# CONNECT

## WITH THE INDIAN INSTITUTE OF SCIENCE

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**Campus Elections**
Students for change

**Elegant Maths**
Beauty in abstraction

**Home and Earth**
Building for the local


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# EDITORIAL

Dear readers,

Many students think maths is a difficult subject. But beyond this bubble of fear lies a world of elegant simplicity and mysterious patterns. In our cover story, mathematicians reveal the subtle beauty behind numbers, theories, and paradoxes in maths, and why they find the subject so intriguing.

We also explore other mysteries in this issue. The universe is so unimaginably vast that astronomers came up with an ingenious idea to make some sense of it – the cosmological principle. But how exactly does it help them? In another story, we delve into the long, fascinating history of the hydrogen bond and the decades-long debate over its existence. In a different kind of inquiry, a design student set out to resolve a common dilemma in the field: When it comes to prototyping, is physical or digital better?

Speaking of design, we also interviewed experts vouching for traditional architectural construction; rooted in cultural and geographical contexts, these buildings might be much better suited for climate resilience.

In historical stories, we chronicle the century-old journey of the JRD Tata Memorial Library, and profile the life and legacy of NS Govinda Rao, the first head of IISc's Department of Civil Engineering. We interview an alumnus working on making the science of science more efficient, and spotlight the life of an assistant registrar who handles much of the Institute's HR activities.

On campus, a student dives into how various representative bodies work to resolve student issues in a timely manner. In our Vox Pop column, students also get candid about their favourite summer memories.

As always, the last few pages are reserved for some extra fun. Flip through a glorious exhibition on dolls of notable scientists and engineers by UG students, indulge in some wordplay, and LOL at a comic submitted by one of our readers. Enjoy!


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# Driving Change

- Shloak Vatsal

***Elected bodies are giving voice to student issues***

Photo courtesy: Gowtham VE

*An open mic performance at the Student Amenities Centre, January 2025*

On a rainy October evening in 2024, Chiranjeevi Sadana, PhD student at the Department of Mechanical Engineering and newly elected Chairperson of the Students' Council, is making arrangements for the first open mic of his term. The Students' Council had finally been reinstated after six months. The unusual delay in elections, due to controversies around candidature, had soured the mood on campus, with no DJ nights, open mics or sports screenings during the gap.

Even the untimely rain could not dampen the anticipation for this first event. Suddenly, Chiranjeevi's phone starts ringing, and his WhatsApp floods with messages. An email from the Registrar had landed stating there is to be a ban on all motor vehicles owned by students, starting from November. Frantic, Chiranjeevi calls the members of the Students' Council to decide on a plan of action. A list of students' concerns is compiled and presented to the administration in a series of meetings. After much persuasion, an extension of the deadline is secured till the end of December. "We brought the administration to the table and reached a compromise suitable to both sides," recalls Chiranjeevi.

The Students' Council, the Gymkhana Student Affairs Committee (GSAC) and the mess committees are the main student representative bodies at IISc. Composed of students from various departments and degree programmes, the Students' Council solves issues relating to different aspects of day-to-day life on campus. It comprises a Chairperson, General Secretary, and secretaries of Hostels, Academics, UG, and Women's Affairs. The GSAC mainly looks after concerns pertaining to the Gymkhana and its associated clubs. Mess committees, led by a mess president, are made up of student members who handle the menu and maintenance of the five messes, named A-E, on campus.

"We represent the voice of the students in decision making, bridging the gap between the administration and the students and ensuring transparency in processes," says Yashika Kukreja, Integrated PhD student at the Division of Biological Sciences and D mess committee member.

***'We represent the voice of the students in decision making, bridging the gap between the administration and the students'***

## The election process

The members of these various bodies are chosen through separate elections held at different times throughout the year. A notification from the Election Commission – comprising of professors, assistant registrars, and arbitrators – marks the start of the election process. Once nominations are filed, days of campaigning, debates, and discussions across platforms follow, during which candidates present their case, up until the evening before the election. On election day, votes are cast via a private voting link, which is emailed to students. The whole process is monitored by students and the Institute administration to ensure a fair election process. Once the voting ends, crowds gather around the Sarvam complex in anticipation. The tension is broken late in the evening when the Election Commission announces the results through email.

For the candidates seeking election, it is a long process. They begin preparations well in advance, talking to students to learn about problems and taking part in campus-related discussions. As election day gets closer, they prepare manifestos with a list of grievances that they aim to address.

Chiranjeevi recalls how he received a huge number of messages complaining about accidents and discomfort caused by potholes on campus roads, especially during the rains. He ran his campaign on the platform of road reconstruction, and it was the first issue he tackled upon taking office. "The administration wanted a permanent solution by building new roads, but that would have taken 3-4 months. We had multiple meetings with them and got them to implement a temporary fix by filling the potholes within two weeks," he says.

Some candidates chose to run their campaigns on problems they observed. Tarushri NS, a third year Bachelor of Science (Research) student and former Woman Committee Member of the GSAC, was one. When she saw the IISc women's kho-kho team performing badly in IISM [Inter-IISER/IISc Sports Meet] in 2022 and noticed their absence in 2023, she wanted to help them. She got a kho-kho competition inducted into Spectrum, IISc's inter-department sports fest. "We got a strong response and had a very good team this time," she says. She also facilitated guided training sessions for women and organised self-defence workshops.


*Photo courtesy: Gowtham VE*

*The members of the Students' Council (from left to right, Kalidas Viswam, Saumya Srivastava, Chiranjeevi Sadana, Utsav Swarnkar, Anubhav Singh, Ananya Chatterjee), in front of the Students' Council building*

Often, students with shared goals and ideals form panels to present a united front, like temporary political parties, with each member contesting for a different position. This makes campaigning more effective and helps coordinate actions if elected together. But there's a catch: when members from different panels win, they have to navigate their differences after the election. This happened for the GSAC election in 2024, when people from two different teams were elected. When they had to choose the chief coordinator for Spectrum, they ran into some trouble. "We had already thought of different candidates for the position," recalls Sveekruth Pai, PhD student in the Interdisciplinary Programme in Brain, Computation and Data Science, and former Secretary of the GSAC. "However, we had a discussion and reached a unanimous decision and selected both as co-coordinators for the event," he adds.

## For the students

Winning the election is only half of the slog. Each body must also come up with feedback mechanisms to collect updates actively. Rankit Kachroo, PhD student at the Robert Bosch Centre for Cyber-Physical Systems and D mess committee member, explains how their committee has identified people from different backgrounds in the mess to provide feedback. "If we want to introduce a dish from a certain state, we'd call some boarders from that state and ask whether it tastes right," he shares. C mess has a discussion group where people give their feedback and opinions. "We also circulate forms to ask which dishes people want on the menu," says Lukalapu Mohnish, second year Bachelor of Technology student and member of the C mess committee.

***The Students' Council prefers to have regular General Body Meetings, open for all students, to collect feedback directly from individuals***

The Students' Council prefers to have regular General Body Meetings, open for all students, to collect feedback directly from individuals. "We also attach our phone numbers with the emails we send so that people can access us easily," explains Utsav Swarnkar, PhD student at the Department of Design and Manufacturing and current General Secretary of the Council. "When our term started, we received complaints that there were no dustbins on the road and people had to carry trash till they reached the departments or hostels. We identified locations, took permissions from department chairs, met with the dean and the registrar, and finally got 20 dustbins installed," he adds. The GSAC, on the other hand, relies mainly on convenors to gather intel about problems.

In addition to routine work, the representatives often have curveballs thrown at them. Muhsin Chalil, PhD student at the Department of Bioengineering and a C mess committee member, says, "Recently, many boarders had signed off during Ramzan. When they returned after Eid, the food demand shot up beyond our control, causing a shortage," he recalls. "Usually, we prepare for such changes during the quarterly mess change window, but this was not such a time. We also keep buffers. Since the committee is the custodian of the money that people [students] are paying, we need to ensure that we don't waste a lot."

Similarly, the old Gymkhana that housed the gymnasium, aerobics, and dance rooms, and dedicated spaces for indoor games, was recently demolished to make way for a new Gymkhana complex. The GSAC was tasked with identifying locations on campus where the facilities could be temporarily shifted. It was challenging as most of the hostels and spaces were out of the question because of the noise that the activities would generate. "We also had to manage the slots for dance and aerobics since the space became limited and 4-5 groups required them," says Sveekruth.

The student bodies also organise DJ nights, open mics, special meals, and sports and cultural events. The events don't just help relieve the monotony and stress of academics, but also the homesickness that students feel. "During festivals, we incorporate regional dishes in a special menu. We Google the preparation, start planning two weeks in advance, sit with the staff to see what all they can make, and check the budgeting and procurement," explains Yashika.

Photo courtesy: Shreenabh Agrawal

*A Students' Council General Body Meeting in progress in March 2025 outside the New Boys Hostel*

## Navigating hurdles

The student bodies also often take on the job of interacting with members of the Institute administration to solve problems faced by students, mainly to make the former understand the latter's needs better. For example, upon the construction of new sports grounds in 2024, the Gymkhana office proposed a "user fee" to encourage the responsible use of the new facilities. However, such a fee, above the annual Gymkhana fee, would have discouraged people from playing, especially those who used the facilities only occasionally. The GSAC decided to raise the concern formally with the Gymkhana office.

***'During festivals, we incorporate regional dishes in a special menu, planning two weeks in advance'***

"We conducted polls across groups and found that most people rejected such a subscription fee. We called a meeting with the President and Deputy Registrar of Gymkhana and presented the findings. They agreed to cancel the additional fee, and instead, the usage rules were made stricter," recounts Sveekruth.

In another incident, the new Tunga and Aryabhatta hostels were not being allotted to new students, forcing them to stay outside campus and pay rent. The problem was because the CPWD (Central Public Works Department), the construction agency, had not handed over the apartment to CCMD (Centre for Campus Management and Development), the campus civil maintenance body. The Students' Council intervened, pushing the administration to get the approvals quickly, as well as shifting students at the earliest. This resulted in the students being moved in early, and the remaining construction work was to be finished later.

Several student representatives feel that one of the more overlooked challenges is the lack of communication between the administration and the various student bodies. Procedural delays can also complicate matters. Muhsin, for example, laments that they have to go through an auditing process every time before any new cutlery can be procured, even when there is a shortage. The GSAC also once saw a change in their Deputy Registrar in the middle of the term, which added to their challenges because new officials can take time to adjust and build a rapport with the team.

Additionally, each committee/student body has its own "jurisdiction", which can create unique challenges. This became evident during the organisation of Sangam, the annual freshers' event. "Generally, the Students' Council takes care of the logistics and finances of events, while GSAC organises cultural and talent showcases. However, since the elections got postponed, we didn't have a Council in place, and the administration refused to release funds to the GSAC. We had to organise the event on a limited budget and were also barred from using the name Sangam," explains Tarushri. This happened again when they proposed hosting the IICM

Photo courtesy: Shantala Kamath

*Sveekruth (left), former Secretary of the GSAC, in discussion with Gymkhana officials at the newly opened cricket ground in January 2025*

(Inter IISER Cultural Meet) at IISc this year. "We had prepared the budget, contacted all IISERs, and even checked the accommodation. But we were told that since the Students' Council is not in place, funds could not be released, even though the Council has never had any role in IICMs before," she adds.

With such struggles and the sheer personal commitment that being part of these bodies requires, why do students take up the mantle? Many say that it is a crash course for their ambitious future as thought leaders. So many lessons emerge from their experiences. How to tackle conflict between students, conveners, and the administration. How to rally the troops and democratically reach a united front. How to multitask and learn the art of diplomacy, all in the face of public scrutiny. "I saw this as a challenge that would help me grow personally, developing my skills in communication and problem-solving," says Yashika. Others like Chiranjeevi see it as a natural calling, their chance to make a meaningful difference. He says, "I've always felt a responsibility to stand up when things need to change. Instead of waiting for someone else to fix the problems, I want to be part of the process."

Photo courtesy: Sachin Joshi

*D Mess Committee members (from left to right, Yashika Kukreja, Utkarsh Khandelwal, Rankit Kachroo, Akash Bhoir) with the Registrar, Captain Sridhar Warrier*

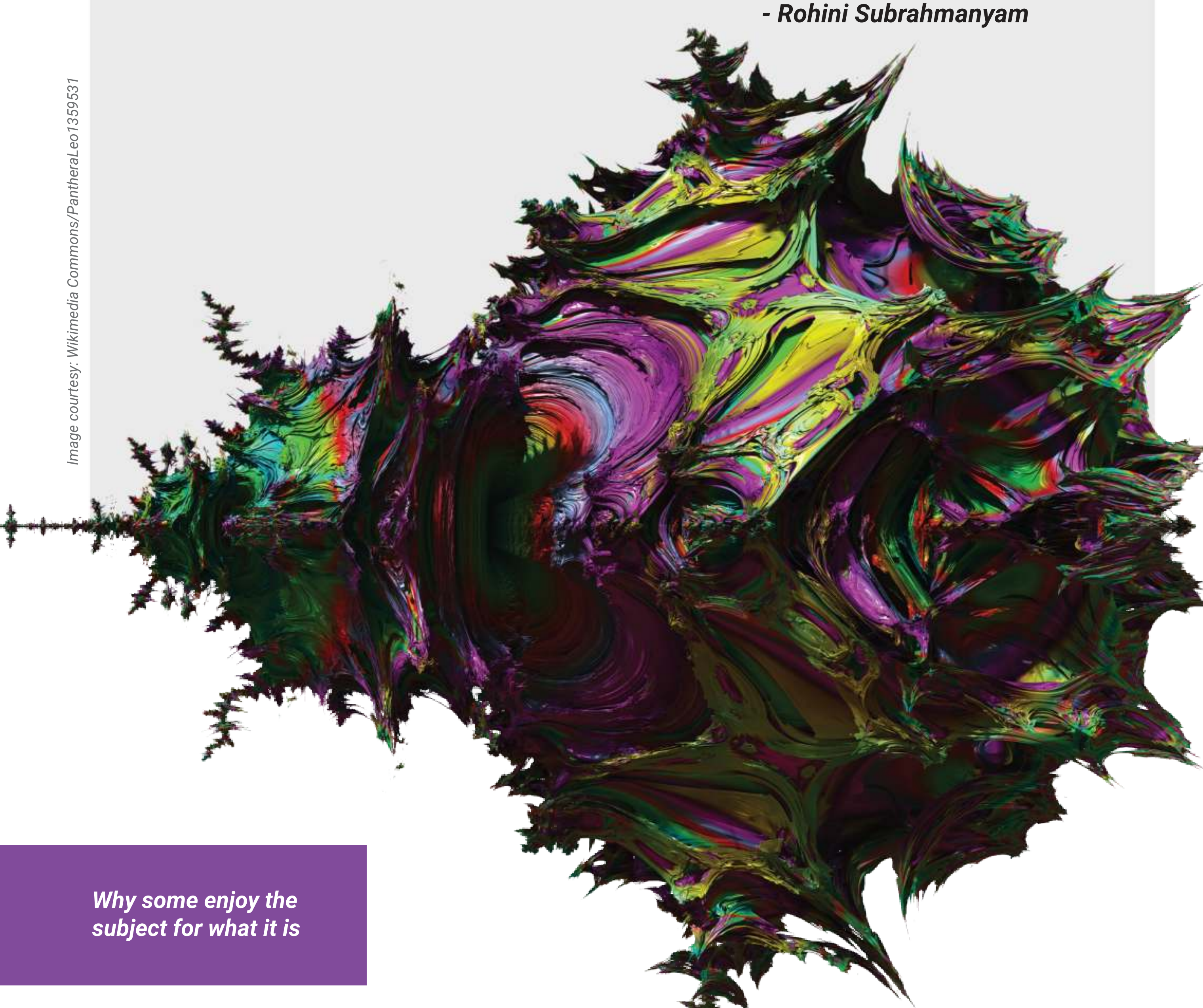
***Shloak Vatsal is a third year Bachelor of Science (Research) student at IISc, and a former science writing intern at the Office of Communications***

***(Edited by Sandeep Menon, Abinaya Kalyanasundaram)***

# The Beauty of Maths

- *Rohini Subrahmanyam*

*Image courtesy: Wikimedia Commons/PantheraLeo1359531*

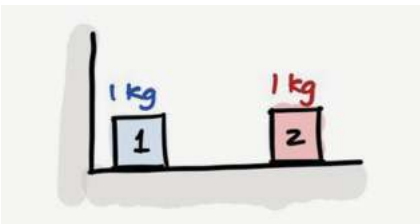


***Why some enjoy the subject for what it is***

*The computer-generated Mandelbrot set is an infinitely complex fractal; intricate patterns keep emerging the further you zoom in*

Let us begin with an unusual counting puzzle. Imagine two blocks labelled 1 and 2, next to each other on the ground beside a wall. Assume that the ground is frictionless, and that the blocks will not lose energy when they hit each other or the wall. B1 is closer to the wall, and both blocks weigh 1 kg. This is the scenario that YouTuber Grant Sanderson, who runs the popular 3Blue1Brown maths channel, sets up in one of his videos.

Illustration: Akshit Goyal

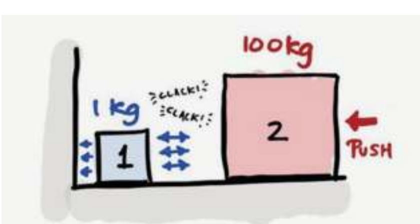



*Block 1 and 2 sitting on the ground next to a wall*

Now, imagine pushing B2 towards B1 and hearing a clack as they hit each other. B2 pushes B1 to hit the wall, resulting in another clack, and B1 rebounds from the wall to hit B2 again, pushing it away. This will result in three total clacks.

What happens if the weights change? Say block 2 weighs 100 kg while block 1 remains 1 kg. Now, B2 hits B1, B1 smacks against the wall and returns to hit B2 again; but since B2 is heavier, it will not move away so easily. B1 will end up bouncing between B2 and the wall again and again, ratcheting up the clack count to 31.

Illustration: Akshit Goyal




*A heavier B2 will keep pushing B1 into the wall, resulting in multiple clacks*

If you keep increasing block 2's weight, to 10,000 kg or $10^6$ kg, the number of clacks will keep increasing, to 314 or 3,141, respectively. If block 2 weighs $10^8$ kg, the clack count is 31,415.

Do you see a pattern yet?

Somehow, as one block gets heavier by a factor of 100, the ensuing number of clacks matches the digits of, you guessed it – pi. But we only know of pi being related to a circle. Why should these clacks – from two blocks hitting each other on a flat, frictionless one-dimensional surface – compute pi?

"What follows is a detective story of tracking down the circle … but not because it is useful," says Grant later in a TEDx talk. " [It's] because the story has drawn you in."

Unsolved mysteries like these are what draw mathematicians to their muse, even if they don't seem to have any direct relevance in our daily lives. They can be about finding intriguing patterns in numbers, studying symmetrical shapes in the world around us, or just finding mind-boggling connections across different areas of maths.

That's not to say that people don't work on "practical" maths, like the equations and processes underlying stock prediction models, neural networks, or weather forecasts. As Grant mentions in his talk, even the study of prime numbers, as "pure and platonic as it may seem", has applications in modern cryptography. But this is not necessarily why some mathematicians study maths.

Harish-Chandra, an influential mathematician from India who worked at the Institute of Advanced Studies, Princeton, USA, succinctly summed up his thoughts on why studying maths is worthwhile. He writes: "Music is not useful in any way except that it makes us feel good. Similarly, the main attraction of mathematics lies in the fact that it is beautiful." He apparently scribbled this on the back of one of his papers, according to CS Aravinda, Professor at the Tata Institute of Fundamental Research (TIFR).

Mahan Mj, Professor of Mathematics at the Tata Institute of Fundamental Research (TIFR), Mumbai, relates to this aesthetic appeal. He explains how doing pure mathematics can, in part, be compared to enjoying Shakespeare. "Mathematics has a dual life. It is the language of science; one needs mathematics to lend precision to science," says Mahan. "But if you look at the language itself… it responds to something fairly deep and fundamentally aesthetic in us as well."

***'If you look at the language [of maths] itself … it responds to something fairly deep and fundamentally aesthetic in us'***

In Grant's talk, I can almost feel his excitement as he describes how some maths problems have all the components of a story. He likens the colliding blocks example to a good mystery novel. The clacks somehow adding up to pi is tantalising evidence that something deeper is at play, but finding and proving the connection needs some deduction. "It appeals to emotion, has comedy and some notion of characters, a mystery you need to see resolved," he says. "[It can] really pull you in for the math that it is now, not what it promises to give you later."

What is so mysteriously beautiful about maths? To find out, first, we will need to journey into the world of one of its key ingredients – numbers.

## Pretty patterns

Apoorva Khare, Associate Professor at the Department of Mathematics in IISc, is always on the lookout for intriguing patterns in maths. When I met him, he was practically bouncing on the balls of his feet as he explained one simple example on a blackboard.

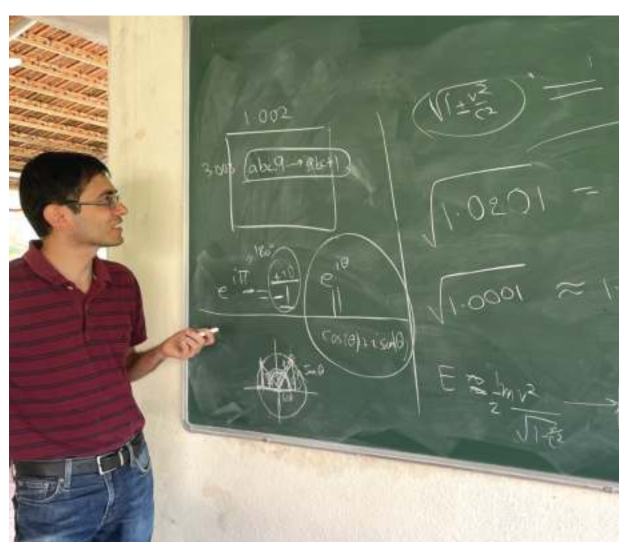


Photo: Rohini Subrahmanyam

*Apoorva works on problems in algebra and analysis at the Department of Mathematics, IISc*

"Suppose I tell you to multiply any two consecutive odd numbers, and then add one, you will always get a perfect square," he says.

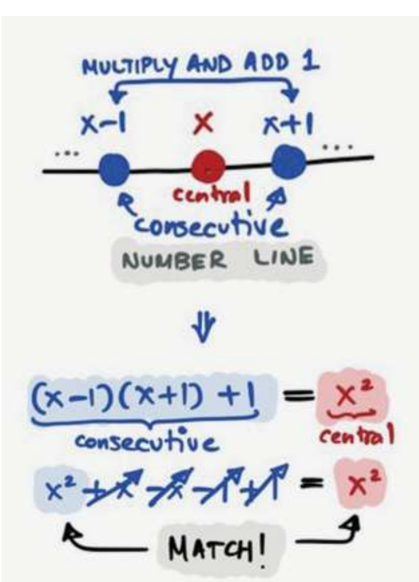
Try this:
$(1 \times 3) + 1 = 4 = 2^2$
$(3 \times 5) + 1 = 16 = 4^2$
$(5 \times 7) + 1 = 36 = 6^2$
$(7 \times 9) + 1 = 64 = 8^2$

Not only do we get a perfect square each time, but the result is also the square of the even number in between the two odd numbers (2 between 1 and 3, 4 between 3 and 5, and so on). There, the pattern emerges.

But finding the pattern is just the first step. One must then prove that the pattern exists for all possible numbers. "Of course, I'm not going to verify every pair of odd numbers; that will take forever. So, instead, can I find a general formula that holds for all these things?" explains Apoorva. "You can verify all of them simultaneously using one calculation in mathematics."

For this, he explains, we can exploit the power of variables – symbols that represent some changing or varying quantity. Instead of juggling an infinite list of numbers, let's just take a number which we can call x, our variable. Now we just need to remember some maths we learned in school, and prove that multiplying x-1 with x+1 (the consecutive odd numbers) and adding 1, will always give the square of x (the central number).

Illustration: Akshit Goyal




*Formula for the proof that multiplying two consecutive odd or even numbers gives the square of the number in the middle*

You will also realise that this pattern holds for all numbers; as x can be any number you like, the proof always holds. Even if you multiply two consecutive even numbers and add 1, you'll get the square of the odd number in the middle.

***'My love for mathematics started with this [finding patterns]'***

"My love for mathematics started with this [finding patterns]. When I was in school, I would do these kinds of things – try to put variables and symbols in and then just [prove] the general [case]," says Apoorva. "Suddenly, you see the truth underlying infinitely many facts. Finding the underlying truth of these things, or why something is true, has always appealed to me."

The above example is a simple pattern with a straightforward proof. But there are many open maths problems that mathematicians have been trying to solve for centuries, with little success. Some of these problems are related to prime numbers.

Mathematicians have eternally been perplexed by primes – numbers that can only be divided into whole parts by 1 and the number itself. "Primes are like the elements [in chemistry]; everything else is built out of them," says Jordan Ellenberg, Professor of mathematics at the University of Wisconsin-Madison, USA. "Every number is made up of primes … so if you understand them, then you understand a lot of other stuff too."

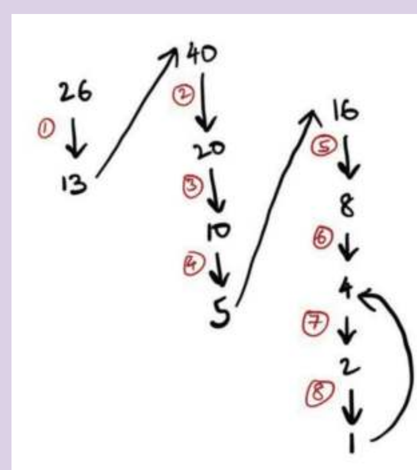
## The Dangerously Alluring Collatz Conjecture

The Collatz Conjecture, also called the 3n+1 problem or the hailstone problem, looks so simple that even school kids can play around with it. But for mathematicians, it is a quagmire – many have gotten stuck for years trying to prove it; some advisors even warn their students to stay away from it. The conjecture became so notorious that in the 1960s, people even joked that it may be a conspiracy to slow down American research.

Here's the problem. Take any number n, and if it is even, cut it in half (n/2). If it is odd, triple it and add it to 1 (3n +1). Keep doing this, again and again, with every number you get, and you will eventually end up in a never-ending loop around 1. The idea is to prove that all numbers end up at 1.

Take 26.

So, 26 goes down to 1 in about eight steps, reaching a maximum of 40 along the way. Intriguingly, just the next number 27 takes a whopping 110 steps to ultimately make its way down to 1, even reaching a massive 9,232 in its journey.




*26 drops down to 1 fairly quickly*

Illustration: Rohini Subrahmanyam

Just like hailstones keep bouncing about collecting more water in the clouds but eventually crash down to the ground, Collatz conjectured that no matter which natural number you start with, you will always land at 1 – only the number of steps varies. Computers have tested this for numbers having up to 18 zeroes, and found that it ends up at 1, but a full proof – which can tie in all the infinite numbers into one neat explanation – has eluded mathematicians for decades. Even Terence Tao, professor of mathematics at University of California, Los Angeles and widely regarded as one of the best mathematicians of our time, hasn't been able to prove it completely, yet, although, he did edge close to cracking it in 2019.

In 1742, German mathematician Christian Goldbach wrote a series of letters to another mathematical great, Leonard Euler. In those letters, he outlined the famous Goldbach's Conjecture, which states that every even number greater than 2 is a sum of two prime numbers. We can test this in our heads for smaller numbers, like 8 being a sum of 3 and 5, 12 being a sum of 5 and 7, 18 being a sum of 11 and 7 and so on, but mathematicians haven't yet proved that it is true for *every* even number that exists.

Another famous unproven statement from around 1849 is the Twin Prime conjecture, which states that there are infinitely many prime numbers that are separated by two, like 5 and 7, 11 and 13, or 599 and 601 – again, we don't know if this holds true for all numbers. Many mathematicians are determined to prove such centuries-old conjectures. "Sometimes, [if] I find the question interesting, just for the sake of it, I'll stop everything else and work on that for a few days," says Apoorva. "I always try to do the maths that appeals to me. Maybe that's what inherently is called beauty here – [it's in] the eye of the beholder."

## Surprising shapes

Sarah Hart, Professor Emerita of Mathematics at Birkbeck, University of London, loves maths because she believes it can help us understand things around us. "[It] can explain how and why it is that the natural world coalesces on really beautiful, symmetrical, mathematical-looking structures," she tells me.

***'[Maths] can explain how and why it is that the natural world coalesces on really beautiful, symmetrical, mathematical-looking structures'***

Just like numbers, the world around us is a treasure trove of beautiful patterns – in structure and symmetry – all of which offer many problems for mathematicians to sink their teeth into. To understand this better, we need to swing towards geometry, or the study of shapes.

Rukmini Dey, Associate Professor of mathematical physics at the International Centre for Theoretical Studies (ICTS), Bangalore, studies the geometry of surfaces found naturally around us. She finds herself impossibly intrigued by how such surfaces are always optimised.

### Fascinating Fractals

Fractals are infinitely complex structures, and many have this unique property of "self-similarity" or zoom symmetry. The further you zoom into these structures, you'll see that they never seem to get simpler – they are made up of smaller and smaller structures that look exactly the same as the original one you started zooming into. The alveoli (air sacs) in our lungs, ferns, trees, rivers, and even lightning strikes, are all fractal in shape.

But self-similar fractals are the ideal case. Any curves or surfaces that are rough or jagged are fractals – shapes that are neither two nor three dimensional, but hover somewhere in between.

Think about a crumpled-up ball of paper. A sheet of paper is roughly two-dimensional, and a perfect paper sphere would have three dimensions. But a scrunched up ball of paper is a roughly 2.5 dimensional fractal – it holds more space than a sheet of paper, but less than a perfect sphere.

Now zoom out further, and imagine the coastline of any country. India's jagged coastline is a fractal with a dimension of about 1.13 and Britain's, which is "rougher" than ours, is a fractal of 1.21 dimensions.


Photo: Rohini Subrahmanyam

*Trees have self-similarity – each branch looks like a mini-tree*

As Benoît Mandelbrot writes in his 1982 book The Fractal Geometry of Nature, "Fractal geometry is not just a chapter of mathematics, but one that helps every man [person] to see the same world differently."

One such example is a minimal surface. You might have heard about how the *shortest path* between two points is a line. Similarly, a minimal surface is a surface that covers the *least area* within some closed curve in space.

Take blowing bubbles and soap films. When you dip a wire loop into a soap solution and lift it out, you will see a thin soap film clinging delicately between the edges of the loop. The loop here is the closed curve, which acts as a boundary – the soap molecules will always try to stay within this boundary and minimise the area that they occupy. The best shape for that is a thin film.

"Of all surfaces which are spanning that curve, the minimum surface is the one which has minimum area," explains Rukmini. Just like soap films, soap bubbles also try to optimise the surface area under some constraint. But they try to minimise the area around a fixed volume (three-dimensional) and end up always forming a sphere.

Soap films and bubbles are shapes that we can clearly see around us, but what about some shapes that are a little more abstract?

Imagine a point on the circumference of a wheel. As the wheel rolls along on a flat ground, this point will carve out a shape in space. That shape is called a cycloid.

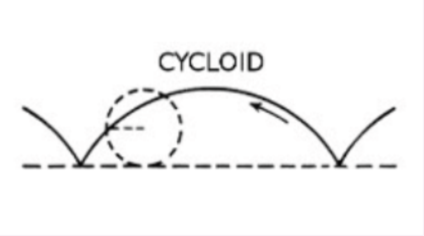


Image courtesy: Wikimedia Commons/ Pearson Scott Foresman

*The cycloid is Sarah Hart's favourite curve*

The properties of this curve are so beautiful, writes Sarah in a *New York Times* opinion piece, that it was even nicknamed the "Helen of geometry." The moniker was inspired by the Greek mythological character Helen of Troy, who was said to have "a face that could launch a thousand ships" and whom the legendary Trojan War was fought over.

For Sarah, however, the cycloid's beauty arises from how it manages to slide into different, unexpected scenarios.

"One of the things that we all love in mathematics," she explains in a podcast called *My Favourite Theorem*, "is when something you've studied over here reappears in a completely different context."

## Connecting the dots

One major aspect of maths that makes it beautiful, according to Harish-Chandra, is "depth". He writes, in his notes, that maths leads to an "establishment of an intimate connection between two facts where none seemed at all likely."

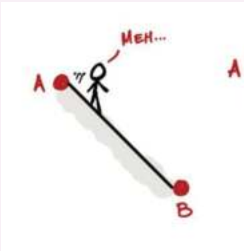
We see this in Dutch mathematician Christiaan Huygen's story. Sometime in the 1600s, Christiaan wanted to make a more accurate clock than what was around at the time. He came up with the pendulum clock, in which, after making a small approximation, one can assume that it takes the same time for the pendulum to swing back and forth, no matter what height you release it from. But the small approximation niggled at him. Is there any curve that genuinely has this property, he wondered, that no matter where one releases a particle on this curve, it slides down to the bottom taking the same time, every time?

He eventually figured it out. The solution to this tautochrone problem (which means "same time" in Greek), actually turned out to be a cycloid.

"We have an arch; you've got to turn the arch upside down. And wherever you release a particle from the top of the [upside-down] cycloid, it will reach the bottom in exactly the same time," explains Sarah in *My Favourite Theorem*. "[It's] what the pendulum almost does … but doesn't quite [fully] do."

A few years later, mathematician Johann Bernoulli publicly posed a related problem, called the brachistochrone problem. Imagine two points A and B, with B somewhat diagonally below A, and you roll down from A to B. What kind of curve should connect A and B such that you reach B in the shortest time?

At first glance, a line pops into mind. But note here that it's not asking for the shortest distance, but the least time. Sliding down a line might help you accelerate downwards, but if the line curves a bit at the start, you might get a bit of a head start and reach down even faster.




Sliding down a line may not be the fastest way to get to the bottom

Illustration: Rohini Subrahmanyam and Akshit Goyal

Lots of famous mathematicians submitted their answers to this problem, but one anonymous entry seemed to have the most elegant and beautiful solution. It was, as you may have guessed it, a cycloid. And the anonymous person turned out to be Isaac Newton.

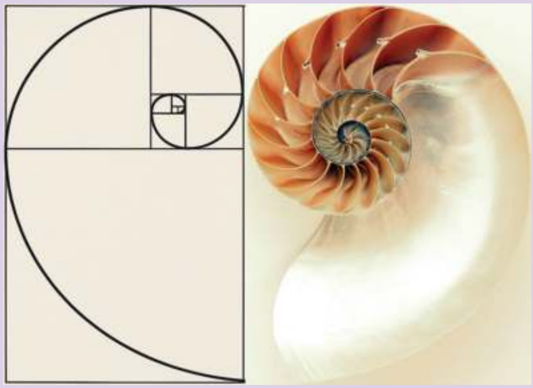
"You've got this amazing curve [the cycloid], which is a natural idea. And then it suddenly also can solve these totally different questions about particles rolling down in the quickest time or taking the same time," says Sarah in *My Favourite Theorem*. "That is why I love the cycloid so much."

### Spirals in nature

Another shape famously associated with nature is the Fibonacci spiral. To understand what that is, let's delve a bit deeper into the famous Fibonacci sequence – 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, and so on. Each number in this sequence is the sum of the previous two numbers.

For numbers higher than 5, if you take a number in the sequence and divide it by the previous number, you will get a ratio equal to about 1.6. As the numbers get higher, this ratio becomes closer to 1.618, called the Golden Ratio. Remember this ratio.

Now, make a series of squares, where the length of each square is a Fibonacci number. Then, run an arc through the squares. The resulting spiral is the Fibonacci spiral, or the Golden Spiral. Each time this spiral makes a 90 degree turn, it widens ever so slightly. It turns out that it widens by roughly a factor of 1.618, the Golden Ratio. A chameleon's tail, seeds in a sunflower, galaxies, nautilus shells – all look somewhat like this spiral.



Not all seashell spirals perfectly follow the golden spiral

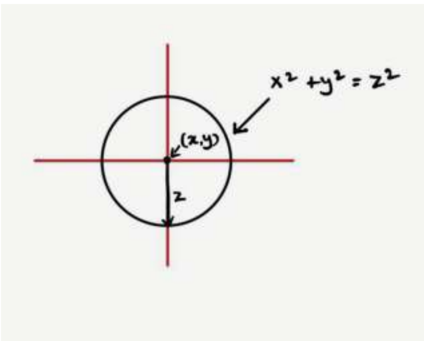
Image: ChatGPT (left) and Pexels/Pixabay (right)

But not all spirals in nature are Fibonacci spirals. "The reason you get spirals [in a nautilus shell] is because of the way that the shell grows – it starts off tiny, and then as it grows, it creates new material while also rotating," Sarah explains. "Only some shells actually have that exact [Golden Ratio] growth rate."

It turns out that if you model this kind of growth and rotation mathematically, you get what is called a logarithmic spiral. This need not always expand by a factor of exactly 1.618, and hence some objects – like galaxies and most nautilus shells – need not always follow the exact Golden Ratio.

Even the circle can be thought of in different scenarios, wherever there is some notion of distance, according to Jordan. “What I like about a circle is that it has such a nice algebraic description – it's the set of points at a fixed distance from a given point,” he explains. The equation of a circle is $x^2 + y^2 = z^2$, where x and y tell us where the circle’s centre is and z is its radius.

Illustration: Rohini Subrahmanyam




*The circle centered at the origin (0,0) of a two-dimensional coordinate plane*

“You could talk about it even in a context like genetic distance. If I want to look at the list of my relatives who share at least 1/8th of their genetic material with me, that's a circle, right?” he adds.

***‘What I like about a circle is that it has such a nice algebraic description’***

He is also amused by how the constants of a circle, like pi, come up in unexpected places. “They are like mathematical celebrities,” he says, with a laugh. “... coming up again and again in different contexts.”

## Rounding off

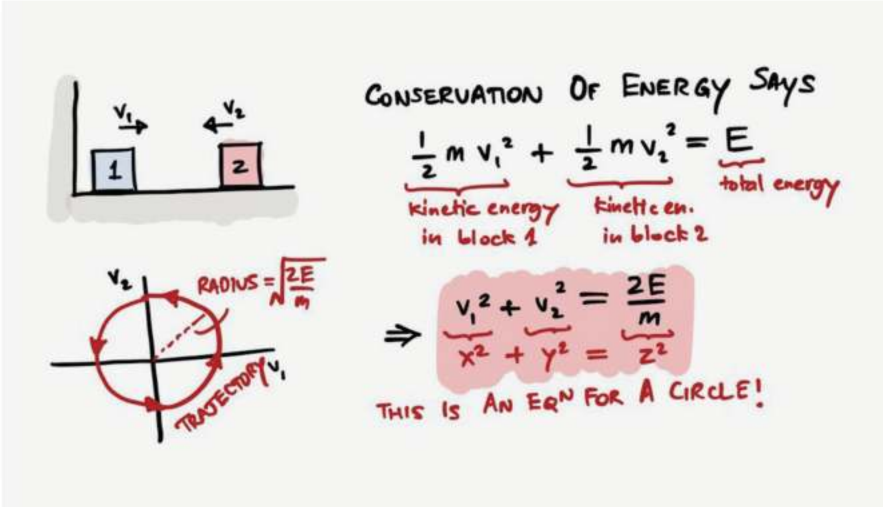
Circling back to Grant’s blocks in the beginning, if we were to now tease out a connection between the blocks hitting each other and counting pi, how would we go about it?

For that, we will need to invoke a bit of high school physics.

Kinetic energy: ½ mass (m) X velocity (v) squared = ½ $mv^2$

Law of conservation of energy: Total energy of the two blocks always stays constant.

Illustration: Akshit Goyal




*As Grant says, we took a problem based on the dynamics of blocks and converted it into a problem of geometry*

In the simplest case of both blocks having the same mass m, let’s say their velocities are v1 and v2 respectively. Then, no matter how many times they collide, their combined energies will be constant. Let’s now find the link.

And that is how colliding blocks connect to a circle, mathematically. If you look closely,  you’ll realise that we took a pattern – one that naturally emerged from moving blocks – and brought it into the context of geometry and shapes.

It takes more maths to go from the circle to pi, but even without that, just by finding the circle, we have solved a part of this little detective story. The beauty of maths, independent of its potential uses, is precisely in this process – of discovering hidden patterns and uncovering unexpected connections.

“People perhaps misunderstand mathematics as just doing really difficult calculations, but for me it's all about symmetry and pattern and structure,” says Sarah. “All humans have a natural affinity for them, so I think we are all mathematical thinkers.”

***(Edited by Ranjini Raghunath)***

### Mathematics in Music

Mathematical patterns are also found in music. As French mathematician Gottfried Leibniz once said, “Music is the pleasure the human mind experiences from counting, without being aware that it is counting.”

When we enjoy the feeling of a rhythm or are drawn to patterns in melodies, we are actually counting, almost subconsciously. “We enjoy a melody which has parts that repeat – we'll sing something and then we sing it again,” explains Sarah.

Even when it comes to harmonies, there is a mathematical explanation as to why some notes sound good together, according to Sarah. For example, two notes exactly an octave apart sound very harmonious together, and that is mostly because going up an octave is exactly doubling the frequency of the note. A lot of melodious music intervals – the pitch difference between two notes – are based on simple fractions.

“Mathematics is a language that is really perfectly suited to describing patterns, that is why it's good at describing beautiful things,” Sarah says.

# Design Dilemma

- *Spoorthy Kannur*

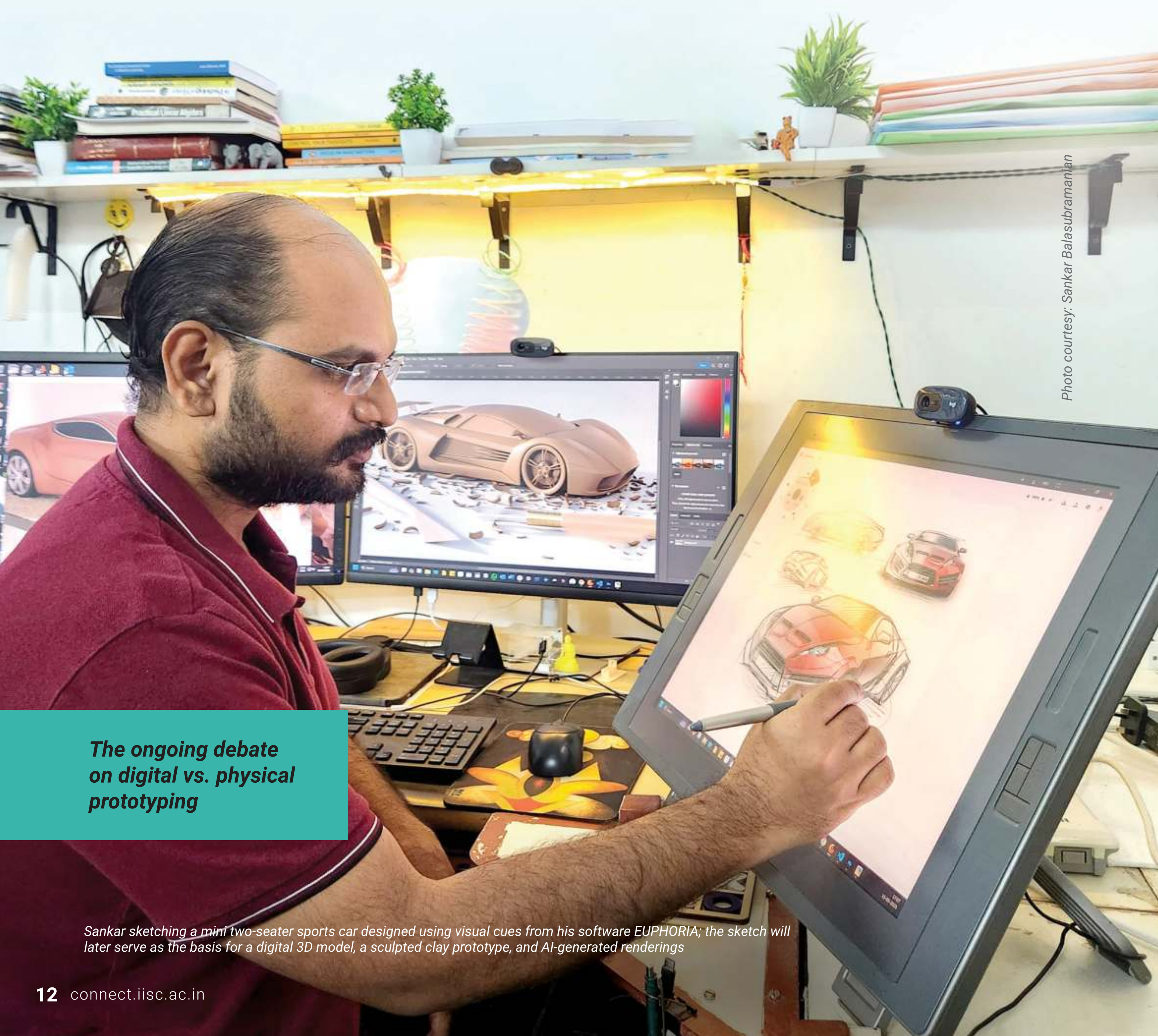


Photo courtesy: Sankar Balasubramanian

***The ongoing debate on digital vs. physical prototyping***

*Sankar sketching a mini two-seater sports car designed using visual cues from his software EUPHORIA; the sketch will later serve as the basis for a digital 3D model, a sculpted clay prototype, and AI-generated renderings*

It was supposed to be a simple task. As part of our coursework project on Applied Ergonomics at IISc's Department of Design and Manufacturing (DM; formerly known as the Centre for Product Design and Manufacturing, CPDM), my team wanted to design earphones with the perfect ergonomic fit, which align most closely with the human ear. We spent hours refining our prototype. We extracted ear dimensions from 3D ear models, designed earphones, ran simulations, and built a CAD model. After multiple all-nighters, we were finally set to print at around seven in the morning, weary but hopeful.

Six hours later, caffeinated and exhausted, the print was finally complete. One of my teammates took out the printed earphones and tried them on. To our embarrassment, they did not fit. Our mistake was glaringly obvious: We had directed the ear tips away from the ears rather than toward them, making the design unusable. With only an hour to go before the presentation, the project was a failure. The mistake was small, almost imperceptible in the grand design process, but its consequences were conspicuous.

If we had started with quick, handmade foam models, could we have caught this error before the design was locked in? The mistake cost us time, material, and momentum. But we learned a valuable lesson – in design, especially when working under pressure, decisions on how, when, and why to prototype make all the difference.

## The design process

Generally, the engineering design process is a step-by-step method to build useful things that solve problems. It starts with identifying a problem, then researching and brainstorming ideas. After that, design engineers plan and build prototypes – a rough version of the final solution. We test it, see what works and what does not, and then improve the design. Above all, it's the iteration of ideas that matters. It's like putting together a puzzle – but here's the catch: you're the one who has to design the pieces.

The process significantly depends on how those pieces are made: physically, digitally, or using a combination of both. Before digital tools arrived, prototypes were built by hand. Designers carved wood, bent wire, and glued bits of foam together, chasing the shape of an idea with whatever their workshop could spare. It was slow, sometimes messy, but mistakes were visible and tactile. When computers entered the picture, screens replaced drafting tables, and digital models let designers test, tweak, and discard ideas without touching a single tool.

***It's like putting together a puzzle – but here's the catch: you're the one who has to design the pieces***

For a while now, the question of when to make digital and when to make physical prototypes has been something of an obsession for me. Maybe it is because I keep returning to the same debate across mediums – digital art versus traditional, e-books versus paperbacks – and how digitisation is infiltrating everything. To see how others felt, I conducted a poll among the Master of Design (MDes) students at IISc: "At gunpoint, if you had to choose between digital or physical prototyping, which would you choose?" To my surprise, most chose physical. Given the scale of our projects as students, it is usually much easier to design a 3D model on the computer and print it than to source hardware and modify it to build a prototype. Physical prototyping demands much more time and resources, especially when balancing coursework and tight deadlines. Yet, despite the challenges, most still favoured the hands-on approach.

"There's something about holding the design in your hands that no screen can replace," says Yash Dudhpachare, a second-year MDes student of DM. "I like that physical prototypes give immediate feedback when you touch and observe them in real life."

## Physical in a digital world

In the real world, too, there seems to be a propensity for physical prototyping. Sankar Balasubramanian, PhD scholar in the Department of Mechanical Engineering at IISc who currently works on Computational Product Design, offers a perspective from the automotive industry. "In automotive design, form comes first," he says. The process begins with sculpting full-scale clay models to capture the essence of the design. These models then undergo testing under various conditions, revealing how light and shadow interact with the surface. This helps assess the aesthetic appeal of the vehicle by refining the curves and edges. Later, this model facilitates collaboration between designers, engineers, and marketers to not only visualise the product but also plan for its performance.

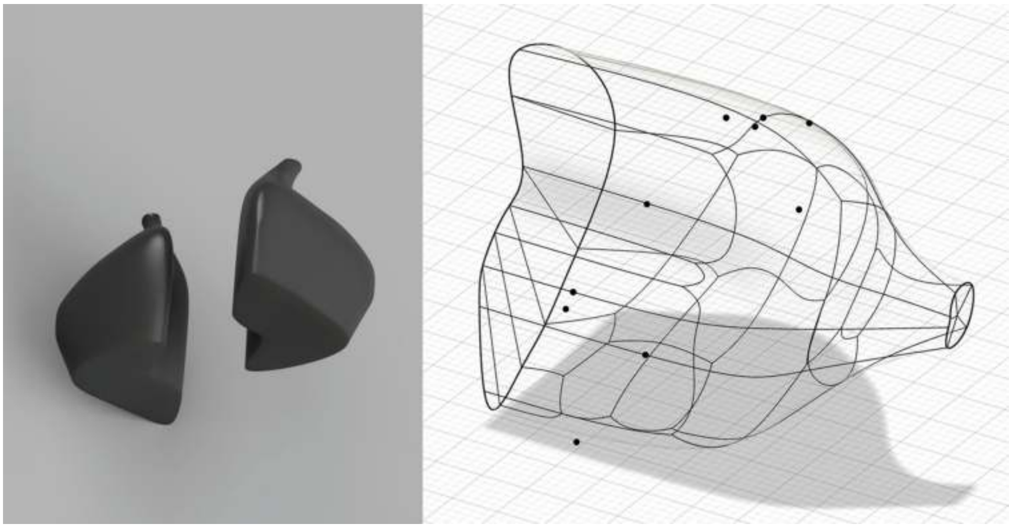


*Image: Spoorthy Kannur*

*(Left) A digital render of the earphones in which the ear tips were mistakenly directed away from the ear; (Right) A boundary model of the earphones highlighting the critical points of comfort for a human ear*

Photo: Spoorthy Kannur

Yash cutting aluminium brackets for making a support channel prototype for his biophilic curtain wall project at the Prototyping Lab, DM, IISc

Once the form is established, the process moves into digital refinement. Through weeks of design and validation through simulations, the team creates a fully functional physical prototype, complete with moving parts. Often, even after extensive digital simulations, the physical version can still reveal unexpected flaws. "Solving one problem can create another," says Jegannathan Kannan, from the Body Design team at a leading car manufacturing company. In one of their product designs, they noticed a discrepancy in the assembly of the clamp-rod system; although it performed perfectly in digital simulations, it failed during physical testing. "It looked perfect on screen, but the physical fit was off by just enough to stop the whole assembly. We modified this, but later learned that this had led to another problem."

This limitation of digital prototypes is precisely why physical models seem to remain indispensable. While digital simulations are more cost-effective and time-efficient – especially in fields like automotive, aerospace, and biomedical engineering, where materials are expensive and regulations are strict – they might miss critical aspects in the design.

***While digital simulations are more cost-effective and time-efficient, they might miss critical aspects in the design***

This becomes even more crucial for products at the nanoscale. "When operations scale down, digital models often struggle to capture the fine details of physics," says Saravanan Murugaiyan, PhD scholar in Product Design and Engineering, DM at IISc. His research focuses on developing a medical device intended for implantation in the brain, where precision is crucial. While the device is the size of a human hair, its electrodes that connect to the neurons measure only a few micrometres. It requires rigorous testing, starting with small animals like rodents, then progressing to pigs, and eventually non-human primates before being considered for human trials. In such cases, the margin for error is almost nonexistent. "When safety is critical, digital simulations alone are not enough," says Saravanan.

## The human touch

Komal Shah's journey from student to entrepreneur began at DM, where she honed the skills that would later shape her startup, Periwinkle Labs, currently incubated at Foundation for Science, Innovation and Development (FSID) at IISc. Komal's startup is developing wearable garments, like a pair of shorts, designed to provide adaptive stimulation for the treatment of urinary incontinence. This would enable patients to manage their care at home and reduce the need for frequent clinical visits.

Komal recalls how the resources and mentorship at DM allowed her to bridge the gap between theory and practice. "What I really learned at DM was to reason and rationalise every decision as a designer," she says. "It wasn't just about making something that looked good; it was about fulfilling a real user need with care, backed by data and understanding."

Komal quickly realised that in the field of pelvic health, her prototyping approach needed to balance both form and function. "For fabric-related issues involving fit, flexibility, and comfort, there's no substitute for a physical prototype. We drape it on mannequins or real users and see how it fits. But when it comes to electronics, like battery placement or signal flow, we start with digital models. It's faster, and we can spot obvious flaws before we commit to hardware."

Using hybrid prototyping approaches is particularly necessary in healthcare-related products. Alumnus Deval Karia, CEO and co-founder of OpenMedLabs – also incubated at FSID – exemplifies this by following a User-in-the-Loop Approach to Engineering Design (UILED).

OpenMedLabs, which designs devices like insulin pumps and related accessories to ease the daily burden of people with diabetes, approaches prototyping as a non-linear process. "It's not about finishing a stage and then testing," Deval explains. "We constantly move back and forth."

***'It's not always clear in the beginning where things will go wrong, but that's why you prototype'***

For example, when evaluating the usability of the insulin pump's interface, they found that digital renderings fell short of conveying how the device would actually feel in users' hands. "We needed a mock-up for users to hold, in order to ensure accurate feedback on portability," he adds. They combined a physical mock-up with digital buttons on a screen to simulate the user experience. "It wasn't ideal," Deval admits. "But it helped people imagine how the final device would function."


Photo courtesy: Vinay Reddy

*A failed prototype of a flower harvesting machine designed by Sickle Innovations*

## Make. Break. Repeat.

There's a peculiar magic in watching a prototype fail – not in the tragedy of collapse or malfunction, but in the slow revelation of what went wrong. Perhaps a component just doesn't hold, the texture simply feels wrong to touch, or a curve just feels a bit off.


Photo courtesy: Komal Shah

*A physical prototype of Periwinkle Labs' shorts being tested on a mannequin*

"Failure is a teacher," says Arjun A, deputy manager at Titan Company. "It's not always clear in the beginning where things will go wrong, but that's why you prototype." Arjun works in research and development, focusing on designing watch movements – the intricate mechanisms that dictate how a watch functions. At Titan, the movement and its variations are what distinguish one model from another, he says. Perfecting it requires countless iterations; the key is in treating every stumble as a signal for improvement. "The first version always fails in some way, but it's how we pivot from there that counts."

With Swiss premium watchmakers expanding into India and market forecasts projecting steady growth in the luxury segment through 2030, teams like Arjun's are under pressure to move faster without compromising quality. His group is introducing AI automation into traditionally manual processes such as gear calculations and harmonic motion modelling to gain speed.

Vinay Reddy, co-founder and CTO of Sickle Innovations, which focuses on improving conventional farming practices through design interventions, concurs that failure is only a part of the process. "You may fail, and that's okay. What matters is that you lead with knowledge. That is the only real level playing field," he says. As an alumnus of DM, he reflects that students working in college labs often face resource constraints – like limited access to specialised equipment, budget restrictions, and tight project timelines – which shape the way projects unfold. "Resource limitations actually push you to design faster, lighter, and smarter," he says.

Prototyping is never as smooth as it seems. It's a crooked road, full of mistakes and discoveries. Foam, fabric, CAD – they all trip you up. Failure is not just expected, it's part of the deal. It is feedback. You go back to the user, the materials, the purpose. You ask better questions, make smarter choices. But the effort can be worth it because in the end, like any good puzzle, it all starts to fall into place, piece by piece, until you've got something that almost feels like it was meant to be.


***Spoorthy Kannur is a Master of Design student at IISc, and a science writing intern at the Office of Communications***


***(Edited by Abinaya Kalyanasundaram)***

# Building a Department

*- Sandeep Menon*

*Photo courtesy: Vinay Sriram*

***How NS Govinda Rao laid the foundation for civil engineering***

A photo of a moustachioed bespectacled man looks down from the wall of the office of the Department of Civil Engineering at IISc. A few steps further, in the Chairperson's office, another portrait watches on from above the door. It is fitting that NS Govinda Rao has a watchful eye on the department's proceedings and decision-making. Although the man never worked in these offices (he sat in room number 303 of the Department of Electrical Engineering), Rao played a pivotal role in the nurturing and growth of the Department of Civil Engineering. It has been more than half a century since Rao left the department, but his name still reverberates in these halls, kept alive by those who knew him and others who know of him.

There are stories of Rao's benevolence, of his love for science, and justified anger. Tales of Rao calling the Registrar and demanding that he sort out a clerical error regarding a student's nonpayment of tuition fee, and slamming the phone receiver (The red tape was cut immediately). Other chronicles talk of Rao securing money and scholarships for his students out of thin air. There are several more interesting tales, many are true, others made true apocryphally. The picture that is painted is that of a man who was accomplished, capable, and humane. He was also the reason the Department of Civil Engineering became a cornerstone of the Institute.

## From industry to the Institute

Rao was born on 6 February 1907 to Radha Bai and NK Srinivasa Rao in a high-achieving family in Mysore city, to which place his great-grandmother had migrated from the small Maharashtra town of Naladurga in 1860. His great-grandfather was the deputy commissioner, and his father a high court judge. As the second child with five sisters, Rao had the environment and aptitude for academic excellence, influenced by his father's intellectual pursuits that extended to mathematics, astronomy, philosophy, and agriculture, among others. After he completed his BE with honors from Mysore University in 1928 (he secured the first rank and two gold medals), he eventually joined the Public Works Department as an assistant engineer.

Rao was jarringly thrust into the real world when he lost his father and had to shoulder the responsibility of his family at the young age of 24. Despite personal hurdles, Rao grew in his career. He worked extensively on cavitation, siphons, and other areas of hydraulics, and he also pioneered research in the area of soil dynamics.

***Govinda Rao worked extensively on cavitation, siphons, and other areas of hydraulics, and also pioneered research in soil dynamics***

He played a major role in the survey, design, and construction of several irrigation projects such as the Krishnarajasagar Dam, Visvesvaraya Canal, and Markandeya Dam. He also taught at the Government Engineering Diploma School in Bangalore for two years. In 1945, he became the Assistant Director of the Karnataka Engineering Research Station (KRS), Krishnarajasagara.

His elevation at his work was the result of his nearly two decades of research publications, particularly his association in the design of the Ganesh Iyer Siphon, which is a special kind of domed volute siphon that ensures excess inflow into a reservoir. This gave him a reputation as a leading voice in hydraulics research and caught the eye of celebrity engineer M Visvesvaraya. It is said that it was upon Visvesvaraya's recommendation that the then IISc director, MS Thacker, appointed Rao as the head of the Civil and Hydraulic Engineering section, which was established as part of the Department of Power Engineering in 1950.

It was a time of great turmoil and flux. The country was thrust into independence and was trying to find its feet. Power and water were major areas of focus, and several structural, geotechnical, and hydraulic problems needed to be solved for the smooth functioning of the country. Rao was seen as an ideal candidate because he married industry knowledge with academic rigour. Though he did not have a doctorate to his name, his research during his time in the KRS Research Station had shown that he had the aptitude to lead a department.

Under his watch, the Civil and Hydraulic Engineering section grew and became the Department of Civil Engineering in 1972, five years after he retired. He developed three research streams within

Photo courtesy: Vinay Sriram

*NS Govinda Rao (seated second right) with his colleagues at the project subdivision, Krishnaraja Sagara in 1934* the department – Water Resources, Structural Engineering, and Geotechnical Engineering. He also started Master's programmes in Power Engineering, and Soil Mechanics and Foundation Engineering. His tenure saw several degrees awarded and many research papers published in leading national and international journals. The department grew from strength to strength and was recognised as a Centre for Advanced Studies by the University Grants Commission, in recognition of the quality of work that came out from the department led by Rao.

## The visionary "non-academic"

Rao was a curious and capable researcher. He published over 100 papers in reputed journals and frequently attended international conferences. His significant contributions were in the areas of cavitation, laminar and turbulent flows, flood adsorption, design of dams and canals, siphons, and more. He also served as the editor of the *Journal of the Civil Engineering Division*, published by the Institution of Engineers between 1962 and 1965, and as a member of the panel of editors for *Hydraulic Research* published by the International Association for Hydraulic Research in 1963. In 1965, he was elected president of the Institution of Engineers, and the Indian Society of Soil Mechanics and Foundation Engineering.

***As good as Rao was at science, he was perhaps a better administrator***

As good as Rao was at science, he was perhaps a better administrator. The Civil and Hydraulic Engineering section at IISc started with fewer than a dozen people. To build it, he needed workforce, expertise, and finances. The finances were straightforward. He dug into his little black book, which had several contacts from his years in government service.

At the Institute, there was plenty of technical know-how. This, combined with Rao's ability to consider real-world impact and outreach, turned out to be a fruitful union. Being a "non-academic" in an academic institute, as he frequently quipped, he was able to make the best of both worlds.

Photo courtesy: Vinay Sriram

*NS Govinda Rao (centre) with dignitaries during the visit of Prime Minister Jawaharlal Nehru at IISc*

"His contacts in the Central Board of Irrigation and Power (CBIP) got him projects [to work on]. Then, he could get students into the department under the CBIP scheme. He built the department through the CBIP schemes," says KS Subba Rao, former professor in the department.

"The civil department had a lot of money because of the projects they were involved in," says K Chandrasekara, former professor of structural engineering at IISc. "Rao's contacts within the government and his rapport with people helped a lot with getting projects, consultancies for dams and other works, and funding."

With the finances sorted, Rao built up a department filled with capable scientists. He encouraged his team to build equipment and was willing to fund it. The high-speed closed-jet water tunnel facility, the first of its kind in India, was designed, fabricated, and established due to Rao's vision, which helped with research in cavitation. "He travelled around the world to learn how to build it, and finally it was built based on a design from Caltech (California Institute of Technology)," says Rama Prasad, another faculty member in the department at the time. The reason for choosing the design was that it was the most suitable for the rocky crust found in the Institute.

The hydraulics laboratory was also built during his time. Research around soil mechanics, hydraulics, and structural engineering developed with his active support.

## Leaving behind a legacy

Rao maintained an open-door policy in his office. When KS Jagadish, a former student of Rao's in 1961 who later became a professor of structural engineering at the department, approached him to change his area of interest, Rao was highly encouraging. "He was very open-minded that way," Jagadish admits. With the department having an interdisciplinary feel to it since its inception, thanks to its close association with power engineering, Rao encouraged his students to seek advice from other heads of departments and even director Satish Dhawan himself.

Rao had an eye for talent and was not averse to accommodating talent that he spotted to the advantage of the system. One anecdotal story talks about Rao encouraging a student who had received a second-class rank in his Bachelor of Engineering degree to author a research paper and publish it in the *Journal of Institution of Engineers (India)*, upon which he was promptly admitted to a research programme in the department.

His students also remember him as a teacher who went beyond books. "He taught students to learn, encouraged them to believe in their research, and to speak out. He also promoted student activities," says S Vedula, a former faculty at the department.

Once part of his department, everyone was treated as an extended family. Conceivably, the role of the patriarch came to him naturally, having had to take over as the head of the family at an early age and then having a family of nine children himself. His daughter describes him as a loving, approachable, and present father. “He was a great storyteller ... talkative, easygoing. All the children found him approachable and he never lost his temper,” says Vatsala Ramamurthy, his daughter.


Photo courtesy: Vinay Sriram

*Group photo with faculty, students and staff of the Civil and Hydraulics Engineering department on the eve of NS Govinda Rao’s (bottom row, ninth from left) superannuation in 1967*

His love for animals and gardening also shows a certain want to nurture. Due to his extended family, dinner time attendance sometimes hit more than two dozen people in the kitchen.

In one instance, when one of the department’s faculty members was given a promotion over the others, he was able to placate the irate parties by securing them scholarships for higher studies in foreign universities. The benefits were two-fold, it ensured harmony in the department and more knowledge as well.

When Rao retired in 1967, the funds and schemes from CBIP also slowly waned, but the department had already established itself as a powerhouse and was more than capable of standing on its own. Since then, the department has grown rapidly, spawning several groups, laboratories, and branches, and contributing to several nation-building projects that are shaping the country. Though the current department might be far from the one Rao was familiar with, he remains a central figure in its collective memory, commemorated by the bi-annual Prof NS Govinda Rao Memorial Lectures held on his birth anniversary.

***‘He taught students to learn, encouraged them to believe in their research, and to speak out’***

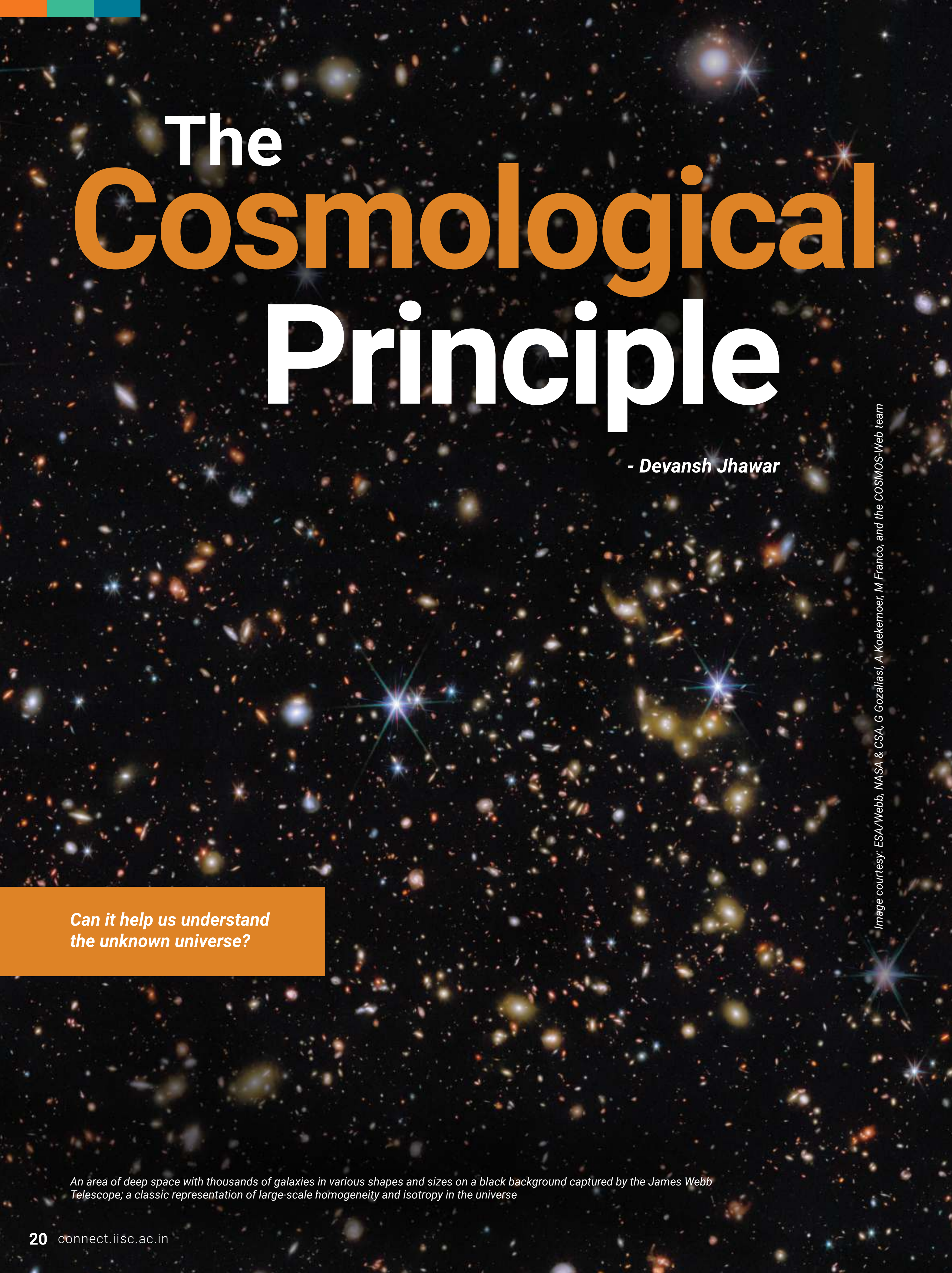
Photo courtesy: Vinay Sriram

*NS Govinda Rao with his wife Saroja Bai and their children at his residence in Bangalore*

Rao passed away on  22 December 1995. In his long journey, he was known for multiple pursuits. Following his retirement, he served as an advisor to the CBIP till 1971. He was invited to various countries, such as Australia and Germany, to deliver specialist lectures. He was also a member and consultant for various bodies in the power and infrastructure field, even serving as the president of a few, such as the Indian Geotechnical Society and the Institution of Engineers (India). But perhaps one of his most lasting legacies is building the core of what would make IISc’s department of civil engineering.

Subba Rao emphasises: "A department of civil engineering research was almost unheard of [at the time]. That was his vision."

***(Edited by Rohini Subrahmanyam, Abinaya Kalyanasundaram)***



# The Cosmological Principle

- Devansh Jhawar

**Can it help us understand the unknown universe?**

*Image courtesy: ESA/Webb, NASA & CSA, G Gozaliasl, A Koekemoer, M Franco, and the COSMOS-Web team*

*An area of deep space with thousands of galaxies in various shapes and sizes on a black background captured by the James Webb Telescope; a classic representation of large-scale homogeneity and isotropy in the universe*

One day in the spring of 1543, a canon named Nicolaus Copernicus, lying on his sickbed, suddenly awoke from a coma that he had been put under because of a brain stroke. Resting beside him was the first copy of his magnum opus: *De revolutionibus orbium coelestium (On the Revolutions of the Heavenly Spheres)*. Copernicus had finally relented to having his work published under pressure from his pupil, Georg Rheticus.

Years of deliberation and fear of ensuing controversy had led to this moment. Until then, most people, particularly religious institutions like the church, believed that the Earth was the centre of the universe, and that the heavenly bodies revolved around our planet. This was called the geocentric model. Anyone with ideas contrary to this would have been considered a heretic.

But Copernicus argued in his work that Earth's place in the cosmos was not special – it was not the centre of the universe. Although Copernicus would not be alive to witness it – legend says that he died soon after he laid eyes on his lifetime's achievement – his work would send shockwaves throughout the scientific community, upending one of the most concretely believed systems of the medieval times. This marked the beginning of what was termed "the Copernican Revolution."

The Copernican model was the first step towards our understanding of the universe. Copernicus had placed the sun at the centre of the universe. Centuries later, a galactocentric model took shape, which placed the centre of the universe at the centre of the Milky Way. "Initially, people were even thinking that our galaxy is the entire universe," says Chethan Krishnan, Professor at the Centre for High Energy Physics (CHEP), IISc.

"Then it happened that, in 1924, Edwin Hubble was the first person who used a very powerful telescope – powerful in comparison to its peers then – to calculate the distance to a nebulous object that we could see, now called the Andromeda galaxy," adds Abhijeet Singh, PhD student at CHEP, IISc. "He proved that it was so far away that it could not be within the Milky Way galaxy. It had to be a separate galaxy, not some cloud within our own."

Over the last century, our ability to peer into the cosmos has grown exponentially. Telescopes around the world and across space have captured billions of images and signals over mind-boggling distances. The huge amount of data about the universe that we have gathered has also led to a humbling realisation: What we know so far is still miniscule compared to what we don't know about the universe. How can we then observe and predict patterns about the universe with the limited data that we have? How do we build models that can help explain unknown processes and entities in the universe?

***What we know so far is still miniscule compared to what we don't know about the universe***

These questions have stumped cosmologists for a very long time. The answers, some have found, lie in coming up with certain theoretical assumptions.

"[For example], given the fact that we know very little about the distribution of matter in the universe, let us make the assumption that it is uniformly distributed throughout," Chethan explains.

This assumption, known as the cosmological principle, is the idea that, on scales larger than 250 million light-years in distance, the universe "looks the same whoever and wherever you are," as Scottish astronomer Andrew Liddle once described it. A spectator on Earth will find the universe to be just as vast and saturated with celestial bodies as another viewer looking up from a galaxy a few billion light-years away.

"The cosmological principle is the symmetry principle that we assume governs our universe at large scales, inferred from what we observe," says Ranjini Mondol, PhD student at CHEP, IISc.

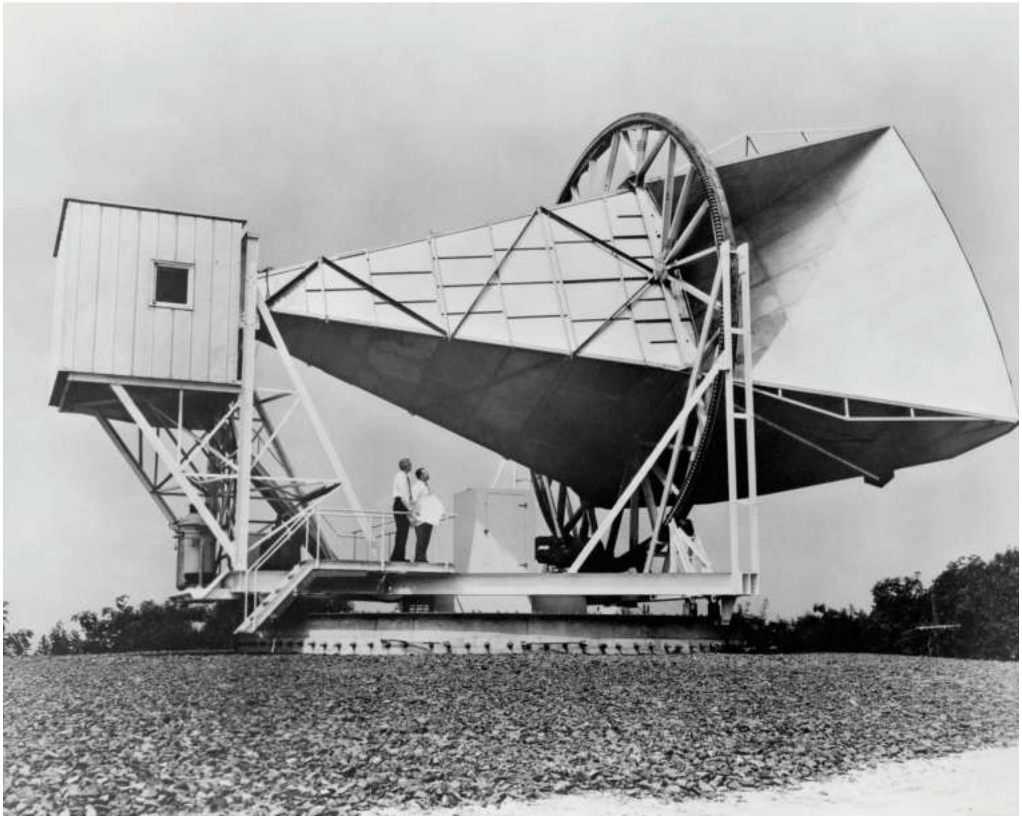
What this means is that scientists assume that the universe displays symmetry (or uniformity) in at least two properties: homogeneity and isotropy. Homogeneity means that any large enough slice of the universe has similar properties – like density and number of galaxies – as every other slice. Isotropy, on the other hand, refers to similar properties in all directions from a particular slice. For example, glass is isotropic because it has similar properties like strength, texture and brittleness in all directions, whereas an anisotropic material could have, say, different values of electrical conductivity along x, y and z directions.

"Suppose the universe is not isotropic, this means that it is preferring a specific direction over others, or maybe a few directions over others. But what is the mechanism that makes the universe pick those directions?" asks Abhijeet. Explaining these preferences might become too complicated, which is why scientists have assumed that the universe doesn't pick any specific direction. With the cosmological principle in place, the universe thus went from being galactocentric to acentric, or having no identified centre.

Assuming homogeneity and isotropy allows us to extrapolate data from the observable universe to the unseen universe, making the modelling of the cosmos much, much easier. Along with that, since the universe does not hold any location to be special, we can conclude that the science we come up with is unbiased, and not different for different locations. The principle also allows us to ignore complex details like the structures of galaxies, and gives us a better overview of the objects that are being studied.

"The cosmological principle is quite like the Copernican idea in some way, which is basically that we are not in a special place in the universe; at least spatially, we are not," observes Chethan. "Almost everything that we know about the universe is built on the cosmological principle."

Photo courtesy: Wikimedia Commons/NASA



*The horn antenna at Bell Telephone Laboratories in Holmdel, New Jersey, used to discover the cosmic microwave background radiation*

This relic radiation, known as the Cosmic Microwave Background (CMB) radiation, is the universe's own background glow, an echo of its creation. It can't be "seen" using a standard telescope, but a sufficiently powerful radio telescope can pick up a faint glow in the form of an electromagnetic wave of millimeter wavelength. The most intriguing part, however, is that the temperature of this radiation is found to be the same, around 2.75 Kelvin or -270.4 ℃, wherever it is detected.

"The fact that the CMB has the same temperature in any direction in the sky is actually a very strong piece of evidence for the cosmological principle," Chethan posits. Of course, the value might deviate very slightly from 2.75 Kelvin, but these subtle variations are very hard to detect. "It is not an easy task to make any object, say a ball of glass, which is as uniform as the CMB is. We would have to use very sophisticated technology to be able to do that," remarks Abhijeet.

***'The fact that CMB radiation has the same temperature in any direction in the sky is actually a very strong piece of evidence for the cosmological principle'***

## Cosmic confirmation

One of the reasons why the cosmological principle came about was because physicists, as they often do, wanted to simplify the mathematical analysis used to study the universe. This had to be done because a major part of the universe was, quite literally, in the dark. The principle helped scientists extrapolate data taken from the observable universe and generalise it to the greater, unseen cosmos. But surprisingly, with more data coming in from telescopes and spectroscopic instruments, scientists realised that a lot of the analysis they made based on the principle held true. "As telescopes became more and more powerful, for a long time, there was nothing that went against [the Cosmological Principle]," notes Abhijeet. "People were surprised that this simple assumption could explain such complicated data sets."

One such dataset is the Cosmic Microwave Background (CMB) radiation.

In 1964, Arno Penzias and Robert Wilson, physicists at the Bell Laboratory in the USA, were tinkering with a hypersensitive 15-foot-long horn antenna to employ it as a telescope in measuring radio signals from outer space. It was critical that all possible ground signals that could interfere with such radio signals be eliminated. However, even after taking stringent precautions, when they pointed the antenna towards outer space, they recorded a mysterious background noise in the data collected – like static coming from an FM radio. It seemed to be coming from all directions in empty space – spots with no seen stars or galaxies. The soon-to-be Nobel laureates even tried scrubbing pigeon droppings from the antenna, thinking it would reduce the background noise, but to no avail.

A short distance away, American astronomer Robert Dicke and his colleagues at Princeton University were preparing to search for microwave radiation that they theorised must be a remnant of the Big Bang – the explosion that created the universe. Now that Penzias and Wilson were at a standstill, they started searching for theoretical explanations, and contacted Dicke. After the phone call, Dicke famously proclaimed to his colleagues: "Boys, we've been scooped." He realised that the noise happened to be exactly what they were looking for.

"Our assumptions on isotropy and homogeneity match with data on CMB at a very, very good level of precision," Ranjini says. "This makes CMB a smoking gun signature that, at least in the very early universe, our universe was homogeneous and isotropic."

Assuming the cosmological principle to be true, scientists have concluded through certain observations that 70% of the universe is made up of dark matter. This has allowed cosmologists to create a model of the universe, called the Lambda CDM model – the most widely accepted model as of today. Simply put, the model posits – based on certain theories and maths calculations – that our universe began with the Big Bang and expanded outward, carrying both visible and dark matter, and dark energy.

"As more data kept coming in, it was just validating this standard model, which relies on the cosmological principle," Chethan says.

But the Lambda CDM model is just one possible explanation for why the universe is the way it is. "So, whenever you come up with any model of the universe which is not based on the cosmological principle, it has to explain everything that this principle has so far successfully explained. That becomes a huge challenge to take on," Abhijeet mentions.

Some bold scientists have decided to take on this challenge, especially because we have now collected enough data about the cosmos to question the universal validity of the cosmological principle. One such weapon in their arsenal has turned out to be the Hubble constant.

*Image courtesy: NASA, ESA, and the Hubble Heritage Team/ H. Bond at STScI and Penn State University*

*Hubble telescope image of RS Puppis, a type of variable star known as a Cepheid variable*

## Constant tension

In 1929, astronomer Edwin Hubble, peering through the 100-inch Hooker telescope – then the world's largest – made an astonishing observation: extraterrestrial bodies like stars and planets were fleeing away from us, and the further they were, the faster they fled. Of special interest were stars known as the Cepheid variables. The brightness of these stars varies sinusoidally, similar to alternating currents (AC) – it repeatedly oscillates between a maximum and minimum value. The time period of this variation in brightness is related to the stars' actual luminosity. Astronomer Henrietta Leavitt was able to predict how far away from Earth these stars were by noting how dim they were as viewed from Earth in comparison to their luminosity. Hubble, along with fellow astronomer Milton Humason, established a mathematical relationship between the distance to these stars and the velocity with which they were travelling away from Earth. This speed was found to be Hubble constant times their distance from Earth. Thus, the Hubble constant tells us the rate at which the universe expands.

There are multiple ways of measuring the Hubble constant. The standard model of our universe which assumes the cosmological principle to be true, along with the help of CMB, calculates the present-day value of the constant to be 67.4 kilometres per second per megaparsec (1 megaparsec is about 3.26 million light-years). However, modern technology has allowed us to precisely measure the actual recession speed of galaxies and their distance from Earth, leading to a Hubble constant value of around 72-73 km/s/Mpc.

The first method calculates the constant from the early universe – using CMB and the cosmological principle. The second method uses late universe celestial bodies – galaxies and supernovae close to Earth – to calculate the value of the Hubble constant. Some cosmologists now believe that perhaps the discrepancy means that the universe may not be as homogeneous and isotropic as previously thought.

Critics of the principle argue that the reason why the standard model has come up with such a different value for the Hubble constant is that it relies too much on the cosmological principle. "Some people say that this means that the cosmological principle is not valid once you try to measure the rate of flying apart of things very, very precisely," Abhijeet mentions.

The discrepancy between the Hubble constant values has led to differences in estimates of the universe's age, and also has some scientists questioning our understanding of dark matter and energy. They even suggest that something fundamental needs to be revised about this accepted idea that began with the Copernican Revolution centuries ago.

"These little hints about the fact that the Hubble constant as measured from the nearby universe and also from the early universe, seeming to be in tension, is kind of interesting. I hope that it is actually a real problem … because then it is a hint about some new thing," Chethan opines.

Abhijeet concurs. "This space [cosmological principle] has to be watched very, very carefully. If it actually turns out not to be true – once we do very fine measurements and put it to serious scrutiny – that would be a very exciting time for physics, and a lot of work would have to be done."

***Devansh Jhawar is a first year BSc (Research) student at IISc, and a science writing intern at the Office of Communications***

***(Edited by Ranjini Raghunath)***

CONNECT ASKS

# What does “summer” mean to you?

Summer instantly reminds me of the time I spent in Germany last year. It was the best three months of my life, and I got to do research in mathematics. I had firsthand experience of what research looks like in mathematics, and I travelled around Germany. I also saw the Eiffel Tower in Paris.

**Anmol**

*Bachelor of Science (Research) student*

Mangoes! I love mangoes. Being from Maharashtra, the amazing varieties I grew up with – Alphonso from Ratnagiri and some local favourites – are hard to find here in Bangalore due to the different climate. My parents generously supply me with these varieties every summer, thus saving me from the FOMO and the expense (*laughs*). A childhood memory that's close to my heart is playing '*lagori*' with my friends all summer, without touching a book. Those were the best days. Being a PhD student at IISc, summer vacations are a thing of the past (sighs). But I occasionally like to indulge myself in bird watching – a hobby that I picked up several years ago from my school teacher, a zoologist, who would take us on birding trips during summers. Bangalore's rainy summer days bring out lots of paradise flycatchers, which can be spotted around the campus.

**Apeksha B**

*PhD student, Department of Microbiology and Cell Biology*

Mostly me dramatically declaring '*bahot garmi hai, yaar!* (It's so hot, man!)' at least 10 times a day. Jokes aside, I love mangoes, and it's mango season. These days, I have them maybe once a week, which feels like a scam compared to my childhood summers, where breakfast was mangoes (*chuckles*). I also like those rare cold breezes that sneak in once in a while … they are like getting results in PhD - rare, refreshing, and over before you can process what happened, but you learn to deeply appreciate them when they show up. Back in the day, I'd spend my entire summer vacation playing cricket in the mornings and evenings with my friends and cousins. We'd only stop when the mosquitoes were out. Aah, the good old days!

**Vivek Kumar**

*Integrated PhD student, Department of Physics*

When someone says summer, the first word that comes to my mind is exploration! It can be an exploration in terms of going on vacation with my family, or in terms of the internships that I have done during my bachelor's, or it can simply be a break. But every break is an exploration for me!

I like to learn new skills during the summer. Last summer, I tried to learn skills that would be relevant for my placements. The summer before that, I did an internship at IISc. During that time, I did not know that I would get admission here later, so during that summer, I was exploring IISc like I would never get to come here again!

**Ujjwal Chaudhary**

*MTech student, Department of Electronic Systems Engineering*

The moment someone says summer, I reminisce about my home. May and June used to be the months of summer vacation, so I remember plucking a lot of mangoes and relishing them. I come from the Konkan coast, and since summer is the season of mangoes, a lot of the cuisine revolves around this fruit. In particular, the Konkani curry made of mango seeds, the dish '*ambe upkari*', is something that I really cherish. I also recollect spending a lot of time in the garden watering plants since the temperatures shoot up.

**Abhishek Ayyappa**
*MTech student,*
*Department of Mechanical Engineering*

To me, summers have always felt bright and happy. Although the entire season brings a positive feeling, I particularly love the beginning part of the summer, right after spring ends. I come from Nagpur, and summer there can be quite harsh sometimes. Here at IISc, this is the time when the weather is refreshing and lots of colourful flowers are in bloom. It is an especially beautiful time of the year!

**Anjali Gawande**
*PhD student,*
*Department of Materials Engineering*

Most people associate summer with hot weather, but I'm from the mountains of Uttarakhand, so compared to other places, the temperature is still quite low there. Be it in the morning or the evening, the pleasant and cool weather makes these months very enjoyable. Another distinctive experience is the extensive trekking, since the melting ice allows us to attempt high-altitude Himalayan treks like Madmaheshwar or Kedarnath. I guess my experiences in summer are quite different from the usual ones!

**Ankit Negi**
*MTech student, Department of Mechanical Engineering*

For me, summer has always meant family. With my father serving in the Indian Air Force, most of my childhood was spent away from my grandparents. Summer was the occasion when our joyful joint family reunited. Every summer, we would visit my hometown, Puri, with its sacred shrines, sweet mangoes, ripe jackfruit, and most importantly, delicious *pakhala bhat*! Summers in Puri also meant "hot oven" rooms, so we'd all sleep on open rooftops and have late-night talks that deserved to be on "Koffee with Karan". However, what I miss most are my conversations with *amma* – heartfelt moments that still comfort me. These days, summer is more about an endless hustle for internships, for jobs, for projects. In academia, asking for summer holidays seems like a crime! So now, summer is just a brief window to talk to my parents. I haven't visited my grandparents in three years, and sometimes I wonder, by the time I finally settle down, will they still be there to share these moments with me?

**Chinmayee Sahoo**
*Masters student,*
*Centre for Neuroscience*

In childhood, summers meant that I could finally stop waking up early for school and sleep peacefully, or get engrossed in workshops that weren't even remotely related to academics. But my fondest memories include how my siblings and I would go to Kochi with our cousins and make terrific (maybe only to us) movies using a camcorder. Since stepping into college, summers now come with an overbearing wave of guilt, given the expectations that we should utilise this time for developing our skillset rather than enjoying the break. Currently, I'm spending my first summer at IISc, indulging in thesis-related field work. Although it's hectic, every time I'm out on the field, I feel an adrenaline surge inside me. Every outing feels like a high-stakes poker game. So, while I would love to get my peaceful summer days back, the "adventure" I'm on these days isn't too shabby either.

**Nandita R Satish**
*MSc in Life Sciences student at the Division of Biological Sciences*

***Compiled by***
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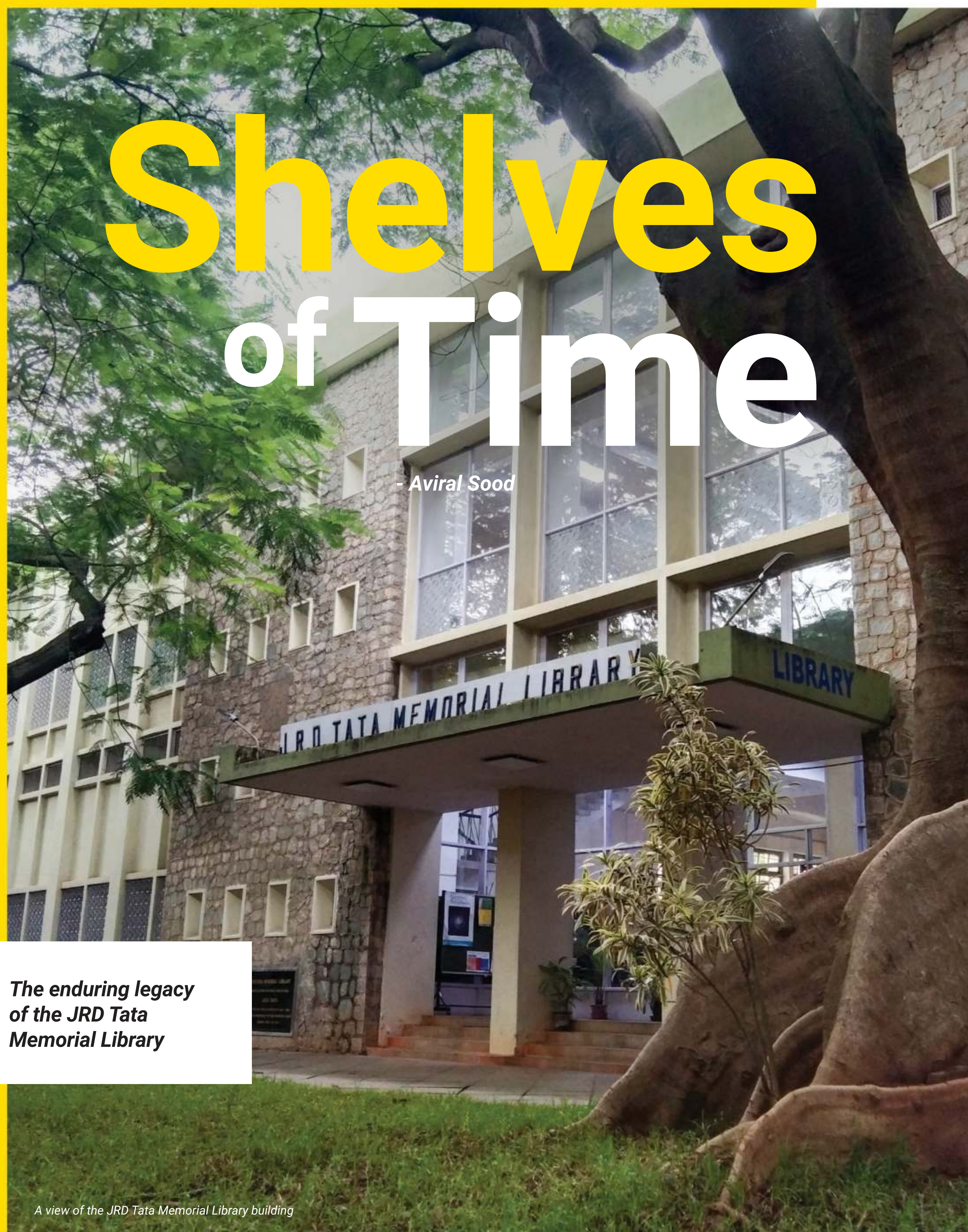
***Creetika Dahal,***
***Shruti Sharma***

# Shelves of Time

- *Aviral Sood*

***The enduring legacy of the JRD Tata Memorial Library***




*A view of the JRD Tata Memorial Library building*

Photo: Kavitha Harish

In the late hours of the night, the bustling and lively IISc campus halts to a slight murmur. The streets are deserted; the silence is broken only by the slow pacing of the night guards and dogs barking at nothing in particular. In this dark tranquillity, one building catches the eye: a massive rectangular structure, not too far away from IISc's Main Building. Beams of light pour out of small windows, giving its white walls a pleasant glow.

Within these walls, we can witness quiet but intense struggles. In the spacious and welcoming interior, students sit at their work stations with eyebrows furrowed, deep in thought as they ponder their assignments, project submissions, and research questions. Clacking of keyboards and the tapping of anxious feet fills the compelling silence, which has an oddly relaxing effect on the students as they burn the midnight oil. Occasionally, the odd student rustles through the bookshelves, their fingers searching for the correct reference before they head back to their workstation, deep in thought. This is an average night at the JRD Tata Memorial Library.

Over the years, the library has grown alongside the Institute as a repository of knowledge. It started functioning in 1911, just two years after IISc was established. At that time, it was housed on the first floor of the Main Building, which was then also called the Library Block. During the Institute's Golden Jubilee celebrations in 1959, plans were announced to construct a separate library building. Officially inaugurated six years later, the building is spread across a massive 54,000 square feet and continues to house the library to this day. In 1995, it was renamed from the Golden Jubilee Library to the JRD Tata Memorial Library. Following a grant from the Tata Foundation, the Digital Library Centre and the Library Annexe (now repurposed into the Faculty Club) were inaugurated in 1998.

When the library started, it had a collection of around 6,000 books, journals and articles from domestic and international publishers, catering to a tiny population of just 24 students. It has since grown to serve the needs of more than 5,000 students and 500 faculty members. It has a physical collection of more than four lakh volumes of books and journals, at an estimated valuation of hundreds of crores.

As with all academic libraries, the primary mission of the JRD Tata Memorial Library has been to curate a quality collection of books and scholarly journals to support teaching, learning, and research programmes of the Institute. In the early days, subscribed print journals from various publishers across the world were shipped to the Institute. Later, the journal articles would arrive in the more compact magnetic tape format, and could be printed into a physical format as required. With the advent of new technologies, this has now been superseded by online journals and databases.

***Over the years, the library has grown alongside the Institute as a repository of knowledge***

To create a bank of scientific information, the library prioritised the purchase of back volumes, which are older editions of journals that are otherwise inaccessible. A lot of effort has been made over the years to fill in these gaps. As a result, the library has an archival collection starting from the very first editions of various high-impact journals published by *Springer Nature, American Chemical Society*, and more. "In 2018, we were approached by *Springer Nature*, who wanted permission to scan the physical copy of the Volume 1, Issue 1 edition of one of their own journals," recalls Suresh Balutagi, the current Deputy Librarian.

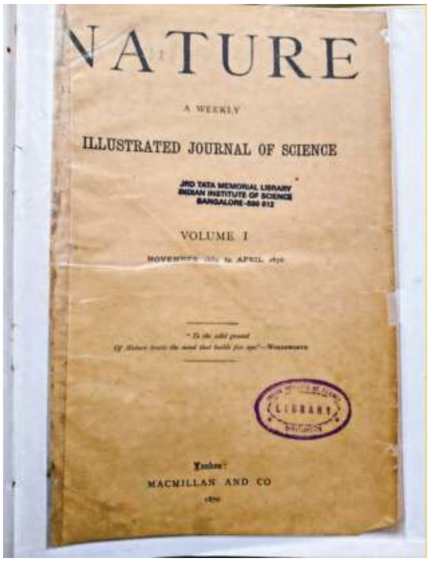



Photo courtesy: Suresh Balutagi

*Volume 1 Issue 1 of the journal* Nature *from November 1869*

Photo: IISc Archives

Photo of the old library, which was housed inside the Main Building

But as the collection grew, maintenance became a chore. By 1980, it had grown to around two lakh books and journals. “Organising the entire collection was a major task. All of us, including the librarian, had to work day and night for a whole month each time the journals would arrive,” explains Puttabasavaiah, who worked as the Deputy Librarian until 2017.

Earlier, current bound volumes were organised subject wise. However, a majority of requests from users were based on the title of the journal. Therefore, it was decided to organise the entire journal collection alphabetically by title. This was a huge task and most of the library staff including the then librarian worked round the clock for more than a month. Similar work was also carried out in segregating pre-1970 bound volumes of journals. In the case of books, a separate compact area was created to stack passive collections.

## Going digital

Digitisation first came about in the late 1980s, when a computer centre and LAN (Local Area Network) for the library were set up. This effort was spearheaded by the National Centre for Science Information (NCSI), which was established in 1983 to provide electronic information services to researchers. The NCSI operated from two rooms within the library building.

In the mid-1990s, the colossal effort of digitisation began. For cataloguing purposes, the library chose the commercial library management software LibSys. Then began the gruelling task of entering the bibliographic details of each item from the library catalogue into the LibSys software. Fortunately, bibliographic data for about 20,000 books which were added in recent years were already available in dBase (a database management system). This data was converted to the ASCII format and later to ISO2709 so that it could be ported to the LibSys database. All this was done in a single day, and the complete bibliographic data was made available for online access, search, and retrieval. As online access was through Telnet, a remote access network protocol widely used at the time, it was very slow and there were complaints from users. To overcome this, all the library data was again ported onto a system called Managing Gigabytes (MG) and access was made available on the web for search and retrieval. This was possible because of help from NCSI.

Later, the libraries of the Raman Research Institute (RRI) and the National Aerospace Laboratories (NAL), which were also using LibSys, joined this effort and shared their bibliographic data. Thus, all three library collections were made available online. “At that point in time, no other library in the country was doing this kind of work,” says Puttabasavaiah, who was employed at the NCSI during this process.

In addition to scanning and uploading the entire collection, an online user ID system for all students and staff had to be created, to have an online record of lending and borrowing. The whole process of digitisation was finally completed on 3 March 1999.

This was a major step in the evolution of the library. Several physical services have since been replaced thanks to the convenience of their digital counterparts, like reference queries from researchers that used to be handled by the library staff earlier. Among them was overnight lending, a feature where you could borrow a book at night and then return it in the early hours of the morning. This was an immensely popular service when introduced. “We used to get around 300 overnight lending requests per day in the 1970s and 80s,” Puttabasavaiah recalls.

There was also a tradition for the Institute Director to visit the library every Thursday to check on the new arrivals. This practice carried on until the tenure of P Balaram, who retired as the Director of IISc in 2014. The photocopy service provided by the library, which would send thousands of pages of high-end journals and papers to researchers and departments around the country, was discontinued, and the cancellation of print subscriptions meant that binding service for journal volumes has also all but gone away.

***'At that point in time, no other library in the country was doing this kind of [digitisation] work'***

The biggest change was the reduction of staff working on the maintenance and upkeep of the library. Starting from around 90 permanent employees in the 1930s, the number has come down to 12 in 2025. This has reflected a general trend within IISc, according to Uma Jagannath, who was the Deputy Librarian until 2007. “In those days, the Institute had a lot more staff members. Employees’ associations were also very active and had regular meetings,” she remembers.

## Money matters

Having an extensive and good-quality collection of journals is a necessity for any established academic library. But over time, the process of acquiring new journals has become much harder, because the price is in the hands of a small oligarchy of for-profit publishers. For example, article processing fees for a single journal can go up to thousands of US dollars, and can be increased by around 10% each year. As such, the library staff has to try different tactics to keep the subscription budget under control.

In earlier years, the library obtained some journals in exchange for access to the Institute's in-house production, *The Journal of the Indian Institute of Science*, which has been maintained by the library since 1914.

One of the other tactics used is to seek discounts in exchange for making subscriptions through intermediary subscription agencies. Another is to form consortia of multiple institutes and jointly negotiate for bulk discounts with a publisher. The largest of these consortia is the eSS (e-Shodh Sindhu) managed by the Government of India with more than 200 member universities. It allows for greater exchange of information between member libraries, with the restriction being that they can only be used to get access to services that are beneficial to the majority of the members.

Given the rising subscription costs, a survey was carried out in 2006 to identify which foreign journals were of least value to the faculty members at IISc. It was decided to retain journals with a high impact factor, journals in which articles by IISc faculty members had published, and journals where faculty publications were cited. Based on this, a list of journals for discontinuance was generated and circulated amongst the faculty for their feedback, after which a final list was created.

"We decided to cut access to journals without mercy. In the end, almost half of them were cut down," shares Puttabasavaiah. In recent years, the library has had to enter into tough negotiations with publishers and make hard choices regarding which services to continue. Despite these efforts, the current annual budget for journal subscriptions has surpassed Rs 20 crore.

## A researcher's best friend

Starting from modest beginnings, decades of coordinated effort have led to the JRD Tata Memorial Library becoming one of the largest scientific and technical libraries in India. It has given continuous assistance for research and publishing to all departments at IISc and has played a notable part in the scientific achievements of the Institute. It maintains ePrints and eBooks, which are online repositories of the research output of IISc in digital format. Since the merging of NCSI with the library, it has also maintained a number of digital repositories, including collections of theses and dissertations, and a list of faculty profiles.

*Photo courtesy: Kavya TT*

*The library offers several services to the IISc community as well as researchers nationwide*

Even those IISc residents who do not visit the library regularly utilise the services it provides. "Between looking at journal articles, reading eBooks and accessing MathSciNet (a comprehensive database of mathematical literature), I use services provided by the library all the time," says Swarnendu Sil, Assistant Professor at the Department of Mathematics.

***The library also allows restricted access to its collection to any researcher within India***

In addition to this, the library also allows any researcher within India to access its collection; one just needs to apply for a library card to get restricted access, making it an invaluable national resource. It has recently joined the One Nation One Subscription (ONOS) initiative by the Government of India, which seeks to provide nationwide access to thousands of journals across 30 different publishers.

There are still many challenges that the library faces daily. Although digitisation has made many processes easier, keeping the digital architecture up to date (for example, moving various digital services to cloud computing) is an extremely complicated and time-consuming task. Then there is the matter of rising prices of journal subscriptions. Despite these challenges, it has continued to expand and has become an essential part of the research workflow in IISc, thanks to a long chain of efforts by successive generations of people.

The library is still constantly looking to improve based on user needs and feedback. Just a few years ago, the operating hours were increased to 24 hours a day, except Sundays, to help students who need a place to study at night. Though so much of the functioning of the library has moved online, the building still attracts many students. "I have spent so much time in the library that it feels like a second home," says Ekta, fourth year BS (Research) student at IISc. "And since it is now open at night too, I can study without worrying about when I will be kicked out."

***Aviral Sood is a fourth year BSc (Research) student at IISc, and a science writing intern at the Office of Communications***

***(Edited by Sandeep Menon, Abinaya Kalyanasundaram)***

# ‘With Gen AI there are now a lot of opportunities, but also challenges’

- *Interview by Abinaya Kalyanasundaram*

*Photo courtesy: Carnegie Mellon University*

***Nihar B Shah is Associate Professor at Carnegie Mellon University, USA, where he leads a research group exploring how human-AI collaboration can lead to more trustworthy research publications and fairer evaluation systems. He completed his ME from the Department of Electrical Communication Engineering (ECE) at IISc in 2010, and also received the Young Alumnus Medal in 2024. Nihar believes that AI can improve the way we do science, provided its vulnerabilities are strengthened. His work has had real-world impact, with his algorithms adopted by academic publishers and grant-funding agencies for peer review, college admissions, and competitions. He is now extending his research interests to new fields, such as large-scale telescope programmes and biomedical sciences.***

***Nihar speaks to* CONNECT *about tackling scientific fraud, building more reliable AI systems, and the Institute's influence on shaping his research and teaching.***

## Can you tell us about your childhood?

I grew up in Vadodara, Gujarat. I don't have siblings, but there were many friends in my locality. We would play a lot, flying kites on 14 January during the festival of Uttarayan. Luckily, as I'm on sabbatical this semester, I got to go back again during the festival this January.  It was a lot of fun. I taught my kids how to fly and fight with kites.

## How did you get into research?

I liked programming, so I wanted to go for a software job; at that time, the software industry was booming. I joined Adobe in Bengaluru. The learning curve was steep initially, but soon became saturated, and I realised that it was not my cup of tea.

I understood what research is only when I joined IISc for a Master's degree. The Institute provided an incredibly supportive atmosphere. I was so fortunate to have P Vijay Kumar as my thesis advisor. He taught me broader aspects of research that I continue to use: how to select meaningful problems, how to approach a problem from various perspectives, how to effectively communicate your research, and how to identify opportunities for real-world impact. He also demonstrated, by example, how to mentor students effectively, and have a fun and collegial atmosphere among research groups.

## You thereafter decided to venture into improving processes in the "science of science". How did that happen?

Near the end of my PhD at UC Berkeley, I was unhappy with the way the conference peer review process worked. So, I approached conference organisers to collaborate and analyse the review data, and make recommendations for improvement. One of the top venues adopted the recommendations, and since then, many others also have.

Many of our scientific processes involve humans evaluating items. For example, peer review involves writing a paper, submitting it to a conference or a journal, and having other researchers evaluate it. This part of the science of science – human evaluations – needs better ways to process complex human data, and also better incentives. If I'm a reviewer, what motivates me to do a good job? There are also different types of fraud that occur, so we need to design incentives to prevent or reduce those.

## Is your focus now on finding fraud in scientific publishing?

Fraud is one key focus. A major problem in scientific paper publications is fraud. We work with various top venues to identify and mitigate this. We have seen extremely creative kinds of fraud – so creative that if the researcher had used this intelligence to do their research, they would have been better off (*laughs*). Then, there are also problems of bias [of the reviewer], arbitrariness and subjectivity.

With the advent of Gen AI, there are now lots of opportunities, but also challenges. Gen AI can improve efficiency, but it has some vulnerabilities and failure modes. A malicious person can game these AI systems in a way they would not be able to game humans.

*Photo courtesy: Rashmi Vinayak*

*Nihar with his PI, faculty member P Vijay Kumar, on the IISc campus in 2010, after receiving the SVC Aiya medal for the best Master's in Engineering student in the Department of ECE*

## How exactly is AI involved in the paper review process?

It is involved behind the scenes. For example, when people submit papers to a conference, algorithms are used to assign topically relevant reviewers to each paper. Algorithms also check for problems of arbitrariness. If there are significant problems, it'll either flag or automatically correct them.

## So, humans and AI work together through the entire review process.

That's correct. Currently, there is some exploration on using Gen AI itself to make the full decision. But our recommendation is to do a hybrid approach, because the failure modes of Gen AI are very different as compared to the failure modes of a human.

## Do you think there's still a lot of scepticism or resistance toward using AI?

Yes, and that's fair enough. Both the excitement and the concern are fair and valid. There are places where AI has been deployed for many years, such as in computer science. Top publication venues have been using machine learning algorithms to assign reviewers to papers for at least a decade. They receive about 10,000 to 20,000 papers; it's too large a task to do manually. But there are cases where people can rightly be concerned about AI. It has its vulnerabilities.

## Can you share an example?

We conducted an experiment a few months ago to test some fully autonomous AI reviewers. We took three different papers from the same field, took different parts of them, and combined them into a completely nonsensical paper, and then gave it to the AI to review. None of the AI reviewers recognised that it was a problem. This was a clear failure mode.

***'We identify vulnerabilities in AI and devise ways to prevent them'***

Another example of an AI failure mode is that it is prone to adversarial attacks from what's called a collusion ring – researchers who make a deal to try to get assigned each other's papers and give good reviews. They also do this to win awards and other recognitions.

## How does that work, exactly?

As AI is being used to assign reviewers to papers, it can be tricked. The AI looks at the text of the submitted paper, and then looks at the text of a list of potential reviewers' previous papers and assesses how similar they are and matches based on that.

If an author and a reviewer are colluding, the author can slightly change the paper they are submitting so that the AI thinks it's very similar to the reviewer's past work. At the same time, the reviewer can selectively show the AI only a few of their papers that seem more aligned with the submitted paper. This way, the reviewer looks like a perfect match.

In our work, we identify such vulnerabilities in AI and devise ways to prevent them. We have also instituted whistleblower reporting mechanisms, where people can report incidents of fraud.

## Was there any incident that really shocked you?

A person wanted their paper to get published in a top conference. But they knew that their paper was terrible. So they went to arXiv [a free, open-access archive of papers yet to be peer-reviewed], where you can download the LaTeX source of papers. They downloaded the LaTeX source of a good paper, made sufficient changes to avoid the plagiarism detectors, and then submitted it in their own name.

When the paper got accepted at the conference, the person switched out the arXiv paper and replaced the PDF with their own paper. But they were not able to change the title on the conference management system because that needed the approval of the conference programme chairs.

This person was brave enough to actually write an email to the conference programme chair asking to change their paper's title. But since the new title had no relation to the old one, they were caught.

## Wow, this is crazy …

This is nothing. There is this entire market where actual companies generate fake papers and sell them to researchers. The researchers can buy a paper and publish it in their own name.

## Just to get a higher number of publications?

Yes. In fact, there are various journals which allow you to change the author list, during and even after the review process. Some of these fake paper companies will even submit a paper to a journal with some random author name, get it reviewed, and once it is accepted, then they will sell it to researchers, saying: "Do you want a paper already accepted to the Journal of XYZ?"

## How common is this fraud?

It's hard to give a number because we don't know what we don't know. Even if the numbers are small, the reason it is a big problem is that science builds on top of prior science. So, if there's something fraudulent and then 10 genuine papers build on it, all of them go down the drain.

## It looks like you're pleased about shifting from working in software to a research career.

Yes, I am very, very happy with my current job. I think academia allows you to pursue things that you think are important in the long run. There's a lot of room for creativity. You choose a problem, and you can throw whatever tools at solving it.

## What is an average day in your life like? You teach classes as well?

It is a lot of multitasking. There will be a one-hour meeting with student one, and then teaching a class, then meeting student two, then student three – who are all working on very different problems – and then going to a committee meeting, and so on. It can be challenging, but then it's all very rewarding.

## Being a teacher now, how do you reflect on your own student days and your relationship with teachers at IISc?

I remember IISc very well, and there's so much that I learned from IISc that I now use in my own teaching. Every single class I took at IISc was amazing. I took a class in my first semester with Neelesh Mehta, who's currently the department head for ECE. He was teaching a class called Digital called Digital Communications. The midterm exam he set was wonderful. When I came out of this midterm, the thought I had in my mind was: "Wow. I learned so much when writing the exam."

He had created a very nice exam where you would use the concepts that you had learned in class and derive new concepts. I even remember one example. There's something called the Box-Muller transform. In the exam, he set us a task to mathematically prove it. He broke down the proof into smaller components. Each of them could be proved by the concepts that we had learnt in class. And eventually we end up with this amazing result, which is very useful, and you yourself derive it in the exam. It's so amazing, and I still use it [this technique]. Every exam that I create, for every question, I explicitly write down a learning objective and create an exam where the students learn something new that can be useful.

## That sounds like a very different kind of exam than what I'm used to!

Yes. I also enjoyed classes with Sunil Chandran in the Department of Computer Science and Automation (CSA). I remember once he was teaching graph theory. He would never prove anything by himself on the board. He would break down the proof into smaller steps and then ask the students to guess how to do each step, and then all the students would discuss, debate, and throw out ideas, and then he would compile all the ideas and we would do it together. Again, I try to do this in my classes.

## What are some of your other favourite memories from your time at IISc?

I have lots of great memories. My hostel was in the PD block. It is far away, and it is kind of secluded from campus. The playground was right next door, and we used to play a lot of football. I remember the food was so good at A Mess at that time. We practised and performed a drama called '*Mera Beta Aayega*' for our seniors at their farewell party. I was part

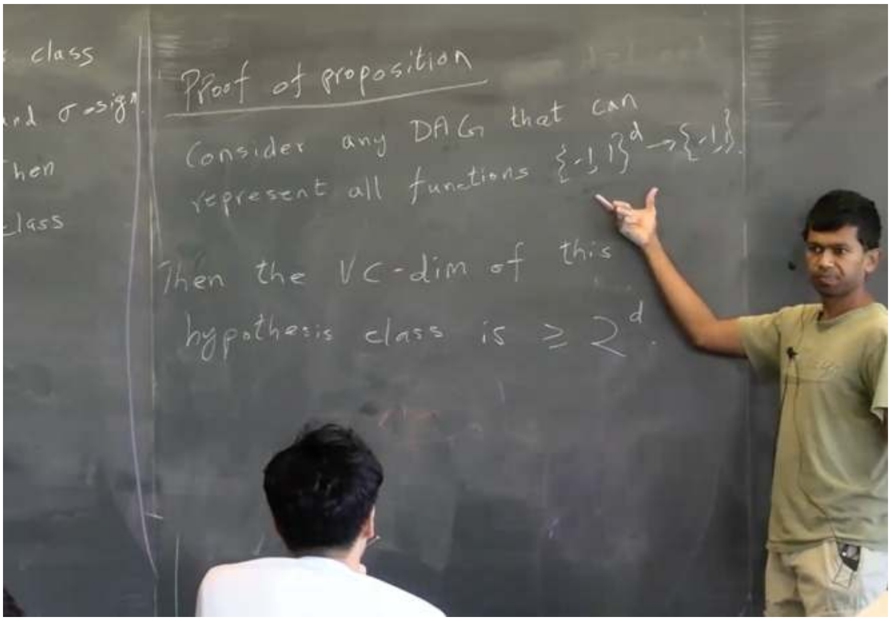



*Image courtesy: Nihar Shah*

*A screenshot from a lecture taken by Nihar Shah at Carnegie Mellon University*

of the Kung Fu classes during my second year. I also remember this one game that I had created where I had photoshopped pictures of various professors in all kinds of situations, and then the professors had to guess which professor was in the image. The professors were friendly, approachable and super cool people.

## Going back to your research, what are you excited to explore moving forward?

With Gen AI progressing, there are more opportunities and challenges. There are a few AI scientist systems now, which will come up with a question or hypothesis, collect data, do the analysis and then write a paper for you. So, how do we make use of these opportunities to improve science, but also understand and guard against the numerous problems that could arise?

The second thing is that we've started recent collaborations with funding agencies, and we're working with them to see how we can make better funding decisions.

The third interesting project we're working on is with astronomy agencies, helping them make decisions about how to allocate telescope time. For example, someone might be studying a celestial phenomenon that's going to happen only on 21 April; or, say, since the European Space Agency funded 20% of the telescope, they want 20% of the time on the telescope for European researchers; or some researchers can't work when there are clouds in the sky. So, we're collaborating with these agencies on how to allocate telescope time based on all of these diverse considerations.

***'There's so much that I learned from IISc that I now use in my own teaching'***

Since I'm now on sabbatical, I'm also using this opportunity to work with a lot of other domains, like biomedicine and life sciences, on their science of science related problems.

## What would you advise upcoming research students on how creatively they can use AI in their research?

If you're already in a specific field and you're excited about certain problems, then AI can help significantly improve your efficiency. It can help in writing code, collecting data, and even writing papers. That said, students should be aware of the various failure modes of AI. So, I encourage students to take a software engineering approach – use Gen AI as a developer, and the students can be the testers. They can do it in 5% of the time that it would have taken to write the whole code. I strongly encourage all my students to use AI a lot.

***(Edited by Sandeep Menon, Ranjini Raghunath)***

# A Chemist's Guide to the Hydrogen Bond

*- Chandana Valaboju*

***How its understanding has changed through the years***

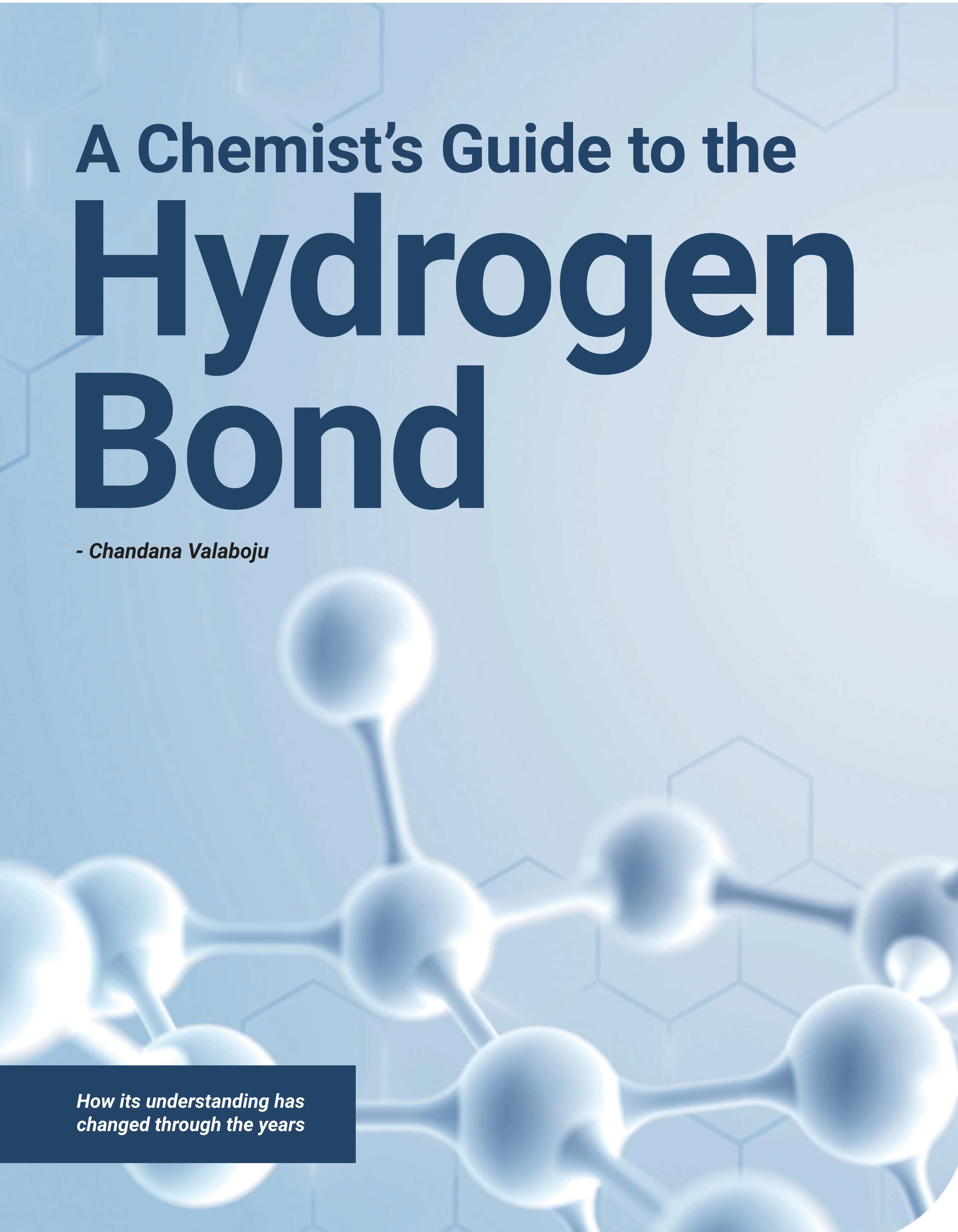


*image: Depositphotos*

The year was 1919. May was approaching and so was graduation season at the University of California, Berkeley in the USA. A young undergraduate student was in deep distress. One of his professors, William Bray, had assigned a paper to be submitted before the end of the term. But the student had not written anything at all.

As a last resort, he approached Bray with an idea. Some of his instructors had earlier discussed 'unsolved problems of chemistry' in their classes, and they intrigued him. He had the reckless idea of just submitting his crude notes of possible solutions for some of those problems.

The student was Maurice Huggins. Among those solutions he presented in the paper was the seed for what later evolved into the concept of the hydrogen bond: he proposed that the hydrogen atom could perhaps be bonded to two other atoms in some organic compounds.

Huggins didn't himself use the term "hydrogen bond". In 1920, chemists Wendell M Latimer and Worth H Rodebush working in the same university expanded on Huggins' suggestion in a paper, in which they wrote: *"Mr Huggins of this laboratory, in some work as yet unpublished, has used the idea of a hydrogen kernel [atom] held between two atoms as a theory in regard to certain organic compounds."*

Many years later, in a 1936 paper, Huggins still only used the term "hydrogen bridge". He thought that the word "bond" only referred to a system having one or more electrons bringing two atoms together. He also felt that calling it a bond might confuse people into thinking that it was a connection between two hydrogen atoms and not between hydrogen atom and the atom of another element.

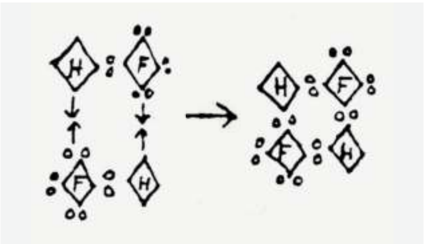


*Image courtesy: Bulletin for the History of Chemistry 1990/ACS*

*The hand-drawn figure from Huggins' student notes showing a hydrogen-bonded hydrogen fluoride dimer*

Huggins was right to have his reservations at that time. In fact, Bray told him that he would never get the chemistry world to believe that such a bond could exist. By then, valency – a measure of how many bonds an atom can form – had been discovered. It was common knowledge that hydrogen was monovalent, meaning that it had only one electron revolving around its nucleus to spare for bond formation. A bond (covalent or ionic) usually needs at least two electrons, one each from the participating atom.

"It was a very strange idea at that time," explains Himansu Sekhar Biswal, Professor at the School of Chemical Sciences at NISER, Bhubaneswar. "The idea of it bridging between two atoms, essentially acting as a "bigamist" as the British chemist Henry Armstrong later sarcastically put it in 1926, seemed completely contradictory to the known rules of bonding."

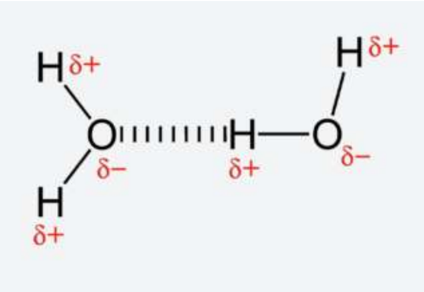



*Image courtesy: Wikimedia commons/Benjah-bmm27*

*Hydrogen bonding in water*

What exactly is a hydrogen bond? When a hydrogen atom forms a covalent bond – in which electrons are shared between atoms – with an electronegative (electron-attracting) atom, the former attains some "extra" positive charge. This is because the electronegative atom is able to pull the shared pair of electrons towards itself, causing the bonded hydrogen atom to develop a partial positive charge. This extra charge allows it to interact with one more electronegative atom in the same or different molecule. Of course, the nature of this interaction is still not fully clear.

Hesitation to call it the hydrogen bond persisted till the 2000s. In a popular textbook published in 1999, former IISc faculty member Gautam Desiraju and Thomas Steiner, former researcher at Freie Universität Berlin, still referred to it only as the "weak hydrogen bond".

Given its mysterious nature, scientists spent a lot of time scrutinising it. Linus Pauling, the most influential chemist of the 20th century, initially declared hydrogen bonds to be electrostatic, meaning that the atoms are able to attract or repel electrons by virtue of electrical charge. But this view waned gradually, as more and more studies revealed that it was not a mere electrostatic interaction.

Scientists thought that maybe the hydrogen bond was formed from dipole-dipole interaction. When two oppositely charged entities – like the hydrogen atom with a partial positive charge and the electronegative atom with a partial negative charge – are separated by a distance (forming a 'dipole'), interaction can arise between two such dipoles. Thus, a dipole-dipole interaction is essentially a form of electrostatic interaction. Typically, the direction of a dipole is indicated from positive charge to negative charge.

***Given its mysterious nature, scientists spent a lot of time scrutinising the hydrogen bond***

Then, scientists looked closely at the structure of a hydrogen fluoride (HF) molecule linked via hydrogen bonding to another HF molecule – called a dimer. If the HF molecules behaved like dipoles, they should have interacted in one of two directions – parallel or antiparallel. In other words, if it were a dipole-dipole interaction, it would assume one of two configurations, either a straight line or a "square".

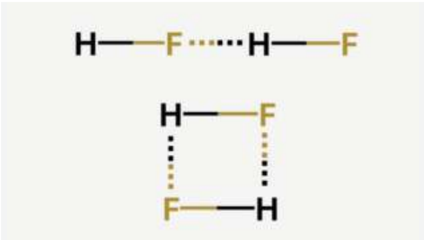



*Illustration: Chandana Valaboju*

*Hydrogen bonding in HF if it was just a dipole-dipole interaction (parallel and antiparallel dipoles respectively)*

But after the development of advanced spectroscopic techniques, the HF dimer structure turned out to be completely different from what scientists had envisioned – more like a step-ladder.

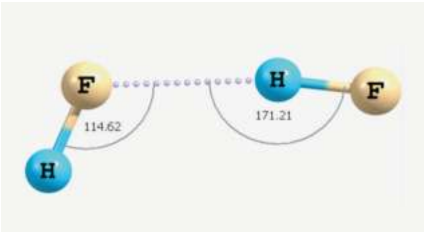



*Image courtesy: E Arunan*

*Actual representation of the HF dimer*

Clearly, the hydrogen bond was not solely a dipole-dipole interaction. After almost a century of research, scientists now widely believe that a hydrogen bond is not a single entity, but a complex interplay of different factors like dipole-dipole interactions, charge transfer, orbital interactions, and other phenomena. Some say that it may perhaps have a bit of covalent character too.

"The hydrogen bond depends on physical parameters, like distance between the donor and acceptor atoms, and the angles involving the three atoms participating in the bond," remarks Suryaprakash Nagarajarao, former Professor and Chair, NMR Research Centre, IISc.

## Hydrogen bond everywhere

Should we care about the hydrogen bond? Some scientists certainly think so. In 2025 alone, about 17,000 papers on the topic have been uploaded on Google Scholar so far.

"Life would simply not exist if not for the hydrogen bond. Everything would evaporate, become inanimate matter," says Suryaprakash.

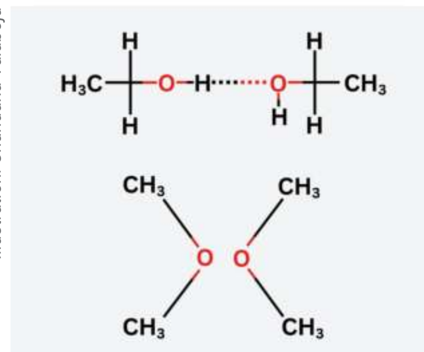
For example, protein structures are held together primarily by a variety of interactions, including the hydrogen bond.

The bond grew in popularity after scientists discovered its role in supporting DNA structure. DNA consists of two nucleotide strands linked to each other through hydrogen bonds, to form a double helix. While an individual hydrogen bond by itself is not very strong, it is the sheer number of bonds between the strands which greatly stabilises DNA.

Another example of how hydrogen bond affects chemical properties of molecules is the stark difference in boiling points of compounds called hydrides formed from elements in a specific group of the periodic table. The boiling points of hydrides are expected to follow certain trends, usually increasing as you go down the table, since the atomic mass increases in that direction. But that is not the case for water ($H_2O$), hydrogen fluoride (HF) and ammonia ($NH_3$). Because they have hydrogen bonding, they have dramatically high boiling points compared to hydrides of their neighbouring elements.

Hydrogen bonding is also the underlying reason for the difference in boiling points of some compounds that have the same mass. Take ethanol and methoxymethane, for example. Both have the same mass of 46u (atomic mass unit). But while the boiling point of ethanol is 351K, the boiling point of methoxymethane is 249K. This is due to the intermolecular hydrogen bonding present in ethanol but not in methoxymethane.

*Illustration: Chandana Valaboju*




*Hydrogen bonding occurs in ethanol (top), while it doesn't in methoxymethane (bottom)*

Suryaprakash's lab has used Nuclear Magnetic Resonance (NMR) to prove the participation of organic fluorine in the hydrogen bond. This is important because around 30% of the commercially available drugs contain at least one fluorine atom. The intra- and inter-molecular hydrogen bonds play a dominant role in determining the structure and conformation of the drug molecules.

Although the importance of hydrogen bonding quickly became clear to scientists, its definition took a long time to gain acceptance.

## Defining the bond

When scientists initially proposed that the hydrogen bond was a weak electrostatic interaction between a hydrogen atom bonded to a highly electronegative atom, the definition felt incorrect as it did not quite seem to capture the essence of the bond. One reason was because many believed that only some electronegative atoms oxygen (O), nitrogen (N) or fluoride (F) could interact with hydrogen in the expected manner.

"It was believed that less electronegative atoms, like sulphur and selenium, could perhaps form very weak hydrogen bonds, but they weren't considered significant players," explains Himansu. The electronegativity value of sulphur was lower than the electronegativity values of N, O and F. Scientists, therefore, believed that only strong electronegative atoms like the latter could participate in hydrogen bonding.

That changed when people started investigating the crystalline structure of $H_2O$ (water or ice) and $H_2S$ (hydrogen sulphide).

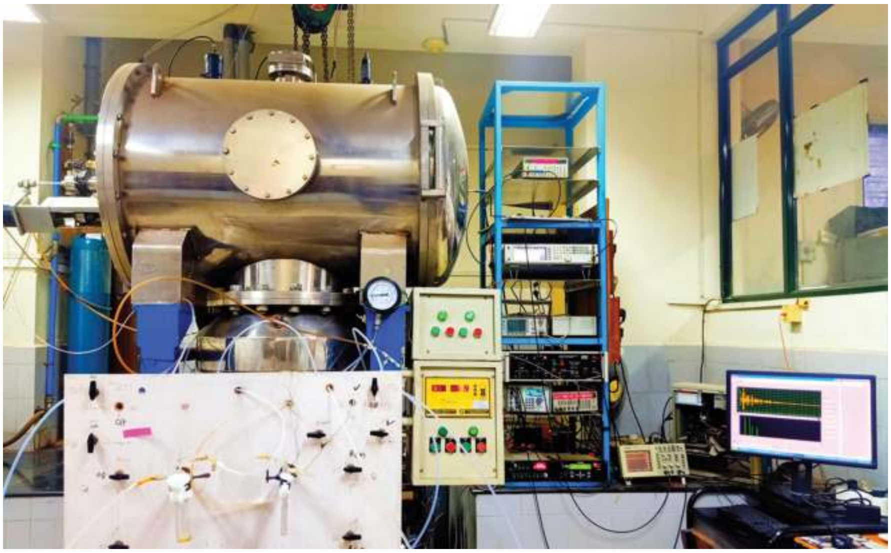
Let's take a step back and look at these two. Chemists consider ice as the ideal hydrogen bonding system. In solid state, each water molecule is bonded to four other water molecules by hydrogen bonds. This makes sense, because each hydrogen atom in a water molecule can get bonded to one water molecule each, and the oxygen atom in a water molecule can accept hydrogen bonds from a hydrogen atom of two other water molecules.

But $H_2S$, with a similar formula to $H_2O$, does not have the same crystalline structure as ice. Scientists found that H2S forms a closely packed crystalline structure, like the one in ionic solids. An individual molecule of $H_2S$ is surrounded by twelve other $H_2S$ molecules.

Pauling ascribed the structure of ice to the presence of the hydrogen bond and that of $H_2S$ to van der Waals interaction. Because he was – and is – a prominent figure in the chemistry world, this distinction went without repudiation for a long time.

When E Arunan, Professor at the Department of Inorganic and Physical Chemistry (IPC), IISc, and his team set out to investigate this, they found something interesting. The structure of a $H_2S$ dimer at ultra low temperatures, when observed in a pulsed nozzle Fourier transform microwave spectrometer, resembled that of ice. "We had to go to temperatures way past its freezing point to unveil this," he remembers.

So, why had the tightly packed structure been seen before? At the freezing point of $H_2S$, the thermal energy of the system is still enough for the molecule to 'rotate' and appear like a circle – like a ceiling fan. The true structure of a fan is three blades protruding from a point, but when rotating, it appears circular in shape. Similarly, the individual rotating $H_2S$ molecules created the illusion of a closely packed crystal structure. However, at lower temperatures, Photo: Sharon Priya Gnanasekar



Pulsed nozzle Fourier transform microwave spectrometer built at IPC and used to study the hydrogen bond

the thermal motion of the molecule reduces. Hence, the true crystalline structure of the $H_2S$ can be determined, which is similar to that of ice.

***The vague definition of a hydrogen bond involving only N, O and F has now become obsolete***

This meant that $H_2S$ too can form hydrogen bonds. Later research has shown that amino acids like cysteine and methionine, which contain a sulphur atom, also participate in hydrogen bonding.

The vague definition of a hydrogen bond involving only N, O and F has now become obsolete. In 2011, the official definition for hydrogen bond was revamped by the IUPAC – International Union of Pure and Applied Chemistry – the world authority on chemical nomenclature.

It now says: "The hydrogen bond is an attractive interaction between a hydrogen atom from a molecule or a molecular fragment X–H in which X is more electronegative than H, and an atom or a group of atoms in the same or a different molecule, in which there is evidence of bond formation."

## Searching for bonds

Back in 1960, when US chemists George Pimentel and Aubrey McClellan wrote the first textbook on the hydrogen bond, they suggested that a hydrogen bond can exist wherever there is evidence that a chemical bond specifically involves a hydrogen atom already bonded to another atom.

What does 'evidence of a bond' mean? How are these bonds visualised?

Usually, parameters like distance and angle between atoms are used to classify bonds. An almost straight angle (180 degrees) of the X–H - - Y (X and Y are the electronegative atoms) and the distance between Y and H being less than the sum of their van der Waals radii (a measure of atomic size) indicate the presence of a hydrogen bond.

One of the most commonly used techniques is Atomic Force Microscopy, which has provided beautiful pictures of the hydrogen bond. NMR and X-ray diffraction can also be used to distinguish normal and hydrogen bonds. NMR is especially useful in differentiating inter- and intra-molecular hydrogen bonds. Each peak in the NMR corresponds to the chemically inequivalent proton (hydrogen atom) of the molecule.

There are a number of NMR experiments available to establish the presence of intra- and inter-molecular hydrogen bonds, such as solvent dilution and temperature perturbation. These experiments reveal a significant displacement in the chemical shift positions of the protons participating in the hydrogen bond. An interesting observation made by Suryaprakash's group is the presence of hydrogen bond-mediated couplings of significantly larger strengths among the spins involved in the bond. Variations of the NMR technique have unambiguously established the presence of the hydrogen bond in many synthesised molecules.

Over the years, scientists have realised that the hydrogen bond may not be the only interaction of its kind. One of the newer discoveries is the existence of a carbon bond between molecules. Similar to hydrogen, a carbon atom, when bonded to an element or group that can attract electrons, becomes partially positively charged, and can interact with other electronegative atoms. Since carbon and its compounds form the basis of life, understanding these previously unexplored interactions can help us learn their roles in biological systems.

Halogen bonding, a new type of interaction, was also defined by an IUPAC task group in 2013. Similar to hydrogen bonding, this interaction depends on the development of a partial positive charge on a halogen atom – like chlorine or bromine – allowing it to interact with an electron-rich region in the same or different molecule.

The saga of the hydrogen bond shows that not only do many such intermolecular interactions exist that are yet to be discovered, but also the fact that the definition of a chemical bond keeps changing.

For example, Himansu's group has been studying how hydrogen bonds are formed by sulphur and selenium, which are similar to oxygen. "We have recently predicted that metal hydrides can form hydrogen bonds," he says. But this doesn't fit the current definition of the hydrogen bond, because in metal hydrides, the metal atom is usually not more electronegative than hydrogen for it to attain a partial positive charge. "We are currently working on experimentally verifying this."

Such findings, Himansu adds, suggest that we need a more "nuanced view" of what constitutes a hydrogen bond and the range of atoms that can participate in it. "The evolving definition of the hydrogen bond is a testament to Huggins' initial, seemingly outlandish idea, which sparked a line of inquiry that continues to reveal the intricate ways in which atoms interact."

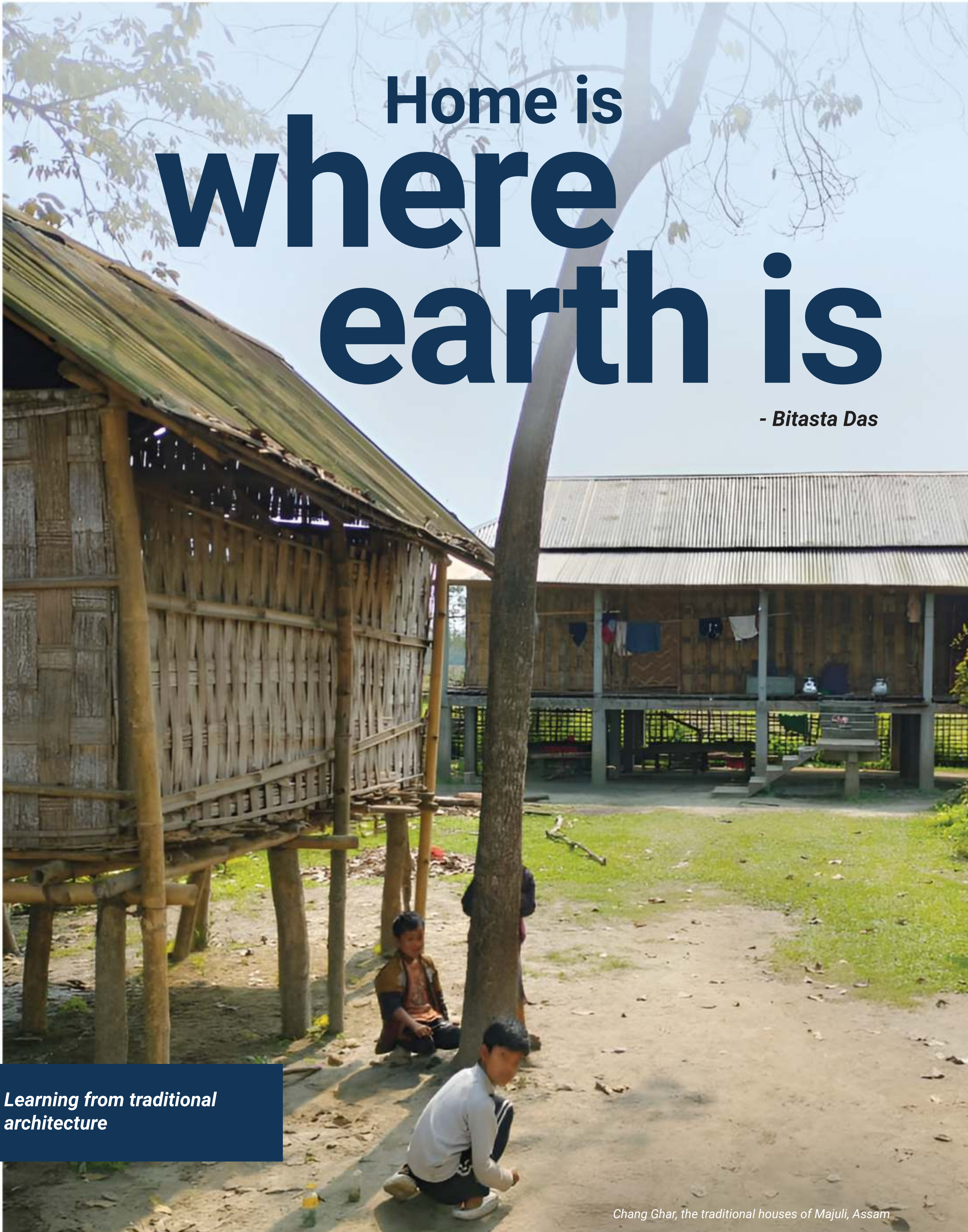
***Chandana Valaboju is a second year BSc (Research) student at IISc, and a science writing intern at the Office of Communications***

***(Edited by Ranjini Raghunath)***

# Home is where earth is

- Bitasta Das

***Learning from traditional architecture***



*Chang Ghar, the traditional houses of Majuli, Assam*

Photo courtesy: Vikram Rao

Walking through the lanes of Majuli, the largest river island in the world, one cannot miss the characteristic houses, the *Chang Ghar*. Situated in Assam, at the heart of the river Brahmaputra and secluded from the rest of the world, Majuli has preserved much of its traditional heritage, including its distinctive architecture. Being a floodplain, the region sees significant floods throughout the year. The houses are mainly constructed with bamboo and are elevated on bamboo or concrete poles to prevent getting inundated. A few have corrugated roofs; however, most are thatched. A wooden ladder connects the house to the ground, and typically every house has a boat for commuting when the water level rises.

On the other side of the country, in the deserts of Kutch, Gujarat, are the *Bhunga*, traditional houses with circular mud walls and thatched roofs. These houses are designed to withstand the harsh desert climate and earthquakes that rock the region. Down south, the *Mannu Veedu* houses of Wayanad are constructed with mud and supported by bamboo, with reeds and rice straw thatched, sloped roofs to allow excess rainwater to drain off. Whereas all the way to the north, the *Dewangrums* of Kashmir are typically multi-storied structures made from wood and mud bricks. Their design ensures cool temperatures during summer and warm temperatures in winter. The architecture of such traditional houses utilises locally available natural resources, and the construction techniques are in tandem with the region's climatic conditions.

India is a country with varied geographic, climatic, and socio-cultural conditions. The traditional dwellings of these diverse regions have been resilient and continue to provide shelter and comfort to the dwellers.

But urbanisation has largely been driven by and structured around the principles of consumerism. In this process, it has marginalised the diverse traditional knowledge systems in favour of a homogenised development. The mounting environmental degradation and civic challenges point to the fact that we should reconsider the course of urbanisation toward a more sustainable and context-specific approach. Several experts from across Bangalore have been studying and applying the learnings from these traditional dwellings to modern homes.

## Sustainable traditions

In contrast to the rich repository of the country's plural architectural traditions, homes in urban India appear exceedingly uniform. The use of materials like concrete, brick, steel, and glass has replaced mud, wood, stone, bamboo and lime. Typical construction styles with Reinforced Cement Concrete, homogenous facades, repetitive floor plans and so on, make modern urban Indian homes indistinguishable from each other.

***In contrast to the rich repository of the country's plural architectural traditions, homes in urban India appear exceedingly uniform***

Experts are increasingly pointing out that standardised housing designs fail to respond to specific environmental and topographical conditions of diverse regions. This often results in poorly ventilated interiors or inadequate insulation, thereby resulting in excessive energy use. These challenges are further exacerbated by the accelerating impacts of climate change.

A study (2021) conducted by the Centre for Sustainable Technologies (CST), IISc, spearheaded by Monto Mani, Khadeeja Henna and Aysha Saifudeen, evaluated the climate resilience of vernacular dwellings in three villages in India, located in different climate zones: Suggenahalli (Karnataka) in a warm and humid zone, Dasenahalli (Karnataka) in a temperate zone, and Bisoi (Uttarakhand) in a cold zone. Using data loggers, the team recorded temperatures inside traditional and modern houses situated in those zones, every 30 minutes for almost a year. Based on these recordings, they built a mathematical model to predict how their indoor temperatures would be in the future. They simulated three future global warming scenarios with different levels of greenhouse gas emissions. This was done to estimate how houses constructed using traditional and modern materials would behave in these scenarios.

In all three climates, traditional houses, built with timber walls or slate roofing, were less affected by climate change than modern houses. In the cold climatic zone, the traditional dwellings were warmer indoors, making them more comfortable for living. On the other hand, in the warm-humid and temperate climatic zones, modern houses had relatively higher indoor temperatures. This would make them more dependent on artificial air conditioning, contributing further to global warming. The study, therefore, suggested that traditional dwellings have design solutions that can help mitigate and adapt to climate change.

"By mapping traditional homes, a resource map of India can be developed to highlight the locally available raw materials and regional skillsets," says Monto Mani, Professor at CST. "I started my research on rural dwellings with two basic questions: how these houses came about in those regions, and the functions they perform."

Mani and his team have been reinvestigating traditional dwellings from a scientific perspective: They are time-tested, but why are they still valid? Are there lessons that can be learnt from them? Most rural Indian traditional dwellings are ironically stipulated as *katcha* or impermanent. On the contrary, these architectures have survived over generations. "Traditional houses survive as long as there are inhabitants in them," Mani points out. The structures might not be permanent, but their strength and utility have withstood the test of time. "We need to shift our perspective," he adds.

***Traditional dwellings have design solutions that can help mitigate and adapt to climate change***

Their studies uncovered compelling evidence demonstrating the advantages of traditional homes. Most traditional dwellings are built with hygroscopic materials that naturally regulate indoor humidity, releasing moisture when the air is dry and absorbing it when the air is damp, thereby maintaining optimal thermal comfort and respiratory health. This design supports the physiological resilience of residents, allowing them to adapt more effectively to varying temperatures. In contrast, modern homes rely heavily on air-conditioning systems, which are not only energy-intensive but also inhibit the body's natural ability to adjust to temperature changes, leaving occupants more vulnerable to environmental fluctuations.

Another important aspect they highlighted regarding the functional performance of rural dwellings is their capacity for restoration. Constructed from natural materials such as bamboo, mud, stone, and timber, these structures can be easily repurposed or reintegrated into the environment, thereby supporting ecosystem restoration. In contrast, conventional modern homes typically generate non-biodegradable debris, contributing to the growing problem of construction waste.

Photo courtesy: Monto Mani

*Monto Mani and his team studied traditional and modern homes in rural Karnataka*

## Bringing the vernacular to the urban

Urban spaces in India are becoming increasingly chaotic and densely packed with buildings, roads, and concrete infrastructure. This pattern of urbanisation is often seen as impersonal and harsh, disconnected from nature. As a result, the metaphor "concrete jungle" is frequently used to describe Indian cities, likening them to literal jungles that feel wild, overwhelming, and alienating.

But some architects are inculcating traditional building processes in cities as well. Bangalore-based architect Sathya Prakash Varanashi has been a pioneer in the field of eco-friendly architecture. His design ideas are rooted in cost, culture, climate and creativity.

"Architecture started with shelter making, followed by the need for shade, security, storage, space, familiarity and comfort. On most occasions, each one of these criteria is overdone in our design and construction industry. From being ecological animals, we have shifted to being economical animals. From economical, it became personal and now we all live our individual aspirations with no due recognition to the eco-impact we are causing," he says.

***Eco-logic – bringing ecology to the centre of our design and construction thinking – is the need of the hour***

Photo courtesy: Sathya Prakash Varanashi

The Varanashi House was built using hollow clay blocks which naturally regulate temperature

He admits that eco-friendly architectural styles, rooted in the local, economical, ecological and natural, are not a prevailing approach in the cities, but there are a few people who do look for sustainable designs. Varanashi himself has built his home, called the "Varanashi House", combining nature with thoughtful design. Instead of using heat-trapping cement walls, he chose hollow clay blocks, which naturally regulate temperature – keeping the house cool in summer and warm in winter. Sliding doors open up the living spaces to the garden, and strategically placed openings on the walls allow hot air to escape. This design incorporates the principles of cross ventilation, displacement ventilation, and body-level breeze. Even after 21 years, the home remains low-maintenance, comfortably cool, and a perfect example of sustainable living, he says.

Varanashi proposes that eco-logic – bringing ecology to the centre of our design and construction thinking – is the need of the hour. "Our architecture needs to evolve from nature, [be] made of nature and [be] made for nature. Many tribes still live with the logic of their contexts," he says.

Vanamu, a Bangalore-based organisation, is also engaged in restoring the connection between nature and human living spaces. With its home base in Yelahanka, it is a collective of practitioners and researchers of natural buildings and dwellings. Besides hosting workshops on these themes, their studio is an open space for any learner with a keen interest in natural patterns of life.

Photo courtesy: Varun Thautam and Namrata Toraskar

A workshop conducted by Vanamu on fine natural plaster

Varun Thautam and Namrata Toraskar are the principal architects of Vanamu. According to them, most architects and urban planners do not adopt eco-friendly methods of construction because of a multilayered problem. Firstly, there is difficulty in getting to know the systems and processes used in natural buildings, which are not easily observable or available. One has to do a lot of research, documentation and travel to see such buildings and also dedicate time with artisans on site to build such structures. Secondly, there are biases against eco-friendly spaces, and sometimes the architect's vision, values and ethics are influenced by those of the client's. The third challenge is finding the right media to communicate the benefits of sustainable building – there is a big gap in understanding between the architects who build eco-friendly buildings and the people who should be embracing them. "It is a long journey of learning how to communicate and how to reach out to people who will value us, or whom we can provide some value to in the realm of ecological building and living," says Namrata.

***Most architects and urban planners do not adopt eco-friendly methods of construction because of a multilayered problem***

Varun explains that throughout his practicing journey, the words of his teacher, the Mexican master dome builder Andres Flores has been a guiding light: "Craft cannot be contained, it cannot be stored, it should flow. We are the medium. Just the way our bodies cannot store food nor water. Craft can only be learnt through the flow of practice." Varun embodies this learning in the many workshops they conduct on sustainable building methods.

Namrata shares an anecdote that has stayed with her in her journey. While working in Himachal Pradesh as an ethnographer and a photojournalist, she spent considerable time with indigenous artisans who had an innate understanding of the land. One day, in a village called Grahan, while plastering a wall with a mix of mud and natural additives, an elder paused, placed their hand on the wall, and said: "If the wall doesn't feel alive, it won't shelter well."

"That simple line stayed with me. It encapsulated everything Didi Contractor, my master, stood for and taught: that buildings are not objects, but living beings shaped with care, intuition, and deep listening. Architecture cannot be studied, lived, and talked about in isolation."

***(Edited by Abinaya Kalyanasundaram, Ranjini Raghunath)***

# High Seas to Human Resources

- *Pratibha Gopalakrishna*

*Photo courtesy: Mithun Nair*

***A day in the life of Assistant Registrar Mithun Nair***

Mithun Nair's day usually begins at 5.40 am. He goes for a morning walk, reads the newspaper, then gets ready and goes to work. On this day, Mithun arrives at his desk at 9 am. He is back after a weeklong vacation and has a busy morning ahead.

As the Assistant Registrar of the Council and HR section, Mithun oversees the recruitment, service and evaluation matters pertaining to Group A employees at IISc, which includes teaching and non-teaching staff. Mithun shares that handling service matters is demanding, as it includes processing of a large number of leaves, No Objection Certificates (NOCs) for visits abroad, visa certificates, passport applications, pension, resignations, retirements, and so on.

***Mithun oversees the recruitment, service and evaluation matters pertaining to Group A employees at IISc***

Located on the first floor of the JRD Tata Memorial Library, Mithun's office is the second room to the left of the HR section. It is a beige minimalist room with two cupboards, two desks, a personal computer, a few chairs and a sofa. One of the partition office walls has a whiteboard embedded into it.

At 9.30 am, Mithun has a short meeting to catch up with some of his staff – Dayanand V Kallapur, MV Sivani, and Kaaviya M. They discuss tasks ahead, such as clearing NOCs, leaves and other requests. Mithun listens to their updates, asks questions to understand the problem at hand, and guides them wherever they need his help.

After they leave, Mithun checks his emails. "After we switched to SAP for administrative operations, the amount of physical paper coming into HR has reduced significantly," he explains. While SAP has made the processes smoother, there are some refinements that Mithun and his team are trying to update.

Mithun was born in Bikaner, Rajasthan. His father was in the army. Like other army families, Mithun's family moved often; they travelled from Bikaner to Barrackpur, then Meerut and Jammu, and finally, once his father retired, they settled in Kollam, Kerala. Mithun joined the Scouts and Guides initially and later joined the National Cadet Corps (NCC) during high school.

While in the eighth grade, Mithun went to his first NCC camp in Jammu, from where he returned early due to the tough training. "After I came back, my brother and sister used to tease me, saying that I couldn't even finish a 10-12-day camp," he remembers.

Eventually, Mithun grew out of his discomfort and attended various camps, which included trekking, parasailing, paragliding, and microlight flying. "In fact, during 12th grade, my attendance was less than 75%, and I had to produce a certificate from NCC to apply for the Board exams," he recalls, with a smile.

Photo: Pratibha Gopalakrishna

*Mithun meeting with his office members*

After completing school, Mithun decided to pursue BCom at St Cyril's College, Adoor. Then, he applied and got into TKM College, Kollam, for an MBA. At the same time, Mithun applied for the Indian Navy and cleared the SSB interview. He decided to drop out of the MBA programme and joined the Naval Academy, Ezhimala, for training.

During those months, in which he missed his sister's wedding, Mithun completed his training while visiting Kochi, Lonavala, Jamnagar and Visakhapatnam. His first posting was at Karwar in Karnataka.

At Karwar, Mithun gradually adapted to the environment during the first few months. When a shooting competition was announced, he was selected and transferred to INS Shivaji at Lonavala. After a six-month training period, the final round of the competition took place. Mithun's group came second. But beyond learning shooting skills, Mithun enjoyed the time he spent there. "What you get in those six months – the bonding, the lessons – that is unforgettable," he remembers fondly.

Mithun then returned to Karwar and was appointed to a naval ship. There, Mithun handled logistics, administration and procurement. During their time at sea, they docked at various ports like Visakhapatnam, Bombay, Mangalore, Kochi and the Maldives.

Upon returning from the ship, Mithun was transferred to Material Organisation in Karwar to handle bulk procurements. During this time, he received the Navy Commendation Award for 'Devotion to Duty.'

He got married in 2012 and after five years at Karwar, Mithun had to go through a mid-career training in 2013, during which he got an MBA from Goa University. Mithun was then transferred to Command Headquarters in Mumbai, where he would travel by boat daily. As he was replacing a senior person, initially, his days were hectic. He would leave home by 7.30 am and return around 8.30 pm. "My daughter would be sleeping when I left and when I returned," he recalls.

By 2019, Mithun had completed almost 12 years of service in the Navy. He chose to retire and applied for a job at IISc, which he joined in April 2019 and was posted as the Secretary to the then Director, Anurag Kumar. "When I gave the interview, I didn't know much about IISc," Photo courtesy: Mithun Nair

Mithun during his posting on a ship

says Mithun. In 2021, he was shifted to the HR section and was eventually put in charge of the Group A section.

Mithun's current job is very different from his Navy days. "It was a huge difference from the Navy to here – especially the cultural changes," he explains.

During the COVID-19 pandemic, when Mithun was still working in the Director's office, a few faculty and students were stuck abroad. IISc's then director, Anurag Kumar, suggested that Mithun write to the relevant embassies to seek permission for their early return. "I sent several emails to the Indian Embassy and the Defence Attache, and eventually, [the students and faculty] all came back. Hopefully, the emails would have helped," he says, smiling.

In 2021, Mithun was transferred to the HR section. "It was very difficult, initially, with the quantum of work and limited staff," he shares. Eleven months later, the newly recruited administrative recruited administrative assistants joined. "Their joining helped a lot," Mithun says. Over the next few years, the HR section expanded and now, Mithun says that things are more or less proceeding smoothly.

At 10 am, Mithun attends an online meeting with all the Assistant and Deputy registrars at IISc. Then, he walks out of the office to talk to other staff members regarding certain issues.

Mithun then meets with Roshen Ravi, one of the administrative assistants looking after recruitment. They discuss the offer letters sent and the responses received. Mithun says that most of the recruitment procedures have been moved online, which saves a lot of time.

Around 11 am, Vasanthan AA, Assistant Registrar of the legal section, drops by to discuss a specific legal issue. Then, Mithun prepares to leave for the meeting with the Registrar at 11.30 am. He meets Aparna Kandi, Deputy Registrar of the HR section, outside his office and along with Michaelraj, the other Assistant Registrar in HR, the three walk together to the main building.

The Registrar meeting gets over quickly, and Mithun returns to the office for some quick work before grabbing lunch. On this day, he has brought curd rice, salad and potato curry, packed in a lunch box. "My daughter goes to the Little Elly Playschool, and we usually go home for lunch. But now, she has summer vacation," he adds.

Back to work at 2 pm, Mithun checks his emails while preparing for another meeting at 2.30. He is meeting with M Senthil Kumar, Assistant Registrar of Academics, to hand over the documents and responsibilities of the Internal Committee Against Sexual Harassment (ICASH). In the meantime, a few people walk into Mithun's office to discuss work-related issues. "Streamlining emails by creating a shared inbox has helped a lot," Mithun explains.

The Council section also assists in organising the Court, Council and other meetings, says Mithun. He adds that the HR section takes care of employee retirements. Every year on 31 July, around 30-40 IISc employees retire, and their farewell takes place in the Satish Dhawan auditorium. "It is a huge function with the employees, their families, Chairs of their Departments, and colleagues," Mithun says.

At 3.30 pm, Mithun leaves for an internal meeting with all the staff in the HR section. The HR section is a flurry of activity, as people move towards the meeting room and shut the doors. The meeting gets over by 4 pm, and Mithun walks back to his office to wrap up work.

"I remember back in 2021 when most of us stayed till 7-8 pm on most of the days, to finish pending work. However, with the streamlining of processes and support from the seniors and colleagues, things have improved," he says.

After a relatively busy day, Mithun heads home at around 6 pm. He spends some time with his children before having an early dinner at 7.30 pm and heading to bed by 10 pm. All to rise again the next morning and keep the wheels turning.

***(Edited by Abinaya Kalyanasundaram, Ranjini Raghunath)***

Photo courtesy: Mithun Nair

Mithun (11th from left) with his colleagues in the HR Section

# Sci-Tech Legends of India

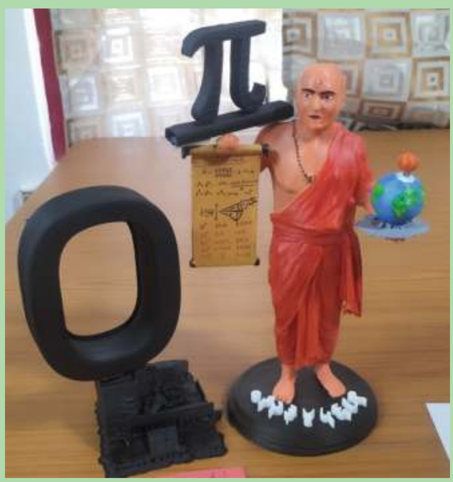
***A Doll Exhibition***

*As part of the undergraduate humanities course, "Mapping India with Folk Arts", taught by Bitasta Das, students made dolls of notable Indian scientists and engineers along with their groundbreaking work. These were displayed in an exhibition at the Office of Communications, IISc, in April 2025. From Aryabhatta and his zero, to Sálim Ali and his beloved birds, check out some of these artful creations!*

## Rohini Godbole

by Anurag Sarkar, Anushka Jain, Avani, Divya Tulapurkar, Geeth Sameer, KR Srikanth, Manya Ganapathy, Nived Nambiar, Parth Kumar, Vijay

## Aryabhata



by Prateek Kumar, Vaibhav Raj, Anuj Bhadbhade, Manish Seervi, Bhavesh Kumar Acharya, Shubham Jha, Aditya Deshmukh, Mohd Ayaan, Abhinav Goyal, Abhishek Kumar Jha, Shaurya

## Salim Ali

by Pratham Gupta, Gavish Bansal, Naman Goyal, Shobhnik Kriplani, Sachin Ghongde, Krishna Agarwal, Sehaj Ganjoo, Udit Shah, Chinmay Panchariya, Kuldeep Jatav, Ayush Priyadarshi

## Subrahmanyan Chandrasekhar

by Akshita Sansugu Palaniswami, Arpita Priyadarshini, Athira Krishna Nayak, Banoth Jyoshna, Baradh Raj B, Haripriya K, Indu Bala, Subraja Sree Harene Chithra Ramamurthi, Vismit

## Homi J Bhabha

by Kalpit Prabhat, Trishna Kodamasingh, Arnav Kumar, Abhimanyu Ambikapathy, Jahin Sadat Mollah, Shivey Ravi Guttal, Saksham Agrawal, Samyak Kasliwal, Ritabrata Ghosh, Achintya Mathur, Aniru

## JC Bose

by Abhinanda Ghosh, Swarnava Chakraborty, Samanwita Pal, Mohar Kanti Biswas, Sriraj Chandra, Debanjan Saha, Writipriya Paul, Kintan Saha, Susmit Roy, Simar Narula

## MS Swaminathan


by Adhinathan M K, Aditya Dhull, Ashwin K M, Bhargav Sashank, Harisrrinivas V, J S Vishnu Teja, K Saisandesh Reddy, L. Sai Harsh, Manoj Kumar S, Shripad Boducharla, Seetha Abhinav

## CV Raman

by Pranav Raghu Koratagere, Nirmit Bhanderi, Aliv Sahoo, Bibhu Prasad Behera, Rolla Siddharth Reddy, Rishabh Hangal, Adithya K Anil, Pasupuleti Dhruv Shivkant, Nikhil Jamuda, Om Prakash Chaudhar

## Rajagopala Chidambaram

by Amrita Notani, Aryan Somkuwar, Kabyadeep Das, Kalpesh Bhatnagar, Kapil, Krish Tundwal, Lad Krishnam Mahendrakumar, Pritesh Jogdhankar, Rashik Das, Vikas Venkanagoud Patil

## Vikram Sarabhai

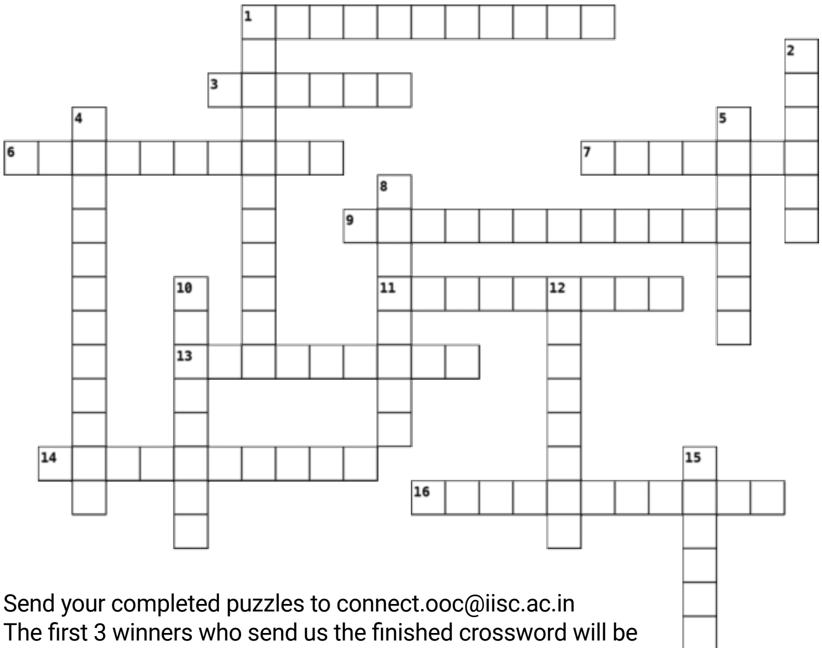

by Aishik Nath, Aldrin Nath, Pranay Kumar, R Lallawmsanga, Rasapalli Ganesh Sai, Saksham Maitri, Sayak Maji, Suresh Karthik N N, Tanmay R Lodhi, Yash Kamble

## Satyendra Nath Bose

by Abhinav Kanneganti, Arjun Karmakar, Vinay, Shreeansh Hota, Devis, Shyam Sundar, Subhanan Banerjee, Aditya De, Aranya Banik, Aarav Desai, Lakshya Lal Choudhary

# Fun Corner

## CONNECT CROSSWORD




Send your completed puzzles to connect.ooc@iisc.ac.in
The first 3 winners who send us the finished crossword will be announced in the next issue!

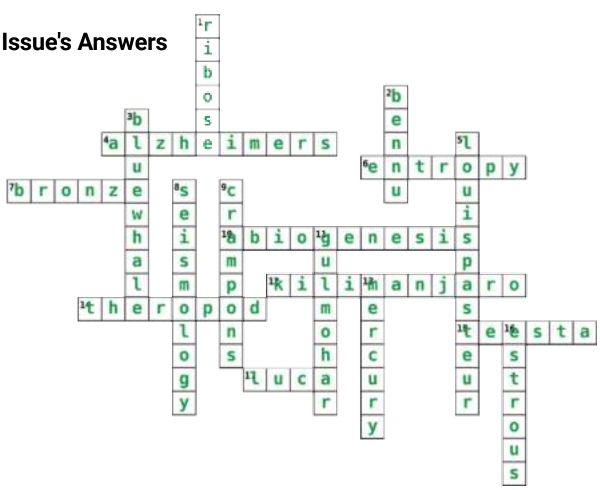
### ACROSS

4. Part of the brain responsible for memory
3. World's largest rainforest
6. Largest desert in the world
7. Hypothetical faster-than-light subatomic particle
9. The principle that the universe is homogeneous and isotropic on a large scale
11. India's first satellite
13. Galaxy closest to the Milky Way
14. Architecture suited to local climate and materials
16. Theory that the Earth is the center of the universe

### DOWN

1. Only birds known to fly backwards
2. Traditional circular mud houses of Kutch, Gujarat
4. Number of protons in the nucleus of an atom
5. Curve generated by a point on a circle's circumference that rolls along a straight line
8. Type of bond formed when two atoms share electrons
10. Complex geometric shapes characterised by repeating patterns at different scales
12. Most abundant element in the universe
15. Element with the highest electrical conductivity

**Last Issue's Answers**




## LAST ISSUE'S WINNERS!

**Connect Crossword**

1. Rajeev Kumar Jain, Associate Professor, Department of Physics, IISc
2. Vijay Subramanian, BS-MS student, IISER Pune

**Guess The Spot**

Kavitha Harish.
(It was near the parking area of the Main building!)

## Conquering Bank Road

By Anushka Jain, 2nd year, Bachelor of Science (Research)

A glimpse into the challenges of rushing between back-to-back classes across campus along Bank Road, infamous for its steep uphill climb.


3/4
3/8
3/8
1/4
3