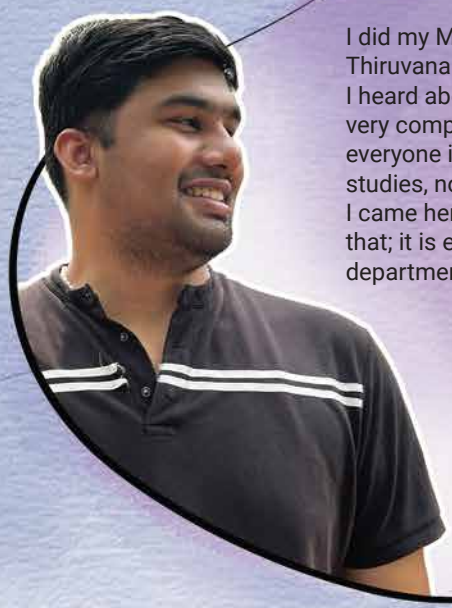
Speaking of which, the third zircon still remains missing. In all likelihood, IISc now harbours the most radioactive primate in Bengaluru.

Devansh Jhawar is a second year Bachelor of Science (Research) student at IISc, and a former science writing intern at the Office of Communications

(Edited by Ranjini Raghunath)

CONNECT ASKS

What is a myth about IISc that you would like to break?



I did my Master's from IISER Thiruvananthapuram, and what I heard about IISc was that it is very competitive, strict, and that everyone is [thinking about] studies, nothing else. But when I came here, it is not at all like that; it is exciting here. My department is also pretty chill.

Nikhil Kollins
Intern, Centre for Ecological Sciences

Before coming to IISc, I thought managing the schedule and co-curricular activities would be very hectic. After being here for two years, I found that it is not. Yes, you have to manage your time, but you still have time to play sports and participate in co-curricular activities. You can find every single sport in IISc; there are clubs for drama and music. Everything.

Jalaj Siroliya
MTech student, Robert Bosch Centre for Cyber-Physical Systems

I came from an engineering institute, where the majority were Bachelor's students, and PhD candidates were fewer. Here it is the opposite. So, how every day goes is very different – the conversations we have with colleagues, people are discussing things. In *Quora*, I read that at IISc, even when you are in the Mess or standing in line, you will find two people talking about science. I found that to be true, and the conversations are natural and genuine. That is different from all other institutes.

Ishita Bansal
PhD student, Centre for Nano Science and Engineering

When I was considering joining IISc, I heard that IISc is better for sciences than for fields like engineering. I heard that if you want to pursue an MTech and follow a technology line, you are better off at the IITs. It is not true; it's good for engineering-based courses as well. I think it [this perception] is because IISc took engineering students much later.

Dayita Chowdhury
MTech student, Department of Computational and Data Sciences

When I first came, I thought classes here were serious, and professors were not friendly; that they just discussed topics and left. But professors here are friendly and approachable. If you have doubts, they have all the answers, and if they don't, they connect with you later and resolve your doubts.

Anooja PS
PhD student, Centre for Nano Science and Engineering

When I was in college, I thought IISc only took people who got a GATE or NET ranking below 50. When I came here, I learned that there are many opportunities and other exams. Recently, they gave opportunities to IISER students with a certain level of CGPA. I know people doing their PhDs here who did not clear exams but were working on some topic [or problem] and got their opportunity that way.

Amrutha AK
Project Staff, Centre for Nano Science and Engineering

(Compiled by Ashmita Gupta, Kavi Bharathi R, Rohini Subrahmanyam, Sandeep Menon)

Fungal Hues

- Kavi Bharathi R

Photo: Vaishally

Demystifying nature's oldest pigment producers

A lac insect nymph imaged using fluorescence microscopy, revealing a yeast-like symbiont (red) in the insect's haemocoel. A study found that this yeast could be involved in the synthesis of the insect's signature red pigment

In Shantanu Shukla's lab, dissecting insects is routine. The well-lit room, located in the Department of Developmental Biology and Genetics (DBG), IISc, is filled with young scientists studying scale insects – tiny plant vampires that feed on the plant phloem sap.

The team investigates the intimate relationship between insects and their endosymbionts (organisms living inside them). One among them is the lac insect, *Kerria lacca*. These tiny insects are the source of a culturally and economically significant vivid red pigment – one that has coloured everything from the vermillion on Indian brides' foreheads to the masterpieces of European Renaissance paintings.

India is one of the world's largest producers of lac pigment, harvested from forests in Jharkhand, Chhattisgarh, and Bihar, where farmers wait months for lac-encrusted branches to mature before collecting them.

Yet, how exactly these creatures produced the pigment remained a mystery for ages.

In the 1930s, two scientists, M Sreenivasaya and S Mahdihassan, from the Department of Biochemistry at IISc, travelled across the country collecting specimens and examining them closely, but the limited tools at the time could only take them so far. After nearly a century-long lull, Shantanu's team set out to unravel the mystery.

"This was a convergence of multiple, interesting topics – scale insects, their microbial endosymbionts, and the culturally and economically important model system which produces the pigment, which has been one of the most famous exports of India for thousands of years," says Shantanu, Assistant Professor at DBG.

They began, as all genomics studies must, by sequencing the genomes of everything they could find – of the insect itself and of the microorganisms living inside it. When they cut open a lac insect, they were in for a fabulous sight. "It was full of red colour – it was just oozing out," Shantanu says. They peered further and discovered something floating in the insects' haemolymph (blood) – yeast-like fungal cells. They also found a single bacterium species of *Wolbachia* living inside the insect.

By mapping the genes, they discovered that these microbial partners were synthesising essential amino acids and vitamins that the insect could not obtain from its nutritionally poor phloem sap diet.

But where was the colour coming from?

The crimson pigment of the lac insect – known chemically as laccaic acid – has two structural components. "The first is a molecular backbone called an anthraquinone. The second is a side chain: the amino acid tyrosine, attached to the backbone like a decoration. To make the pigment, you need both," explains Shantanu.

Shantanu's team ran a process of elimination: Does the gene for making each pigment component exist in the genome of the insect, bacterium, or fungus, or did it get it from its diet? For tyrosine, the answer was easier. The related genes were not present in the insect's or the bacterium's genome, nor in the diet. Only the fungi's genome had them. "That was the first concrete hint that the fungus was making a critical ingredient of the pigment," notes Shantanu.

The source of the backbone anthraquinone was harder to decipher, as it has a more complex structure than tyrosine. The team suspected that it should be built by a class of enzymes called non-reducing polyketide synthases. When they searched all three genomes (insect, bacteria, and fungi) for the genes that could produce such enzymes, they eventually found one gene in the fungal symbiont.

Many fungi produce pigments as chemical weapons – antimicrobial and insecticidal compounds that help them survive in competitive environments

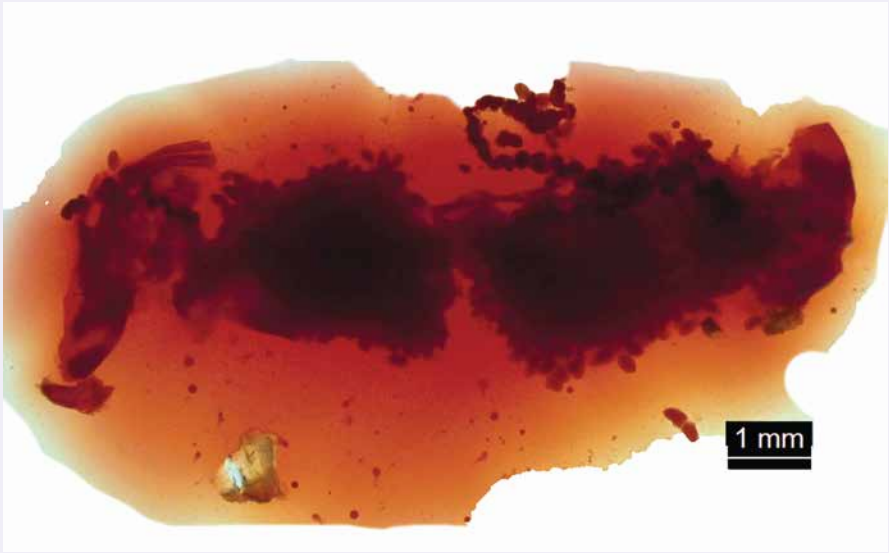
It turned out the insect was not producing this famous pigment. The fungus living inside it was.

"There's lots [more] to understand about it. There are multiple enzymes involved, with complex chemistry," notes Shantanu.

Photos: Sourajyoti Pal

Life stages of the lac insect on a host plant Flemingia semialata*: First-instar nymphs (left), second-instar nymphs after shedding legs, covered with resin and white wax fibers (centre), and late-stage adult females (right) clustered within resin (Scale bar = 1 cm)*

Photo: Shantanu Shukla and Vaishally



A dissected adult female lac insect showing copious release of crimson red pigment diffusing into the surrounding buffer

Hidden world of colours

When most people think of fungi, mushrooms come to mind – ones you eat or, occasionally, the kind that alters your mind. Since ancient times, humans have domesticated fungi to produce food, including baked goods, wine and beer, and several revolutionary medicines such as penicillin.

But fungi also have a lesser-known talent: making colours. For centuries, people have used natural dyes without realising that some were from fungi. Shantanu's findings now add to this ever-growing repository of fungal pigments, which are increasingly being considered better alternatives to synthetic dyes. They are more stable, eco-friendly and can be used in a variety of industries from food and textiles to cosmetics.

'When you zoom in, it's beautiful – just the way that the pigment is patterned across the organism'

Many fungi produce pigments as chemical weapons – antimicrobial and insecticidal compounds that help them survive in competitive environments. "These compounds happen to be coloured, which is what makes them valuable to us," notes Shantanu.

"The category of pigments is largely human-defined – things that look coloured to our eyes. Many fungal pigments are secondary metabolites – these colours are not strictly required [by fungi] for basic growth or reproduction, but they can provide critical advantages for surviving," explains Sunanda Sharma, an interdisciplinary research scientist and artist based in Berkeley, USA.

Sunanda's research journey began over a decade ago in Massachusetts, with a biology degree, followed by early research focused on spatial and emotional memory in neuroscience. Her passion to combine science and design made her take an unlikely turn, and she began working with a designer and an architect at MIT's Media Lab, where her obsession with colours in nature took root.

"Why do organisms as distant from each other as humans and cephalopods (like the octopus) share the same pigment chemistry? Why does the same class of molecule that colours the ink of an octopus also appear in the human brain? What does this reveal about the evolutionary history of colour itself?" pondered Sunanda.

It was during an artist-in-residence programme with Vera Meyer, a self-taught artist and professor of applied and molecular microbiology at TU Berlin, that she began to focus on fungal pigments, specifically working with one of the most overlooked organisms – *Aspergillus niger*, the black mould found on bathroom corners, rotting fruit, or the forgotten bread at the back of the shelf. "It's there, everywhere, and I never really paid attention to it until I did that project [during the programme]," says Sunanda.

Then came COVID-19, a lockdown, and a decision. Sunanda refused to let her research stop. Without a laboratory, she did what scientists with limited resources and burgeoning curiosity have always

Photo: Sunanda Sharma

The edge of a colony of Aspergillus niger *growing on potato dextrose agar in a petri dish*

done – she improvised. Her basement became her lab. She ordered a cheap egg incubator from Amazon, the kind people use to hatch chicks. She used a baby bottle steriliser as an autoclave for glassware. She also rescued a microscope from a university loading dock. And in this makeshift space, she slowly began growing *Aspergillus niger*.

When she saw it under the microscope for the first time, she was stunned. "When you zoom in, it's beautiful – just the way that the pigment is patterned across the organism," notes Sunanda. Melanin – the same class of pigment that colours human skin, eyes, hair, and the substantia nigra deep in the human brain – was patterned across the fungus in striking ways, almost portrait-like. She calls this 'chemical kinship.'

Sunanda also noticed a gap between scientists, who understood fungal pigments at the molecular level, and designers, artists, and textile makers who wanted to use them but didn't know how. So she founded the Living Colour Database (LCDB) – an online dictionary of microbial pigments useful to both researchers and artists. The inspiration came partly from a book called *Werner's Nomenclature of Colours*, published in the 1800s by a Scottish painter, Patrick Syme, based on the German mineralogist Abraham Gottlob Werner. "It was one of the first biological colour dictionaries – a guide to the colours of the natural world, with swatches, names, and examples drawn from animals, plants, and minerals," notes Sunanda. The book was famously used by Charles Darwin during the *HMS Beagle* voyage – a five-year coastal survey expedition in South America, the Galapagos Islands, South Africa, and more – to record the colours he encountered in nature.

'Every colony was saturated with a rich, intense blue that looked nothing like what they [the yeast] had been producing before'

LCDB currently has about 445 pigment entries, covering 110 unique pigments from 380 species, primarily of fungi and bacteria. Sunanda aims to expand it to include pigments from algae and protists.

Photo courtesy: Marilyn Chung/Berkeley Lab

Aindrila Mukopadhyay and colleague Maren Wehrs inspecting a bioreactor full of their Bluebelle strain

While understanding, cataloguing, and making fungal pigments accessible matter, a persistent question remains: Can these colours move from laboratory curiosity to real-world industry use at scale?

Scaling up

In most synthetic biology laboratories, success is measured in milligrams. A researcher spends months engineering a microorganism, optimising hundreds of conditions, and, if everything goes right, might produce a few milligrams per litre of their target compound. They publish, declare victory, and move on to the next project.

Aindrila Mukopadhyay, a senior scientist at Lawrence Berkeley National Laboratory, was not expecting anything different. The molecule her lab was working with was indigoidine – a vivid blue pigment known to scientists since the 1950s. Indigoidine has a deep blue colour remarkably similar to indigo, the textile dye notably used in denim. Processing synthetic indigo has health and environmental risks as it is derived from petrochemicals. So, scientists are considering turning to microbial dye production.

"Fully chemical synthesis of Indigoidine hasn't been worked out, but biology seems to be a real champion at making this molecule," notes Aindrila. Her team was using genes from *Streptomyces* bacteria (which naturally produce these pigments) and *Bacillus* bacteria, which they engineered into yeast as a host. But the problem was that it only produced a pale blue pigment at low levels. Usable for experiments – not for industry.

They then tried something almost on a whim. Colleagues at the same institute were developing a fungal expression system, *Rhodosporidium toruloides*, as a host for biofuel production. They had engineered a strain that produced remarkably high quantities of a terpene compound, bisabolene. "That strain was named 'Golden Boy'," says Aindrila.

Aindrila's team borrowed some *Rhodosporidium* and engineered this with the *Streptomyces* and *Bacillus* genes. It was not a guaranteed bet. "The organism was not a conventional, synthetic biology host as *Saccharomyces* [yeast] is," states Aindrila. It is harder to engineer.

However, to their surprise, the *Rhodosporidium* produced a deep blue colour. "Every colony was saturated with a rich, intense blue that looked nothing like what they [the yeast] had been producing before," says Aindrila. When they measured the yields, they

were astonished. While 10 to few hundred milligrams per litre could be considered a publishable result, Aindrila's lab was producing about 18 *grams* per litre.

"Something about *Rhodosporidium* – its natural metabolism, its capacity to accumulate precursors – simply clicked with the indigoidine pathway in a way that yeast metabolism never allowed," says Aindrila. Keeping up with the tradition established by 'Golden Boy' down the hall, "we called this new strain Bluebelle," she adds.

Aindrila notes that indigoidene is not a direct replacement for indigo but is a fungible replacement. But there is a concern – a highly hydrophobic compound, which has very low solubility in most solvents. And the few solvents that do work are not easy to distil.

"In this case, the challenge was not just the biology but also in the downstream processing. They will have to figure out how to extract this material and get it to purity," she adds.

Commercialisation and future

Engineering and scaling fungal pigment production may take time, but an even greater challenge lies in first identifying them. Sanjay Singh, a scientist and curator at the National Fungal Culture Collection of India, points to *Monascus* as proof. For centuries, communities across East Asia have been producing a fermented food called 'red rice' using a food colouring substance so deeply embedded in their culinary tradition that most have never stopped to think about where the colour comes from.

The answer is "*Monascus*, a fungus that produces more than eight chemically distinct red compounds," each with its own molecular identity. "*Monascus* red pigment was granted GRAS (Generally Regarded As Safe) status for use in food," says Sanjay.

India has roughly 28,000-30,000 fungal species, which remain largely unexplored for pigment production

It was one of the earliest examples of a fungal pigment being used in the food industry, notes Sanjay. Then came a complication. Decades after *Monascus* was deemed safe, more sensitive analytical tools found that it had a mildly toxic compound. Though it retained its GRAS status, considering it was only mildly toxic, the episode was a warning: the same biological machinery that makes a fungus a master chemist can also make it dangerous for human consumption. Some pigment-producing fungi co-produce mycotoxins as a byproduct of their metabolism. "There is no simple spot test. Every candidate organism must be rigorously screened," says Sanjay.

Sanjay has spent over two decades collecting pigment-producing fungi from India's forests, studying them in his lab in Pune. India, with its biodiversity hotspots, has roughly 28,000-30,000 fungal species, which remain largely unexplored for pigment production. But the path from forest floor to factory is long – it needs fermentation expertise, downstream processing, a regulatory framework, and eventually an industry partner.

But the case for pushing them forward is strong, as they are environmentally safer than synthetic dyes. "Synthetic dyes are largely non-biodegradable. Their industrial effluents pollute waterways, accumulate in soil, and disrupt microbial ecosystems," says Sanjay.

Can fungal pigments ever completely replace synthetic dyes? "Even if it replaces 50% of synthetic dyes, it is a big task. Even if fungal dyes are a little expensive, but are safe for human beings, our environment, and our planet, I think nobody will hesitate to pay a little bit extra for that," notes Sanjay.

Besides, as Aindrila notes, replacing synthetic dyes entirely is not the goal. "Even a partial shift builds something valuable: a premium market for products people put on their bodies and in their food, and a manufacturing base that is not hostage to a single chemistry or a single supply chain."

For Sunanda, the field of fungal pigments is about more than applicability. It is, at its heart, an act of rediscovery. "We are still learning from the natural world, and also our foremothers and forefathers. People have been doing textile dyeing for an extremely long time. So, in some sense, we're rediscovering and relearning what's there. It's a nice lesson in humility, that even though we may have newer methods, there's a heritage that we're building on and it's worth figuring out."

(Edited by Abinaya Kalyanasundaram)

Photo courtesy: Marilyn Chung/Berkeley Lab

Aindrila Mukopadhyay holding a vial of purified indigoidine powder

The DIY Scientist

- Mihir Prakash Kapse

Photo: Pavan Kaushik

Creating under constraint

An apple fly tethered to a VR-like setup made by Pavan to study stimulus responses in insects

When Umesh Varshney joined IISc as an Assistant Professor, he was excited to dive straight into microbiology research. It was 1991, and he had just returned from his postdoctoral stint at MIT in Cambridge. He planned to study protein synthesis in *Escherichia coli* and DNA repair in mycobacteria, among other exciting topics.

But it wasn't going to be an easy road. "My first grant from the Department of Science and Technology was for Rs 6 lakh, to be used over three years," recalls Umesh, now Honorary Professor at the Department of Microbiology and Cell Biology, IISc. He had to set up his entire lab, admit PhD students, conduct research and publish papers, all with this meagre amount.

He first purchased a computer, an Intel 286 with 4 MB RAM and 40 MB storage on a hard disk. He then had to order various products and equipment, such as reagents and enzymes, from abroad, which took months to arrive and cost almost twice what they had cost when he was in the USA. "You had to keep track of prices in the USA and then negotiate with them," he recalls.

He had to come up with better ideas that would save time and money, and produce good results.

One day, while reading the newspaper, he noticed how pen ink spread on the paper, just like it would on blotting paper. A strange idea struck him – why not actually use newspapers as blotting paper? Southern blotting – his lab's go-to technique for identifying specific DNA sequences – consumed large quantities of the stuff.

He began thinking of similar hacks. Instead of buying enzymes, his lab began purifying enzymes from specific bacterial strains, which also proved to be of higher quality. He cut and used plastic combs of different sizes to create a varied number of wells in gels for gel electrophoresis. Instead of plasticware, he used glassware, which is reusable and recyclable, and stored them in chromic acid to sterilise them.

These were all trial and error; some worked, some didn't. For example, the teeth of the comb were sometimes uneven, so he had to throw them away. But, at that time, these kinds of do-it-yourself (DIY) tricks were crucial.

"In retrospect, these were small ideas, but at the time, you needed those ... if we wouldn't do any of these, we would not publish, and if we would not publish, we would not advance," says Umesh.

Resourceful improvisation is not unfamiliar to scientists. As Ernest Rutherford, a pioneering physicist known as "the father of nuclear physics", once told his students: "We haven't got the money, so we've got to think." Rutherford believed in simplicity and hated both raising money and spending it. When he couldn't create a vacuum-tight apparatus for his famous scattering experiment (which led to the discovery of the new atomic model at that time), he had to rely on sealing the gaps using wax, the same viscous substance used to close envelopes at that time. It was not glamorous, but it worked.

But limited funds are just one impetus. Sometimes, the world stops for a pandemic, disrupting the procurement of tools. Or there's a delay in an order, and scientists have to build something out of what they have at their disposal. And sometimes, it is the need to have something so specialised that it is not available in the market. This was the case for Ambarish Ghosh, Professor at the Centre for Nano Science and Engineering (CeNSE), IISc.

Built to specification

Ambarish started with a simple, curious idea. He wanted to understand and design the motion of small objects in fluids. As it progressed, he and his team realised that this fundamental research had applications in multiple domains, including medicine.

His lab designed and developed nanorobots. Like *Doraemon*, these do not make decisions on their own, but can still show signs of intelligence. These were very small coil-shaped structures. Their motion can be controlled in all directions using a time-varying magnetic field. Ambarish wanted to test them inside living systems.

To keep cancer cells alive under a microscope for long periods, they must be maintained at a specific temperature, around 37°C. However, all commercially available setups were made of metals, which, when placed in time-varying magnetic fields, would heat up, killing the cells.

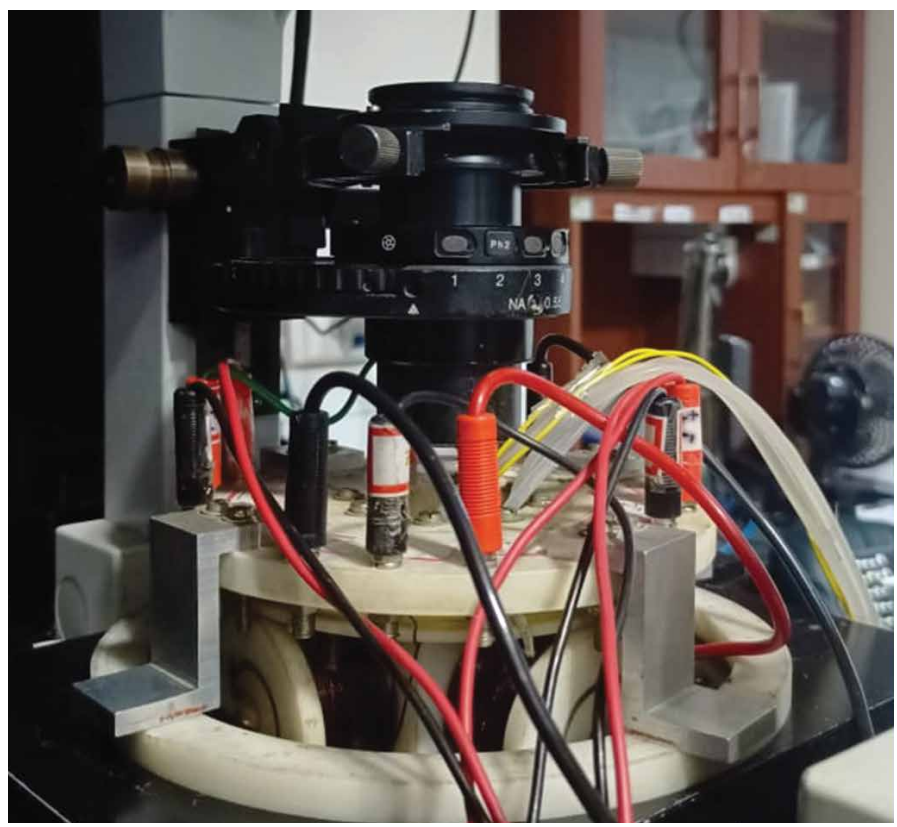


Photo: Ekalvy Vashist

Side view of a microscope with the magnetic coil system and live cell set-up at the centre

Another problem was accommodating a temperature- and pH-sensitive system within the magnetic fields, which were generated using Helmholtz coils – two parallel flat circular coils separated by a distance equal to the circle's radius. Both carry current in the same direction, producing a uniform magnetic field at the centre. To generate magnetic fields in all directions, they had to use a triaxial Helmholtz, with three perpendicular pairs of coils.

These issues pushed them to build their own live-cell imaging system, a miniature non-metallic chamber, using derlin – a highly durable plastic; a chamber which could fit inside the uniform space of a triaxial Helmholtz.

Paramita Modak, a PhD student in Ambarish's lab, built the first setup. Using a feedback loop, the system maintained a temperature of 37°C with a 1° tolerance. Later, wanting more precise temperature control to carry out their experiments, Benexy Correya, another student in the lab, designed a second model with a tolerance of 0.1°C by introducing slow cooling and heating with better thermal insulation.

With their new improvised setup, cells stayed alive under continuous exposure to magnetic fields for more than 36 hours. Ambarish's lab is now tackling various fundamental and real-life problems, including dental hypersensitivity, intracellular properties, and more.

"We do this all the time in our lab. I encourage my students to make their own equipment," says Ambarish. "The advantage is that once you build it, only you can do that now and answer questions that no one else has. The disadvantages are that it makes the research work harder and more time-consuming."

Frugal by design

For PhD student Anil Yadav, who sits a few rooms away from Ambarish's lab, harder work and longer times were no deterrent.

When Anil joined IISc to pursue his PhD in 2021, he wanted to test the change in electrical properties of semiconducting polymers after infiltrating them with inorganic materials using gaseous molecules. His PI, Aditya Sandhala,

Photo: Mihir Prakash Kapse

Anil Yadav, with the ALD tool they built at CeNSE

Assistant Professor at CeNSE, suggested that they build their own infiltration system, as none were available commercially at the time.

Later, given the identical deposition mechanism, the idea was expanded to build a full atomic layer deposition (ALD) tool that is capable of operating in multiple modes.

After three years of trial and error, they managed to build an ALD that can operate at much lower temperatures, around 50°C

An ALD machine allows you to deposit highly uniform and fine layers of atoms over one another, even over not-so-perfect flat surfaces.

Commercial ALDs operate at high temperatures, ranging from 150-400°C and require specialised precursor substances – the raw chemicals introduced into the machine as gases that react with the surface to deposit one atomic layer at a time. These precursors are highly specific to the material being deposited and have to be purchased from outside India. "The delivery time is around six months, and the transportation cost is almost double or triple that of the precursors. It also takes around Rs 6-7 lakh just to buy one precursor … [and] the shelf life is also not that long," says Anil.

So, Anil, in collaboration with three other researchers, started to build their own ALD in March 2022, alongside regular lab work. It was a challenging process. One of the main concerns was potential

leaks – the precursors used are pyrophoric (they ignite instantly in air). "Making it completely leak-proof was a big task," says Anil. Helium-leakage test kits were available but expensive, so Anil found other ways to test for leaks, such as using acetone, an easily available and comparatively inexpensive solvent.

After three years of trial and error, they managed to build an ALD that can operate at much lower temperatures, around 50°C, and can use solution precursors readily available in India, such as diethylzinc and trimethylaluminium in organic solvents for zinc oxide and aluminium oxide thin film depositions. It also allows one to control the precursor exposure time, enabling highly customised experiments.

Even more remarkably, their ALD tool costs under Rs 20 lakh; commercial ALDs can easily go up to Rs 5-6 crore.

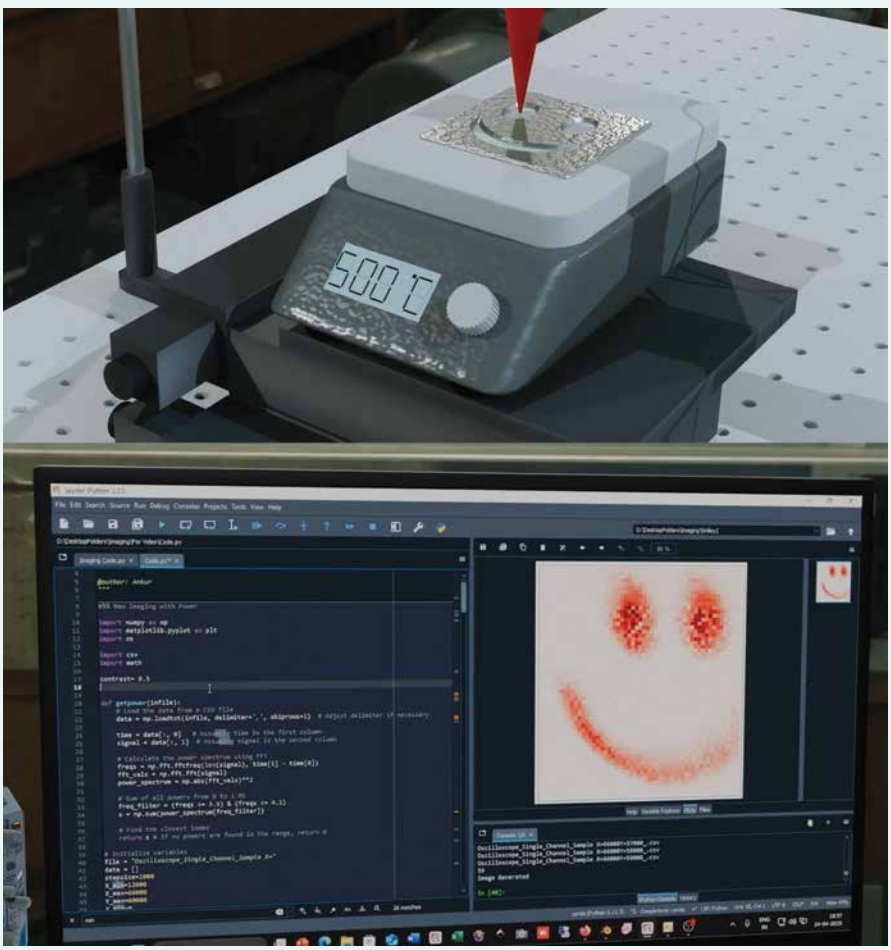
"There were many things that were still expensive. We cannot make the [vacuum] pump, and that alone costs around Rs 8-10 lakh," shares Anil.

The ALD system now sits in Aditya's lab. It still requires some fine-tuning to perform on par with the commercial one; nonetheless, the tool is able to perform operations at a rudimentary level. After successfully obtaining the patent for the ALD setup, Anil is now drafting a second patent for the infiltration.

A variable process

For some, making their own equipment was more straightforward. Biman Jana, an ex-PhD student in the lab of Anshu Pandey, Professor at the Solid State and Structural Chemistry Unit (SSCU), built an infrared photodiode material that could operate at room temperature. Such diodes can be used for highly sensitive gas sensing and for long-range search-and-rescue drones. Someone was needed to test the material's efficiency and functionality. The task fell to Ankur Bhaumik, a former BS-MS graduate student.

Photo: Ankur Bhaumik



Top: Infrared Radiation (IR) generated via a heating plate passing through non-covered regions and focused onto the detector using a parabolic mirror. Bottom: The images were then reconstructed by stacking pictures, demonstrating the photodiode's ability to capture IR

The core problem with infrared photodetectors is thermal noise. "When you use the device, you have to cool it down to a very low temperature so that you can reduce the thermal noise," says Ankur. The new IR photodiode sidestepped this issue. But it had to be tested first.

The COVID-19 pandemic had recently ended. The world was just going back to normal. Ankur had to work with what was available in the lab to come up with a proof-of-concept for the photodiode.

"People have done this in other labs ... they often use lenses. We didn't have lenses, so the idea was to do it with mirrors," he explains.

He used a heating plate capable of reaching 500°C as the source of infrared radiation (IR). He then covered the plate with different cutouts of aluminium foil to block IR at specific locations. Using two parabolic mirrors, he focused the IR onto the photodiode, which was connected to a sensor and a monitor to capture the readings. By motorising the plate, he captured one pixel at a time and later used a program he built to reconstruct the image.

He successfully reconstructed images, demonstrating the photodiode's ability to capture IR. This provided a proof-of-concept for an IR photodiode that could operate at low temperatures.

Obtaining the necessary drivers for the motorised platform to control its precise motion and the optical alignment of the setup was tricky. "The drivers were not readily available," says Ankur. He spent over a month in back-and-forth email exchanges with the equipment manufacturer before finally receiving the software needed to control the platform's precise motion.

They also wanted to prove that the IR photodiode was sensitive enough to detect even weak IR signals. But weak signals are easily drowned out by noise. To clearly capture them, Ankur added an oscillating chopper, an amplifier, and noise filters to the setup. It worked.

"It was a fun thing to do," says Ankur.

Virtual worlds

Like Ankur, Pavan Kaushik found a lot of fun in the DIY process. A few years ago, while doing his PhD at the National Centre for Biological Sciences (NCBS), he wanted

to study the motion of *Diptera* (flies) in large environments and their responses to stimuli such as odour plumes and air flow, using a VR setup. But creating a true VR setup was not possible with the funding he had. So, he took inspiration from his lifelong hobby – video gaming. "The only thing I knew was video games. So, I built one for insects," says Pavan.

He learned coding from scratch and developed his own software. He then purchased three high-refresh-rate displays and built a cubicle to create a 360-degree virtual environment that provided visual stimuli for the flies.

Each fly was fixed in place by glueing it on its back to a thin rod inside the cubicle, but its wings were left free to move. A camera was placed on top to capture the motion of these insects' wings.

When the displays were turned on, showing photorealistic scenes of a vast open landscape – trees, grass, and sky rendered across a virtual world stretching over a kilometre in each direction – the flies would flap their wings in place. Based on the flapping motion, Pavan trained a model to determine whether the fly wants to turn left, right, or just fly straight.

In effect, the flies' wings served as their joystick to navigate the virtual environment. The camera captures how hard the insect flaps its right versus its left wing. This data was fed to the model to allow the insect to control their motion. As the virtual environment around them changed, they responded by adjusting their flight direction.

In effect, the flies' wings served as their joystick to navigate the virtual environment

Later, Pavan inserted capillaries into the setup to introduce air flow and odour. This allowed him to test various hypotheses about the flies' navigation in response to different odours and airflow rates.

Using this setup, he was able to propose a few theories. When presented with two virtual trees – one large and far away, and one small and close by – even though both appeared the same from the flies' starting position, the flies always chose the smaller one. This showed that the flies were using motion parallax – the phenomenon in which nearby objects appear to move faster than distant ones – to judge distance and make navigational decisions, much like humans do. Pavan also observed that the flies didn't effectively react to the odour plume trail without a directional wind flow.

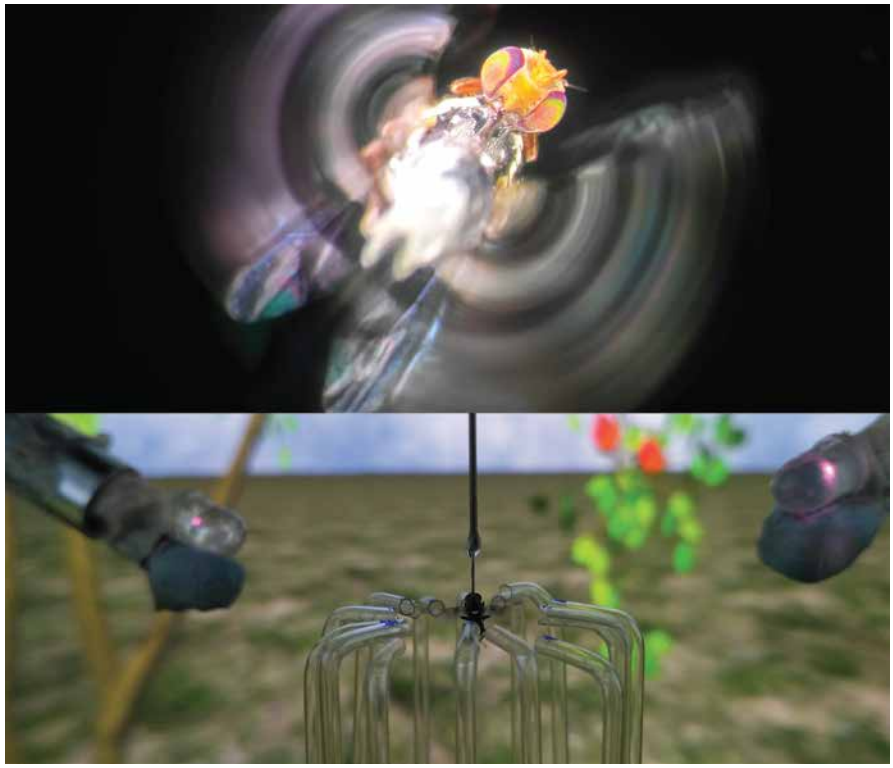


Photo: Pavan Kaushik

Top: An apple fly flapping its wings in the setup. Bottom: Glass capillaries around a fly providing 360-degree airflow and odours

While his research focused on the apple fly, his team also successfully tested the VR system on a variety of species, including moths, lice, and mosquitoes. His paper was published in *the Proceedings of the National Academy of Sciences (PNAS)* in 2020.

"Making an insect play video games by giving out realistic vision, airflow, and odour still feels unreal to this day," shares Pavan.

A culture of 'jugaad'?

It is no surprise that India's affinity for 'jugaad' has infiltrated research too. Science has always been about negotiation – between ambitious questions and modest tools. Researchers have navigated this gap for ages with clever improvisation. Now, they are going much further, building entire equipment on their own.

As Ambarish points out, modern problems are very complex. They require much more planning and precision. "I would not call it jugaad," says Ambarish. According to him, this is quite the opposite. Jugaad is much more preliminary; for research, he says, you need expertise and the right planning.

"Very often, the natural tendency is to buy some equipment. For certain times, that works ... but there are no custom-made tools, so you have to set up your own experiments," he adds.

And that's how research happens. You start with a small idea, make several tweaks in the process, which could lead to a mistake or – if you're lucky – to good, optimal results. There might be situations where you don't know if the solution to your problem will even work. Then it becomes a question of belief in your instinct and abilities, and whether you can find a way to learn and have fun through it all. "It was exhilarating building things, not knowing if it could even work," says Pavan. "It began as an attempt to replicate an existing system; it quickly went off-road and became its own thing, unlike anything before it."

Mihir Prakash Kapse is a second-year Bachelor of Science (Research) student at IISc

(Edited by Abinaya Kalyanasundaram)

Journey of an Experiment

- Amrapali Datta

Photo: Amrapali Datta

On research, failure, and learning to work with the mess

Cancer cells grown as a flat monolayer culture under the microscope

The experiment, at least on paper, was simple: watch what happens to the physical forces between cells as a healthy tissue starts becoming cancerous. Push, pull, tension mapped onto something as messy as a living tissue.

I remember feeling all tingly when I came up with this idea a couple of years ago, while finalising my PhD research topic – the excitement of stepping outside the usual route that cancer was investigated. Most cancer research I had seen so far was at the level of genes, molecules, and signalling pathways. But here, the question felt tangible. I could actually watch cells pushing against each other, holding shape, and reorganising as cancer takes over in a healthy tissue.

And the way I planned to study it made it feel even more real. Instead of growing cells as a flat layer in a flask or dish, I would grow them in a gel that allowed them to organise in all three dimensions as in an actual breast tissue. I was drawn to breast epithelial systems because of their organised architecture, neat layers, and clear boundaries that made the tissue appear almost geometric under a microscope. Over days, the cells

assembled themselves into small, spherical structures called acini, resembling the tiny milk ducts where most breast cancers are known to begin.

If the experiments worked, I would be watching the earliest moments of cancer taking shape and maybe even publish a groundbreaking paper. But a few months into the project, things started falling apart.

I was in the lab one evening, staring at the screen for so long that the fluorescent green cell outlines blurred into each other. The acini were supposed to have formed neat, hollow spheres with a single organised shell of cells wrapped cleanly around an empty centre. Instead, the images looked cloudy and indistinct, flooded with green haze and fuzzy light yet again! I kept adjusting the microscope's focus, hoping the blur would suddenly resolve into something meaningful. But ... nothing.

The lab was unusually quiet that evening. The hum of the incubator, the faint whirr of a centrifuge in the background, the harsh white light reflecting off stainless steel surfaces. Everything around me felt steady, working exactly as it should.

Except this.

I sat there for a while longer, willing the image to make sense. But I could not ignore the heavy sense of dread creeping into my stomach.

Had I just spent the last six months building an experiment that simply wasn't going to work?

Nothing looks the way it should

Doing a PhD was never part of my career plan. After my Master's in biotechnology from St Xavier's College in Kolkata, I had imagined a more straightforward path for myself in industrial R&D – something structured and predictable, with clearer timelines and outcomes. But when my father was diagnosed with cancer, I found myself becoming increasingly drawn to questions around the disease. My interest eventually took shape through understanding how cells physically interact and reorganise as healthy tissue begins to turn cancerous.

Eventually, I joined the Department of Bioengineering at IISc for my PhD, and when my thesis idea of working on the mechanical aspects of cancer was finalised, I was thrilled.

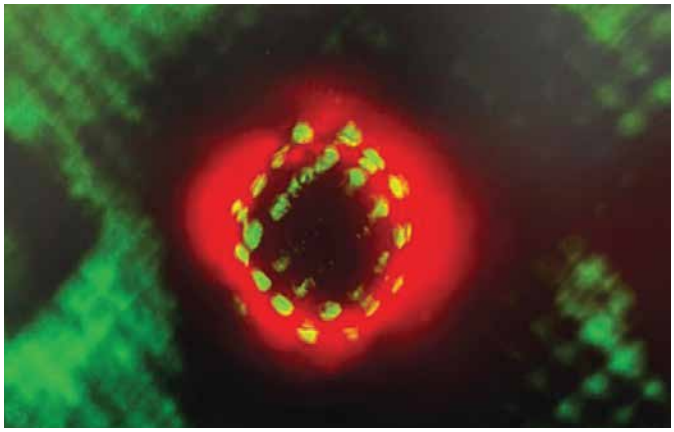


Image: Amrapali Datta

Early attempts to visualise the acini appeared blurred, with the brightfield (red) and green fluorescent signals appearing mostly as background noise

That is, until I hit that snag a few months in, and I suddenly had to rethink my entire strategy.

What made it worse was the timing. My comprehensive exam was approaching, and I still had no concrete data to show. For months, I had been building and imaging the acini system, but I still had not figured out how to see the structures clearly enough to extract anything meaningful. Every week that passed made me feel more behind. The project that had once felt exciting now felt unstable. My entire PhD was now resting on an experimental system I still could not properly access.

Maybe I didn't need a three-dimensional model after all, I started telling myself. If there are forces acting within tissues, they would also exist in simpler cellular systems, right?

So, I took a step back. Moving to the monolayer felt, at first, like stepping away from the biology. The three-dimensional system had always felt closer to the real thing. A monolayer was different. The cells spread themselves flat across the bottom of a dish, more like a thin sheet than the native architecture of biological tissues. It was simpler to image, easier to manipulate, but also further away from the complexity of a real organ. And somewhere in my head, I had started equating complexity with importance.

I spoke to my PI about this, half expecting resistance, but she approached it far more pragmatically than I did and told me that if this was the system that could give us something measurable and reproducible, then it was worth following. That clarity felt reassuring. While a part of me felt like I was conceding, I was also relieved.

The pivot itself took a few weeks. I had to abandon many of the routines I had spent months optimising for the acini experiments and return to much simpler setups. Different dishes, different imaging conditions, different ways of preparing the cells. Not to mention the added stress I felt – for the next several weeks, my days became less about chasing the original idea and more about rebuilding the experiment from scratch. But slowly, as the first usable images started coming in, curiosity began replacing that discomfort.

I grew two populations of cells together in the same dish – one healthy and one carrying cancer-associated mutations which were dyed fluorescent green. Over time, the two populations expanded until they met and formed a boundary. During the acini experiments, I would often spend hours adjusting the focus through thick layers of tissue, fighting blur and fluorescent haze just to see what was happening. In the monolayer system, the cells sat exposed in a single plane, their interactions unfolding directly under the microscope. The cell boundaries were sharper. Movement was easier to follow.

The first images from the monolayer didn't look remarkable. The cells were arranged in familiar patterns, interfaces forming where the different populations met. However, I quickly found myself lingering at these interfaces between the healthy and cancerous cell populations.

Something strange was happening.

The cell boundaries weren't fixed but were moving, changing, almost as though they were being negotiated.

I breathed a small sigh of relief. Something more dynamic than I had expected was happening. I zoomed in and followed the same regions again, frame by frame.

As excited as I was, it took me a while to trust the validity of my observations. Was it noise? It often is. Random fluctuations in the imaging, small inconsistencies from one experiment to another, things that look like patterns until they disappear on repetition.

But the movements didn't go away. Across different fields of view, across repeat experiments, the same behaviour emerged. The boundary wasn't passive, it held shape in some places, gave way in others, and reorganised itself.

This was not the assumption I had started with. I had thought that the cancerous cells would simply grow faster and overtake the healthy cells because of their mutations or growth advantages. I wasn't expecting the interface itself to behave dynamically or mechanically, almost like a physical boundary under tension.

Instead of cancer cells simply overpowering healthy cells because they grew faster, the boundary between the two behaved like an active mechanical interface that influenced whether the cancer cells advanced or were restrained.

The system, in its simpler form, was revealing something.

Finding a new avenue

Something acting at the boundary between healthy and mutated cells played a role in how the cancerous cells behaved. I started with this initial hypothesis and began to test it more deliberately.

I tried to break down the boundary between the two populations – healthy cells and cancerous cells – and watched how the cells reorganised afterwards. Sometimes, the cancerous cells would begin pushing forward collectively, slowly displacing the healthy cells. At other times, the boundary would hold its shape more rigidly, resisting that movement altogether. In some regions, the interface straightened tightly, while in others it loosened and buckled slightly before settling again.

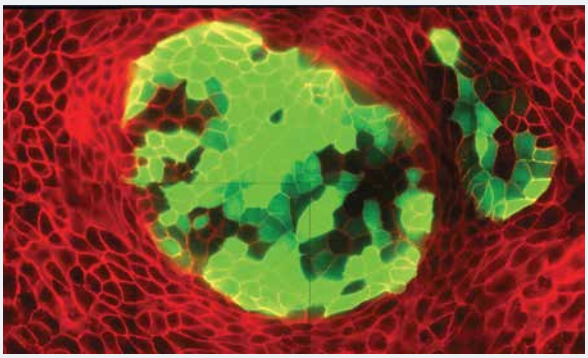


Image: Amrapali Datta

The boundary between healthy (red) and mutant cells (green) was behaving like an active, mechanical interface determining the dynamics of cancer initiation in breast tissue

I kept going back, almost expecting them to disappear if I looked closely enough. A different batch of cells, a slightly altered condition, a repeat on another day. Weirdly, each time, a small part of me hoped it would disappear – so I could go back to the original plan, to something that met my initial expectations.

But they didn't go away. The cells seemed to behave according to some underlying physical rule.

I didn't have the language for it at first.

Only later, after many more late evenings spent staring at the same regions of the same images, could I begin to describe it.

It was not just movement or rearrangement. It was tension.

Interfacial tension, to be more specific. The forces acting at the boundary between healthy and cancerous cells weren't just shaping how the interface looked; they seemed to determine what happened next – whether the cancerous cells pushed forward and colonised the tissue, or whether the normal cells held their ground.

And all of it was happening right in front of my eyes on the computer screen.

While the idea of physical forces in tissues is not new, what I was seeing suggested something more urgent – that even at the earliest stages, the interaction between healthy and cancerous cells could be shaped by simple physical forces at their boundary.

Once I saw it that way, everything else began to align. It was strangely satisfying to observe something so interesting emerge organically from a system I had initially dismissed as too simple.

The experiment hadn't worked the way I wanted it to. But it had worked. By approaching the original question from another direction, it revealed something more fundamental that might have remained hidden in a more complex system.

What had felt like limitations at the beginning – the inability to perturb the tissue and the lack of resolution – had shaped the discovery itself.

Ironically, around the same time, the original acini system, which I hadn't (rather couldn't) fully abandon, had also started behaving better. I had been trying to improve the imaging pipeline, and the three-dimensional cultures eventually became far more reproducible. But by then, the monolayer experiments had already opened up an unexpected avenue that I could not stop chasing. The results felt too interesting to abandon midway, so I decided to follow that story first.

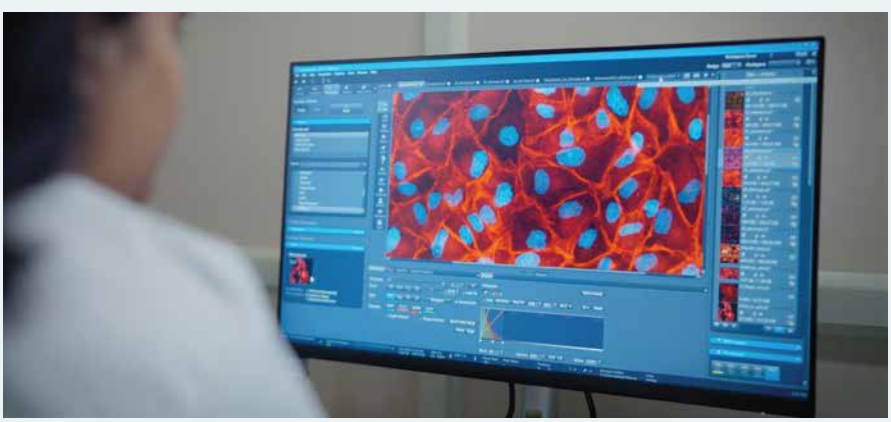


Photo courtesy: Amrapali Datta

Unlike the blurred acini images, the monolayer system produced clear cytoskeletal signals (red), making the organisation of the cells immediately visible

Making sense of what I found

When I finally had a complete set of meaningful results, I showed them to my PI. She went through them quietly and said something along the lines of, "There's something interesting happening here. We should follow it carefully." That was all. Which meant that it would still be a while before any of this could be woven into something I could call a concrete discovery.

The next few months were ... different.

There was a different kind of urgency now. Instead of trying to make something happen, I was now desperately trying to understand what was happening. I made small variations while repeating the same experiments, used careful controls, and spent long hours on analysis that didn't feel as frustrating as before.

Finally, I laid out all the data I had collected in order. I loosely placed the images next to each other. Microscope snapshots of two groups of cells meeting their boundaries shifting over time. I drew arrows along the interfaces, tracing where one population pushed into the other, where the boundary straightened, where it buckled.

Notes scribbled in the margins: repeat? noise? pattern? A story was forming, not in words yet, but in images.

Figures were revised repeatedly, often during quick discussions with lab mates or long evenings with my PI pointing out inconsistencies I had missed.

The next challenge was writing all of this down into a paper. This phase demanded a clarity that the experimental process never had. The messy progression, the failed attempts, the shifts in direction, the long stretches of uncertainty, all had to be distilled into something that looked intentional.

I found myself thinking more about why I had started this research in the first place. When my father was going through his own experience with cancer, it was an immediate and lived experience. Appointments, treatments, small routines built around managing something that didn't have the neat outlines of a research question.

I had entered the PhD assuming that enough effort and persistence would eventually lead to something concrete – something directly connected to helping patients.

This was different.

What I had found was more fundamental. A way of thinking about how cancer cells organise and interact with healthy cells. But it wasn't a solution. Was it enough?

For a while, I was caught between the satisfaction of finally having something that worked and the uncertainty of what it meant beyond the experiment itself.

Over the next few months, that tension softened over mundane moments – while explaining the results to lab mates, while sitting with the same set of images for hours, zooming in and out. Even while walking back from the lab after a long day, I kept replaying the same images in my head.

The big picture

The paper itself took shape slowly through months of writing and rewriting, revisions and addressing comments from publication reviewers who weren't always convinced.

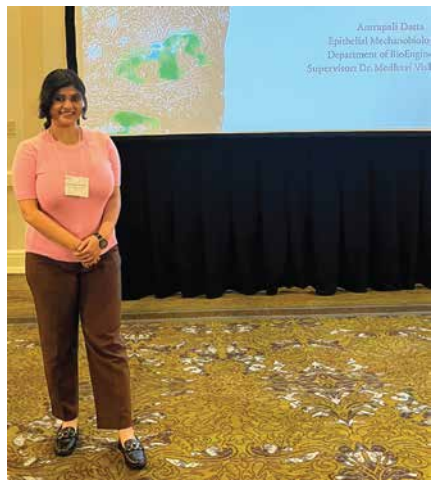


Photo courtesy: Amrapali Datta

Presenting the final paper at the Gordon Research Conference on Physical Science of Cancer, held in Los Angeles in 2025

Eventually, after three whole months of back-and-forth with the reviewers, revisions, more experiments to answer unanticipated questions, and countless moments of fear and doubt, my paper was accepted. After two and a half years. I was alone when I got the email. I kept rereading the first line to be sure I hadn't misread it.

For most of its life, the experiment was uncertain. It resisted, stalled, shifted direction without warning. It asked for patience in ways I hadn't anticipated and gave answers only when I was willing to change my approach.

The version that exists now, the one that fits into a paper, that can be explained in a few figures and a few paragraphs, is only the final form. But the life of the experiment – its hesitations, its refusals, the way it changed shape under constraint – remains mostly hidden. Yet, that is where most of the work really happened.

Looking back now, I think my most important accomplishment was not the paper or a result but being able to sit with uncertainty long enough to eventually figure something out.

Now, after publishing the monolayer work, I find myself returning to the acini system again for the next phase of my PhD, only this time with a much clearer idea of what I am looking for.

Amrapali Datta is a fifth year PhD student at the Department of Bioengineering, IISc, and a science writing intern at the Office of Communications

(Edited by Abinaya Kalyanasundaram)

Photo courtesy: Amrapali Datta

Much of science happens over messy discussions with colleagues over half-formed ideas, and debates that slowly sharpen into clarity

Mission Spin-possible

- Shreya Vashista

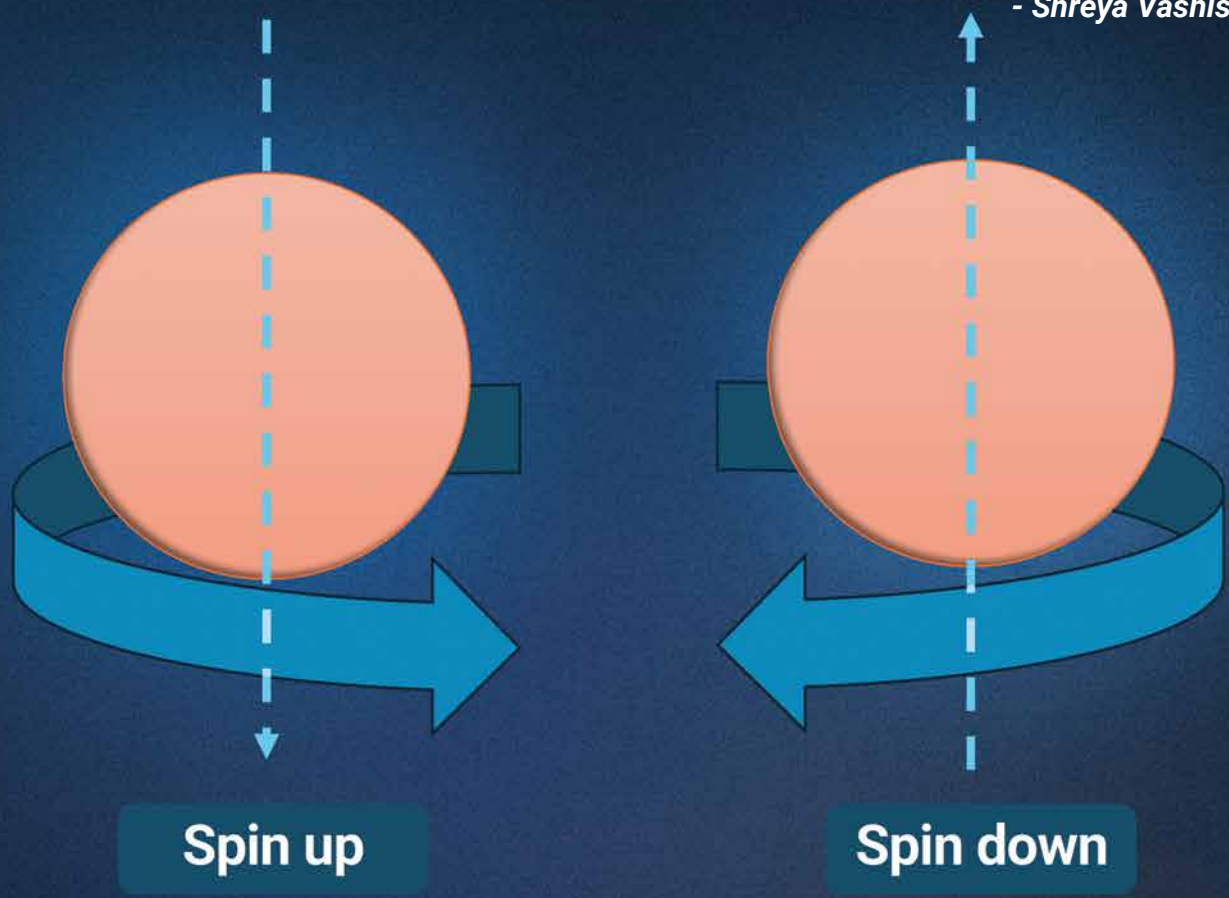


Image: Shreya Vashista

How electron spins can boost computing

Two distinct electron orientations of spin-up and spin-down create tiny magnets with opposite directions that act as binary information units, analogous to 0s and 1s in conventional computing

You wake up late. Your assignment is due in two minutes. You grab your laptop with a standard 8 or 16 GB RAM, a 512 solid state drive (SSD) that is "supposed" to be fast, a decent processor that usually gets the job done. You press the power button. The screen lights up … slowly. The system begins its familiar ritual – boot sequence, background processes, apps waking up one by one. The fan starts spinning, a faint whir growing louder. You're staring at the loading screen, watching seconds slip away. By the time your desktop appears, you rush to open your document. The cursor lags for a moment. The file loads. You hit "Send."

Alas! Deadline missed.

Somewhere in the background, billions of electrons have rushed through circuits, colliding, dissipating energy as heat, doing their job, but inefficiently, noisily, wastefully.

Now imagine a laptop with no heat buildup and no energy wasted moving charge back and forth. Just quiet, near-instant computation. One day,

this might be possible – using spintronics.

Spintronics (spin+electronics) is a field that exploits the electron's spin, in addition to its charge, to process and store information. The electron is not a "spinning" ball, rather spin is an intrinsic quantum property that makes electrons behave like tiny magnets.

If you measure how an electron responds to a magnetic field, you will find that the electron exists in one of two orientations – aligned in the same direction as the field (up) or aligned against it (down). "Up" and "down" are two possible states of an electron's tiny built-in magnet, like north or south in a compass. These states can represent binary information, much like the 0s and 1s used in computers. Spintronics uses this binary information to enable new ways of computing, allowing devices to be faster, energy-efficient, and non-volatile (retaining charge even when power is turned off) compared to conventional electronics.

In everyday materials, the electron spins point in random directions, cancelling each other out. But in ferromagnetic materials used in spintronics devices, like iron, cobalt, or nickel, many of these electrons naturally align in the same direction – some of them can be "spin up" and some can be "spin down". This creates a flow of electrons that carries both charge and spin information.

Spintronics has already made its way into some of the technology we use every day. Our phone's digital compass relies on a magnetometer built on spintronic principles. Wheel speed detection in anti-lock braking systems (ABS), which play a critical role in vehicle safety, uses spintronic sensors.

Now, as conventional computing grapples with a growing energy crisis where faster processors demand more power, generate more heat, and rely on increasingly inefficient memory systems, scientists are increasingly turning to spintronics. Having seen it evolve from a strange quantum mystery to a Nobel-winning breakthrough, many now believe spintronics could reshape the future of computing itself.

From bad cigars to iPods

The story of spintronics began with a simple question – does the electron have more to it than just charge? In an experiment in the early 1920s, German physicists Otto Stern and Walther Gerlach passed a beam of silver atoms through a non-uniform magnetic field. The beam split into two distinct paths, defying classical expectations and hinting at quantised behaviour. The splitting deposited tiny amounts of silver onto a detection plate but they were invisible. In a twist of serendipity, Stern's cigar smoke helped reveal the result.

"My salary was too low to afford good cigars, so I smoked bad cigars. These had a lot of sulphur in them, so my breath on the plate turned the silver into silver sulphide, which is jet black, and so easily visible," Stern is quoted as saying, as recounted by Dudley R Herschbach in his Nobel lecture on molecular dynamics of elementary chemical reactions. Stern described it as being 'like developing a photographic film.'

The result was so striking that Gerlach immediately wrote to Danish physicist Niels Bohr, suggesting that it supported emerging quantum theory, though no one could yet explain why only two beams appeared. As physicists debated explanations, Austrian-Swiss theoretical physicist Wolfgang Pauli introduced his exclusion principle, the idea that no two electrons in an atom can occupy the exact same quantum state. He proposed that electrons must possess an additional unknown quantum property. In 1925, Dutch-American physicists George Uhlenbeck and Samuel Goudsmit finally solved this mystery, proposing that this unknown feature of an electron could be its "spin" – an intrinsic form of angular momentum that gives rise to two allowed orientations in a magnetic field (corresponding to the two beams).

At the time of its discovery, the idea of a "spinning" electron left even Pauli's head spinning as it seemed to make little physical sense, yet the concept held firm and became a cornerstone of quantum mechanics. A major turning point came in 1988, when Albert Fert and Peter Grünberg discovered giant magnetoresistance (GMR), for which they won the Nobel Prize in Physics in 2007. They showed that the relative alignment of electron spins can dramatically affect the electrical resistance of a material. This meant that an electrons' spins could directly control electric currents and electronic signals, which transformed spin from a theoretical curiosity into a practical

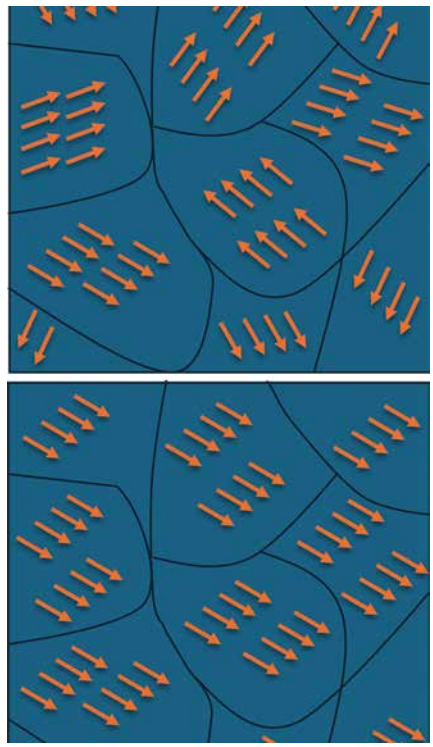


Image: Shreya Vashista

Top: Electron spins in different domains of materials are randomly oriented which cancel out each other resulting in no net magnetism, but in ferromagnetic materials. Bottom: Electron spins align in the same direction, producing a strong overall magnetic property

tool for technology. Building on this, the term "spintronics" was coined in the late 1990s by researchers at IBM, particularly Stuart Parkin.

The GMR effect enabled a 100–1000 times increase in storage per inch of hard disk drives, driving the miniaturisation of modern data storage technologies. "You would not have an iPod without this effect," Borje Johansson, member of Royal Swedish Academy of Sciences (RSAS) said to *The Guardian* in October that same year.

"GMR is the one of the fastest discoveries to transition to the market," says PS Anil Kumar, Professor in the Department of Physics, IISc, who set up one of India's earliest spintronics labs at the Institute.

Laying the foundations

Spintronics is built on three core ideas: how materials create and align electron spins (magnetism), how those spins move through materials (spin transport), and how they can be controlled using electric fields (spin-orbit effects).

Some of the theoretical groundwork for these ideas were being explored as early as the 1970s in IISc. KP Sinha and his

young collaborator Narendra Kumar, who joined the Institute around 1972 at the invitation of the then Director Satish Dhawan, helped build a strong foundation in magnetism and electronic transport. Around the same time, a young PhD fellow at the Department of Applied Mathematics, G Baskaran, was drawn into physics after attending Kumar's lectures. Baskaran joined Sinha and Narendra, in their exploration of how magnetic excitations, known as magnons, interact with collective electronic behaviour in materials.

Published in the journal *Pramana* of the Indian Academy of Sciences in 1973 and reviewed by Hannes Alfvén, 1970 Nobel laureate in physics, their study on magnons interacting with electrons (titled 'Plasmon Magnon Interactions in Magnetic Semiconductors') was initially seen as a negative result because the interactions were very weak. "Since I found the interaction to be weak, I used to tell my friends jokingly that I'm working on weak interactions," says Baskaran (a pun on the weak nuclear force, one of nature's four fundamental forces studied in particle physics). But four decades later, with advances in 2D materials and experimental techniques, such theoretical formulations gained recognition. "Unfortunately, Sinha is not around to enjoy that," Baskaran adds.

Kumar and Sinha helped lay the groundwork for faculty member TV Ramakrishnan, who joined IISc in 1986. He played a key role in shaping the Department of Physics, with influential contributions to the understanding of electron localisation in disordered systems, which are materials in which impurities, defects, or randomly arranged atoms disrupt the regular crystal structure and alter how electrons move. By understanding how disorder affects spin orientation, researchers can design better materials for spintronics devices.

Advances in materials science have been equally critical. CNR Rao, former Director of IISc, explored transition metal oxides and magnetic materials, significantly expanding the range of systems in which spin-dependent phenomena could be explored.

Together, these early studies in magnetism, electronic transport, and materials science created the scientific foundation on which modern spintronic devices are being built today.

Building an ecosystem

In 1999, Anil Kumar, then a postdoctoral fellow at University of Twente, Netherlands, started building a spin valve transistor device, which controls electric current using the "spin" of electrons, allowing signals to be switched on or off based on magnetic alignment. This was his first encounter with spintronics. "At that time, this area was called magneto-electronics," he recalls.

By the late 1990s, researchers could see how electrons move inside materials, but they struggled to measure how their spin changes with their motion. Methods to detect spins were inefficient.

During his second postdoctoral work at the Max-Planck Institute of Micro-structural Physics in Germany, Anil and his colleagues built a novel electron energy-loss spectrometer to measure how an electron changes the direction of its spin from "up" to "down" or vice versa after interacting with a material and exchanging a small amount of energy.

Anil was awarded the Max-Planck India Fellowship in 2004, which was instrumental in setting up his lab in the Department of Physics at IISc. Anil shipped the spectrometer he built in Germany down here and got it re-assembled. This practice continues till now – his lab has built several customised experimental setups to track spin orientations in materials and to fabricate ultra-thin magnetic films for experiments. His lab focuses on understanding how spin currents interact with magnetic materials, bridging a fundamental understanding of electron spin behaviour with work in device fabrication and emerging applications.

Walking into the lab, one is immediately struck by the sight of these ultra-high vacuum chambers wrapped in aluminium foil. These chambers are used to fabricate and characterise spintronic materials under extremely clean conditions. Aditya Wagh, a postdoc in the lab, explains that these chambers need to be "baked" at high temperatures to remove trapped gases, which leads to excessive heat loss. Wrapping them in aluminium foil helps reduce this loss, making the heating process more efficient.

"A good example is chocolates. You've seen that thin foil wrapping, right? Chocolates are made so that they melt

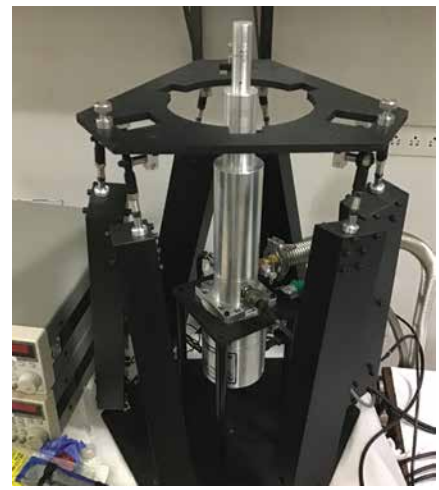


Photo: Aditya Wagh

In-house built Stewart platform that mounts spintronic devices inside a closed-cycle helium refrigerator, enabling experiments at temperatures as low as 10 Kelvin at the Spintronics and Thin Film Magnetism Lab, IISc

when you eat them and not outside during transport," explains Aditya. He has also contributed to the lab's practice of building instruments in-house by designing a custom Stewart platform that mounts spintronic devices inside a closed-cycle helium refrigerator, enabling experiments at temperatures as low as 10 Kelvin. The platform allows precise control over the orientation of magnetic fields, helping rule out measurement errors in spin signals.

"We try to minimise reliance on commercial equipment, which significantly reduces costs. For example, the sputtering system built in-house for the cleanroom cost around Rs 1.1 crore, whereas a comparable commercial system would have been close to Rs 3 crore. Beyond cost savings, this approach gives students valuable hands-on experience, making them familiar with how these systems work. Similarly, most of the vacuum systems in the lab have been designed and fabricated in-house here in Bengaluru, often with support from local collaborators," explains Anil.

Spin physics to smart memory

"There is a fundamental gap in today's computing systems. Your processor operates at gigahertz speeds, meaning it responds on nanosecond timescales. But your storage devices, like SSDs, are much slower; they take microseconds to milliseconds to access data. This mismatch creates what we call a memory gap, where the processor is much faster than the memory it depends on," explains Bhagwati Prasad, Assistant Professor in the Department of Materials Engineering, IISc.

Traditional memory devices store information by moving electrical charges through transistors and capacitors. For example, dynamic random access memory (DRAM) in our computers needs constant power to retain data, while flash memory writes information by trapping charge but is slower and wears out over time. As data moves back and forth, it consumes time and power, generating significant heat, especially in modern AI devices. Alternatively, spintronic devices store information using an electron's spin, enabling fast, non-volatile memory, where information can be stored and accessed quickly with much lower energy.

In such devices, spins can be manipulated using a technique called spin-transfer torque (STT). Imagine two magnetic layers separated by a very thin barrier called a magnetic tunnel junction. One layer has electron spins locked in place, while the other is 'free' – spins can align in any direction. When current passes through the fixed layer, electrons having spin in the same direction as the fixed layer pass easily. After crossing, more electrons end up aligning in that same direction – a phenomenon called spin polarisation. When these spin-polarised electrons reach the 'free' layer, they push on the spins of the 'free' electrons and force them to flip direction. The torque in SST corresponds to the force needed to flip direction.

A more recent approach is spin-orbit torque (SOT), where instead of passing current directly through the magnetic layers, the current flows through an adjacent heavy metal layer (like platinum), generating spin currents that can switch magnetic states even more efficiently. This switching creates two distinct states – when both layers point in the same direction, the device has low resistance and when they point in opposite directions, the resistance is high. These two states can represent binary information as 0s and 1s. Writing data involves sending a current to switch the state, while reading it involves measuring the resistance. This is what happens in magnetoresistive random access memory (MRAM).

Unlike conventional memory, which stores information as electric charge that disappears when power is turned off, MRAM stores information in magnetic orientations, which remain stable without electricity. The spins remain in their orientation until another flow of current intentionally flips them. Switching in MRAM simply involves rapidly flipping magnetic orientations, which can happen in nanoseconds. This makes MRAM faster, more energy-efficient, and highly reliable.

Between 2006 and 2008, during his Master's at the Indian Institute of Technology Kanpur, Bhagwati found himself captivated by the idea of spintronics. During his PhD at the University of Cambridge, he fabricated various devices starting from metal junctions (like those in MRAM) to more advanced spin filters. Spin filters allow electrons with one spin orientation to pass while blocking those with opposite orientations, enabling controlled spin-polarised currents.

When he was later at University of California, Berkeley, he contributed to the invention of many new fundamental device concepts in collaboration with teams at UC Berkeley and Intel. He then moved to the R&D center of Western Digital in San Jose, California, where he worked on the development of MRAM technologies for industry.
His lab at IISc now works on discovering new materials, designing novel devices, and developing energy-efficient memory and sensing applications.

A major challenge in magnetic memory is that switching the orientation of tiny magnetic elements often requires large magnetic fields, which are typically generated using high currents and bulky coils. To overcome this limitation, Bhagwati's group is developing approaches in which electric fields can directly control magnetic states, drastically reducing power consumption. Several projects from his group have also attracted support from industrial partners, including Micron and Lam Research, with a focus on developing low-power memory technologies across different material and device platforms. "In the next 10-15 years, we are likely to see a decade driven not by logic, but by memory, which is going to make a big difference, and we aim to be among the leading groups in the world contributing to this transformation," he says.

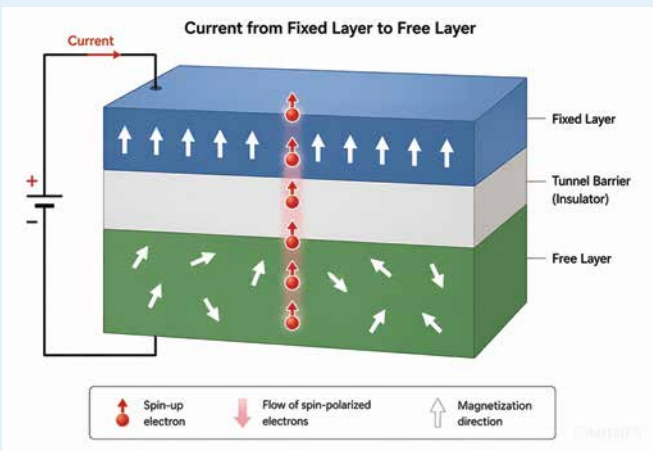
It's not just memory that spintronics can revolutionise. It could also lead to entirely new computing architectures beyond the limitations of conventional electronics. Massive data centers that currently consume enormous amounts of electricity and vast cooling infrastructure that exist just to prevent overheating, could become far more energy efficient. AI systems, which demand ever-increasing computational power, may process information faster without the steep energy costs they carry today. Edge devices, from smartphones to medical wearables, could run longer on a single charge. Even future technologies like autonomous vehicles and space systems could benefit from faster, more reliable, low-power computing.

And then maybe, one rushed morning in the future, you'll wake up late again. Same panic. Same deadline. You tap your laptop. It's instantly awake. No boot screen. No fan noise. No lag. Your document is already there – not "loaded," because it was never truly "off." Memory didn't need to be rewritten; it simply remained. You make your edits, hit send, and are done in seconds. The laptop may look the same. But deep inside, electrons might be doing something entirely different – spinning their way towards the future of computing.

Shreya Vashista is a second year MTech in Bioengineering student at IISc, and a science writing intern at the Office of Communications

(Edited by Rohini Subrahmanyam, Ranjini Raghunath)

Image refined using ChatGPT



Schematic of a spin-transfer torque (STT) device, where spin-polarised electrons transfer angular momentum from a fixed magnetic layer to a free layer, enabling magnetic switching for next-generation memory and computing technologies

You Name a Game, I Know It

- Interview by Kavitha Harish

Photo: KG Haridasan

Growing up in Coorg, Karnataka, CP Poonacha was always engaged in sports and outdoor activities. He enjoyed them so much that he decided to make it his career. After completing a Bachelor's and Master's in Physical Education, he started his career at Karnataka University and later worked at Jyoti Nivas College, Bengaluru. He joined IISc in 1986 as a Sports Officer, where he has guided students in a wide range of sports and events and even provided personal mentorship. Now retired, the 69-year-old speaks to CONNECT about his beginnings, his three decades of service on campus, and how he is spending his retirement back in his hometown.

Please tell us about your childhood.

I hail from Coorg, where I completed my schooling through grade 10 at a rural government school.

My father was an agriculturist, and my mother was a housewife. I was their only son, with an elder and two younger sisters. We tended the family land growing coffee, pepper, and areca nuts. My father, despite studying only up to grade seven, was a voracious reader. He told me captivating stories about world leaders, including the Maharaja of Mysore, Napoleon, Hitler, and Tipu Sultan. Later, when I joined IISc, he would devour every Kannada book in the JRD Tata Memorial Library, then regale my children with those tales.

'My love for physical activity and games has always been a part of who I am'

Coorg is described as the "Scotland of India" for its rolling hills, mist-covered valleys, lush green coffee estates, and cool, pleasant climate. With plenty of walking trails, streams, and open spaces, the environment naturally encourages physical activity and outdoor life.

Is that why you chose to study sports?

Yes, my love for physical activity and games has always been a part of who I am. In Coorg, people are naturally sports-oriented and very fond of outdoor games. Growing up, I enjoyed playing almost every sport – football, hockey, athletics, and indoor games. That passion naturally drew me towards a deeper understanding of sports through formal education.

After school, my goal was to become an expert in various sports so that I could guide and train others effectively. I believe that a sports officer must be well-versed in all the rules, techniques, safety aspects, and coaching methods to coordinate activities, conduct tournaments, and support athletes across disciplines. This conviction motivated me to study sports and build a career in physical education and student welfare.

I pursued my Bachelor's degree (BA) at St Philomena's College in Puttur Mysore University, Bachelor of Physical Education (BPEd) from MVAS College of Physical Education, Dharwad, Karnataka, with first rank and distinction. I also obtained a Diploma in Coaching Athletics from the National Institute of Sports in Bengaluru. I then completed my Master's in Physical Education (MPEd) at Bangalore University. During my student days, I was a Decathlon champion and excelled at hockey and football. I secured first rank from the National Institute of Sport and Physical Education, and I was felicitated by the then Karnataka Chief Minister, Shri Gundu Rao, under the Bangalore Youth Services Department, which included a cash prize of Rs 5,000.

I had the privilege of being part of the team that trained athletes for the Asian Games in Bengaluru and of serving as an Athletic Coach for the 1982 Asian Games in New Delhi. I have also been a member of the Bangalore University committee for hockey for about 25 years.

Were you working before coming to IISc?

I worked for a year as a Lecturer at Karnataka University and then served for two years as Director of Physical Education at Jyoti Nivas College, Bengaluru.

The college was exclusively for girls and had a well-maintained feel. Because the college was autonomous, I enjoyed a great deal of freedom in my role.

Since it was a new campus, I developed grounds for all major outdoor sports. I formed teams across disciplines and recruited expert coaches, enabling students to compete and win numerous prizes. Over time, I built a good reputation for the sports programme.

How did you join IISc?

I was staying with a friend at the HMT quarters in Bengaluru. On my way to work, I would often admire the IISc campus and the large grounds near Yeshwantpur. One day, I walked through the entire campus and wished to work at such a renowned institution. As if by providence, a vacancy for the Sports Officer post opened, and I applied. A distinguished panel interviewed me. I outperformed 44 candidates and was shortlisted for the viva. After the interview, I was selected as Sports Officer on merit.

Initially, Jyoti Nivas College tried hard to retain me. However, the IISc post was a higher-level, permanent Group A position and was an important step in my career, and I was required to join immediately. I had to meet the IISc Registrar and the Chair of the Gymkhana to request an extension of the joining date to complete my responsibilities and find a replacement at Jyoti Nivas College.

About 10 months after receiving my appointment letter, I joined IISc in 1986 as a Sports Officer. KV Shenoy was the Sports Officer before I joined. I eventually retired as Senior Sports Officer, having received two promotions during my service.

Photo courtesy: CP Poonacha

Poonacha (bottom row, third from left), along with Gymkhana staff members, the IISc director, registrar, and students' managing committee members, in the year 1998

You stayed at the Institute for more than 30 years. What sports did you teach?

The size and quality of the Institute's campus, its sports infrastructure, the support staff, and the opportunity to work with vibrant students were the major reasons I chose to stay at IISc. I have always been an all-round sportsman. You name a game, I know it. I engaged students in a wide range of sports, including cricket, football, hockey, badminton, and more. My main specialisation is athletics, and I coached students on running, jumping, throwing, and fitness training. I also provided coaching in billiards, snooker, and general gym-based fitness.

'The size and quality of the Institute's campus, its sports infrastructure, the support staff, and the opportunity to work with vibrant students were the major reasons I chose to stay at IISc'

We built a strong sports culture at the Institute, with teams from different departments, a dedicated students' team, and a staff team. Regular matches and competitions were organised on special occasions involving students, staff, and their families, promoting fitness and fostering camaraderie.

Were there any challenges you faced?

Working with highly intellectual students posed a challenge. Unlike regular universities, research institutes like IISc have a different rhythm; our students often have to balance heavy academic workloads with sports and cultural activities.

Another major challenge was the Gymkhana's limited budget. With requirements for 25 different games and events, it was difficult to provide quality equipment and facilities for everyone. Due to financial and administrative constraints, I could not take our team to tournaments such as those at IISER Bhopal, and later, even sending UG students to external competitions became difficult.

Have any IISc students participated in national or international events?

IISc students have participated in state-level teams in athletics, football, hockey, cricket, tennis, basketball, volleyball, billiards, and snooker. These players competed in varsity leagues and state association matches but often prioritised studies over advancing to the national or international levels because of the intense practice demands.

Tell us more about the Gymkhana activities and management.

The Gymkhana buzzes with a wide range of sports and events. It offers indoor games like badminton, chess, and table tennis, as well as outdoor sports such as football, hockey, cricket, and basketball. General activities include taekwondo, frisbee, aerobics, dance, film club, yoga, cross-country races, and swimming. Student fests in the past included *Vibrations*, and today there are *Rhapsody* (PG) and Pravega (UG), as well as events like a 32-km campus marathon from IISc to HAL.

The Gymkhana committee ensures seamless organisation and promotion of all athletic activities. It is composed of the Honorary President – a dedicated faculty member who provides strategic oversight and institutional support – the Sports Officer – the operational lead handling day-to-day logistics, event planning, and resource allocation – and the Students' Body with elected student representatives who bring a lot of energy, gather feedback, and champion peer participation.

This model has proven highly effective, fostering school spirit and lifelong fitness habits among the IISc community.

There were also movie screenings held at the Gymkhana earlier, right?

Yes, there used to be a movie screening on Friday nights. We borrowed movie tapes – mostly English films – from Mumbai and obtained the necessary permissions. A licensed technical person, Murthy, was appointed to operate the projector. I remember going to the commercial tax office to pay the required tax before each screening, as there were many formalities involved in showing a film in any place other than a regular theatre in those days. A generator was also arranged for an uninterrupted power supply.

These movie nights became a major source of entertainment for students.

When I joined, the movie screenings had been suspended due to complaints about films allegedly being shown illegally. I discussed with the concerned authorities and helped regularise the process to make it fully legal. I serviced and restarted the projector. With the help of Thimme Gowda from the Department of Electrical Engineering, we checked the power connections, arranged proper entry and exit boards, and installed exhaust fans, trying to make the Gymkhana hall feel like a real movie theatre.

Similarly, the swimming pool had also been closed due to a lack of maintenance. I appointed a professional to maintain and operate the swimming pool and gradually brought it back into regular use.

Did you meet any dignitaries or sports icons during your tenure?

Yes. I have met eminent national leaders, including APJ Abdul Kalam, Ratan Tata, and the Honourable Minister Murli Manohar Joshi.

Photo courtesy: CP Poonacha

Poonacha with the IISc cricket team during the year 1995-96

Beyond these, the Gymkhana invited many world-class athletes, Olympians, and Arjuna Awardees to inspire our students during sports events, including Cheppudira Subbaiah Poonacha (1992 Olympian); Indian track and field stars Vandana Rao, Reeth Abraham, and Ashwini Nachappa; hockey player Ashish Bhalla; kabaddi legend C Honnappa Gowda; badminton star Prakash Padukone, and cricket legends such as Brijesh Patel and Anil Kumble, and many more wonderful sportspersons.

Do you have any fond memories with students?

Many. When injuries occurred – most often during hockey matches – students would ask me to stay with them while the doctors attended to them. I remember once assisting the Medical Officer with wound stitching, much like a nurse, offering comfort and support. On several occasions, both faculty members and doctors asked me to support students with psychological or emotional issues, providing informal counselling and meeting with parents to address concerns. I tried my best to encourage and uplift students, giving them courage and a sense of reassurance.

Additionally, I was actively involved in organising various games and competitions during the Great Days celebrations, such as Independence Day, Gandhi Jayanthi, Ambedkar Jayanthi, Kannada Rajyotsava, and International Women's Day, which helped build a strong sense of community spirit on campus.

Tell us about your family life.

My wife is a retired Vice Principal of Renukacharya College for Women in Bengaluru and a keen hockey player. During my service at the Institute, she would often invite Directors of IISc and other senior faculty members as Chief Guests for her college events.

Our first son, Nithin, holds an MTech from the Department of Computational and Data Sciences (CDS) at IISc and works at Lam Research. Our second son, Nishank Bopanna, is a lecturer at Kuvempu University in Shimoga, and is pursuing PhD in Physical Education in the same university. Both are married and well settled.

I am proud to say that my family is actively associated with sports. I have spent a considerable amount on sports equipment, including sports shoes and badminton and tennis racquets. While studying Bachelor's at St Joseph's College, Nishank represented the Bangalore University football team three times.

Did you stay on campus?

Yes, I stayed in the campus quarters, which felt very safe and secure, and I never missed Coorg. Many students visited for tea and snacks, turning my home into a mini office where students would come to discuss sports, studies, and personal matters. They felt like family to me, and I enjoyed being part of their lives.

'Students would sometimes ask me to switch on the lights so they could keep playing basketball or other games'

I truly enjoyed my career with the Institute and its students. My day often began as early as 6 am and went on until around 9 pm. Students would sometimes ask me to switch on the lights so they could keep playing basketball or other games, and I was happy to let them continue as long as they were safe and engaged.

I was also given the responsibility for Hostel Administration, which kept me closely involved in student life beyond sports.

Having a Sports Officer is essential at the Institute, given its large grounds and many sports complexes.

How are you spending your time after retirement?

After retirement, I am happily settled in Coorg, where I manage my father's agricultural land, which keeps me fully occupied. The routine and connection with the land give me a deep sense of purpose and satisfaction.

I also support underprivileged students and help deserving families during marriage ceremonies. This is a small but meaningful way to give back to society and contribute to the well-being of my community.

I sometimes feel I could have built a house in Bengaluru, but I don't regret not doing so. I am content knowing that I was part of such a great institution in our country.

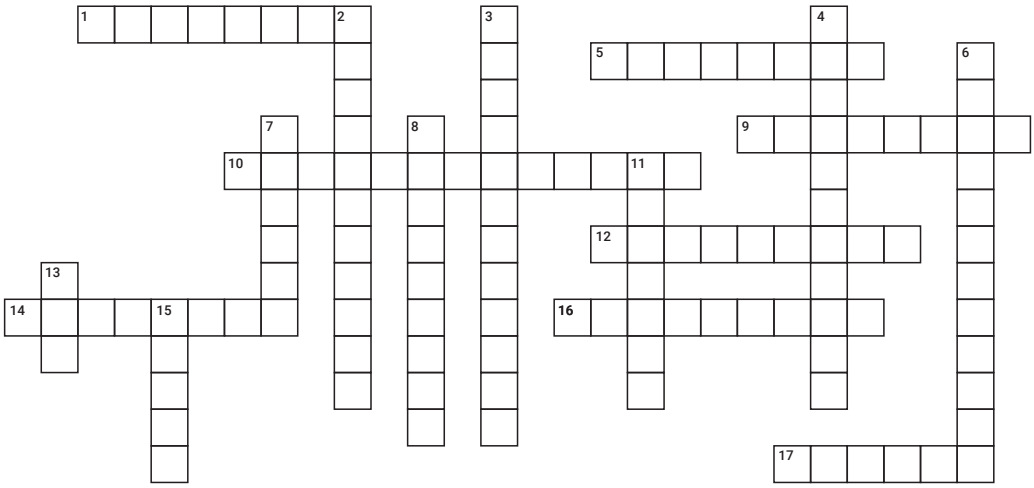
(Edited by Kavi Bharathi R)

Photos courtesy: CP Poonacha

Ashwini Nachappa (top), Olympian and international medallist, and Prakash Padukone (bottom), legendary badminton player, during past Gymkhana Day celebrations at IISc

Fun Corner

CONNECT CROSSWORD



Send your completed puzzles to **connect.ooc@iisc.ac.in**

The top 3 winners will be announced in the next issue!

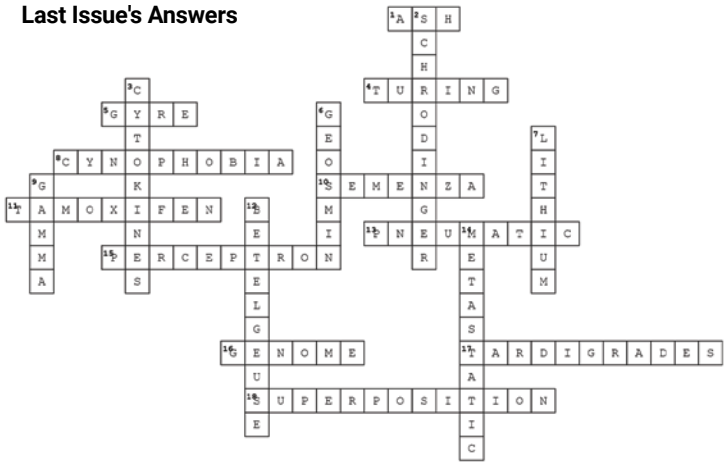
ACROSS

1. India's first biosphere reserve established in September 1986
5. A potent opiate painkiller naturally obtained from the seeds of the opium poppy
9. A chemical reaction between amino acids and reducing sugars to create a distinctive "caramelised" flavour in foods
10. Lakshadweep's officially designated state animal.
12. Widely used metal that provides clear reflections in mirrors
14. Orange pigment found in carrots
16. The unit of radioactivity defined as one decay per second
17. One of Jupiter's four Galilean moons heavily covered by a layer of ice

DOWN

2. A technology that utilises both the charge and the intrinsic "spin" of an electron to store and process data
3. India's longest limestone cave system found in Meghalaya
4. A natural, deep-blue pigment and antimicrobial metabolite produced by various bacteria
6. Single-celled organism with a shell, used as a paleoclimate proxy, found in ocean sediments
7. The scientist who discovered the universe is expanding in 1929
8. Miniaturised, three-dimensional tissues grown in the lab from stem cells, which mimic human organs
11. Element scientists study as a possible alternative to carbon for building life on other planets
13. Insect which hosts a fungus that produces a widely used red pigment
15. The “lost” planet hypothesised to have collided with Earth, forming the Moon

Last Issue's Answers



LAST ISSUE’S WINNERS!

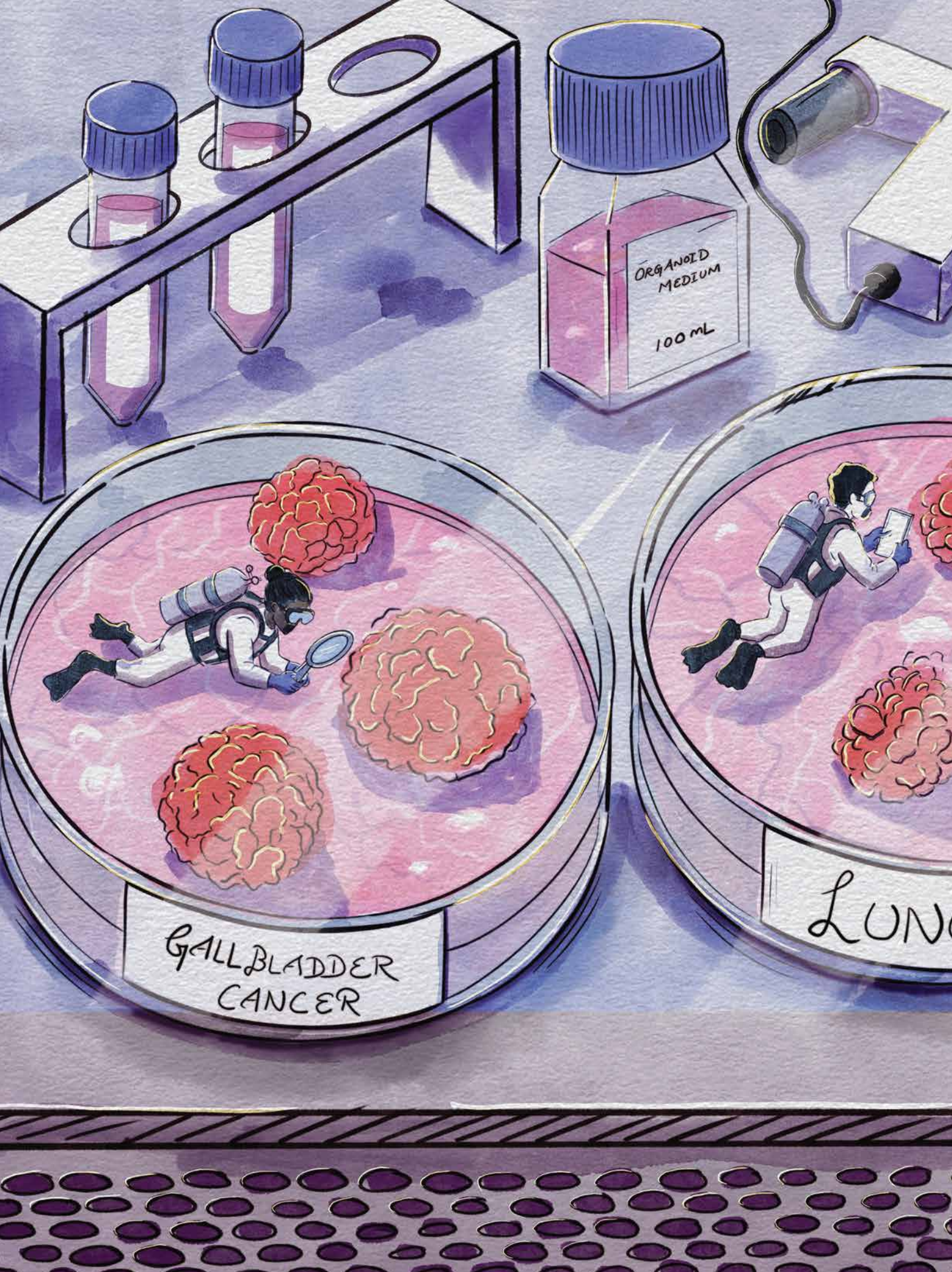
Ranjitha TK, Technical Assistant, Solid State and Structural Chemistry Unit (SSCU), IISc

Can you guess where this photo was taken on campus?

GUESS THE SPOT!

Email your answer to **connect.ooc@iisc.ac.in**

Abstracts | Anupam Barman, IISc Photography Club


ORGANOID
MEDIUM
100 ML
GALLBLADDER
CANCER
LUNG