

InScight

THE IISER KOLKATA SCIENCE MAGAZINE

#6 | NOV 2025

THE PHYSICS OF FORGETTING

When Information Becomes Heat

Tanmoy Pandit

THEMED CROSSWORD

Women In Science



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BREAKING THE ICE

India's First Women
In Antarctica

comic by Arya
Mhatre

Behind The Pages

The newest *InSight* issue, a few tens of MBs in your laptop, other than being jam-packed with the latest updates of the science world, holds something way more profound in the fact that every bit of information, a PDF or the lyrics of a song, when deleted or forgotten, releases a very tiny amount of heat to the surroundings – a tussle of debt which we cranial beings are stuck in with the universe. Information is physical : As Tanmoy Pandit, reflects on Landauer in this very issue, a few pages later.

That science is harmonious is emblazoned by the fact that Marie Curie, the famous physicist's, birthday coincides with the day of National Cancer Awareness (November 7th) in the country. Madame Curie's pursuits shaped modern day radio-therapy, a boon to millions, heightening the fact that science transcends territories, time and systems.

From a cheek cell to a nuclear bomb, we play by the rules, bending some, making new ones.

Brought forth in contrasting taste is a walk back in time to the Carboniferous era when tiny dragonflies you trap in your palm were massive creatures whose survival had integral connections with contemporary temperatures and oxygen saturation, elucidated by Atri Majumdar.

iGEM Team 2025 brings forth A touch of Cancer (a phrase by John Green's protagonist Augustus Waters, trying at hilarity), and a new onco-weapon : the probiotics on your bedside table wherein bacteria engineered to protect, reheat immune-suppressed 'cold tumors' and facilitate the immune system.

A strive to study the rarest diseases of all, brings forth Apurba Das and her insights on neural manifestation of MPS VII, a lysosomal storage disease (LSD), arising from the dysfunctional lysosomes, the terminators of the cell as we call them.

Leading on the front, we have IISER-K's researchers listening to the Rhythm of Rivers for climate management and water-harvesting to 'memory' hunting in magnetic and phase-change systems.

The fact that 'life' and its very possibility is both a 'wonder' and a 'courtroom' of rules, is elucidated by the fact that the gross rules for the existence of life, from the lowest energy to stay alive to the speed of replication of a cell, are pre-determined by the physical quantities : *InSight's* final insight.

Mankind hunts evolution, and physics is an old friend.

With this *InSight's* newest issue, celebrates and unites minds across miles and time dimensions. True to our cause, we plead curiosity, patience and just a tiny home for your crazy ideas.

Happy Sciencing!

Sharanya Chatterjee
Editor, *InSight*

Breaking The Ice

—comic by Arya Mhatre



India's First Women in Antarctica

FIG 1 : Arya Mhatre of IISER Kolkata depicts the pathbreaking achievements of Aditi Pant and Sudipta Sengupta as they became the first Indian women to participate in the Antarctic program. Read her comic to find out more.

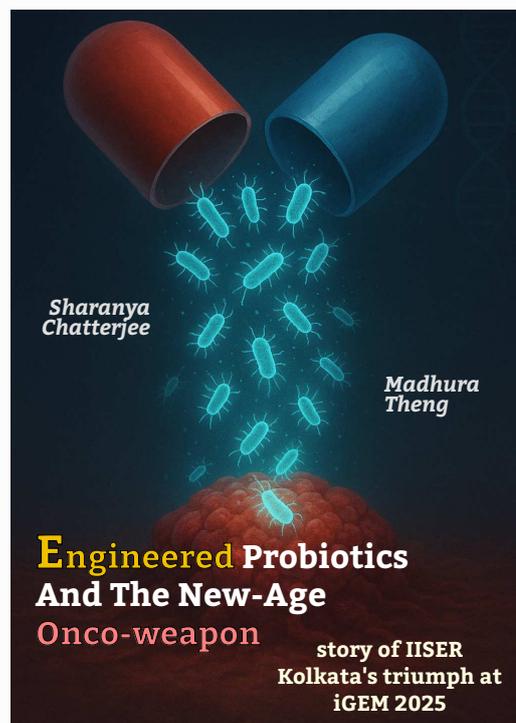


FIG 2 : Sharanya Chatterjee and Madhura Theng from *InSight* cover the story of IISER Kolkata's iGEM 2025 team has engineered ReSET, a probiotic-based theranostic system that senses tumor-specific cues. Learn more in this article.

Lighting the Spark of Science Communication

Foreword by Soumitra Banerjee

I warmly welcome the initiative of the IISER student community to publish the popular science magazine *InSight*. Popular science has the remarkable ability to spark curiosity in young minds and inspire schoolchildren to pursue careers in science. It also plays a vital role in educating the general public about genuine scientific ideas, helping them distinguish science from pseudoscience. This is truly the need of the hour if we aspire to build India into a scientifically informed nation. Yet, India faces a shortage of quality popular science writers; we have not seen the emergence of authors comparable to George Gamow, Carl Sagan, Isaac Asimov, or Richard Dawkins.

Excellence in any craft demands continuous practice, and popular science writing is no exception. No one is born with the ability to communicate science compellingly. One must learn from the works of the great masters—observe their style, structure, and clarity—and then practice consistently. But such practice thrives only when there is a platform to showcase it. I hope *InSight* will become that platform for budding popular science communicators.

India also lags behind advanced nations in another crucial area: science journalism. Very few Indian newspapers employ dedicated science journalists, and consequently, scientific breakthroughs achieved within the country seldom reach the wider public. I sincerely hope that some IISER students will consider science journalism as a career path. Here too, a medium is needed for students to develop and refine their journalistic skills, and I trust that *InSight* will help fill this gap.

The November 2025 issue presents an engaging spectrum of topics—from physics to biology—and I am confident that readers will find it both enlightening and enjoyable.

Prof. Soumitra Banerjee,
Retired Professor, Department of Physical Sciences,
IISER Kolkata

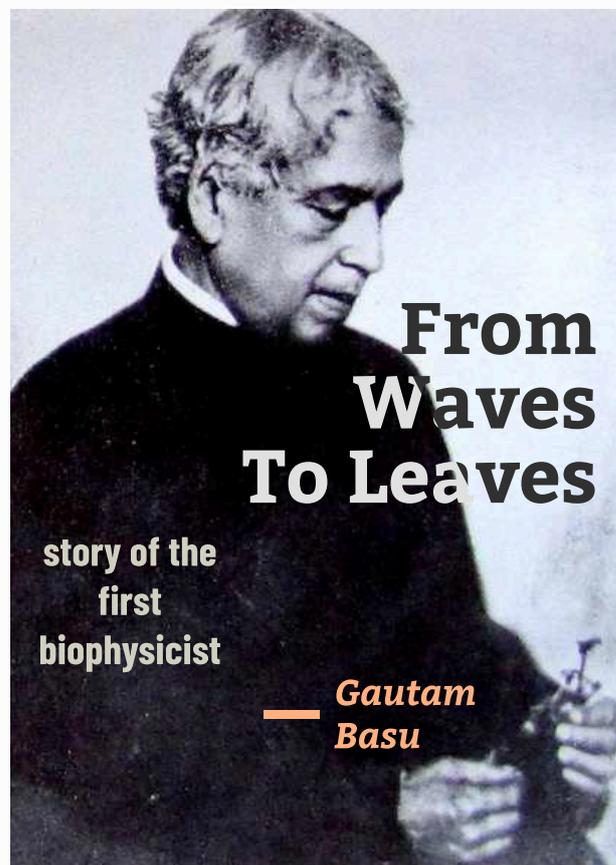


FIG 1 : Gautam Basu traces Jagadish Chandra Bose's extraordinary scientific evolution - from pioneering wireless communication to founding the field of biophysics. Read the article to find out more.



FIG 2 : From a financially humble childhood, doing odd jobs to fund his education, to becoming a scientist shaped by Germany, industry, and decades at NCL, this interview with Prof. Arvind Natu brings out the inner self of the current top most office holder of IISER Kolkata, the chairperson of the Board of Governors.

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Academic Listings: Internships, PhDs, Post-docs

INTERNSHIPS

- DoS/ISRO Internship & Student Project Trainee Schemes  **Deadline:** —
- Visiting Student Research Program at KAUST  **Deadline:** —
- Training as a Material Tester  **Deadline:** 2025-12-30

PHD POSITIONS

- Max Planck Institute for Informatics - PhD Applications  **Deadline:** —
- UC Berkeley's Physics Graduate Program  **Deadline:** 2025-12-15
- Arizona State University Physics PhD Admission  **Deadline:** 2026-01-31
- Exoplanet Characterisation Predictions via Gravitational Microlensing:
Competition Funded PhD Project  **Deadline:** —
- University of Chicago Graduate School Programme  **Deadline:** —
- University of Texas at Austin Graduate School Programme  **Deadline:** —
- University of Utah Graduate School Programme  **Deadline:** —
- University of North Carolina at Chapel Hill PhD Programme  **Deadline:** 2025-12-16
- University of North Carolina at Charlotte PhD Programme  **Deadline:** 2025-12-01
- Louisiana State University PhD Programme  **Deadline:** —
- PhD Position - EPFL  **Deadline:** —
- PhD Position (m/f/d) | Decoding symbiont establishment through systems
modeling and multi-omics integration  **Deadline:** 2025-12-15
- Fully funded doctoral positions | Epigenetics, Biophysics and Metabolism  **Deadline:** 2026-02-06
- PhD student (m/f/d)  **Deadline:** 2026-01-31
- Doctoral (PhD) and postdoctoral position (m/f/d) in Computational Biology
| Biomathematics | Biosystems Engineering  **Deadline:** —
- Ph.D. Student Opportunity (Computational hydrology)  **Deadline:** 2025-12-12
- Doctoral (PhD) and postdoctoral position (m/f/d) in Computational Biology
| Biomathematics | Biosystems Engineering  **Deadline:** —
- Doctoral (PhD) position (m/f/d) in Glia Biology | Neurobiology at the
Dioscuri Centre for Chromatin Biology and Epigenomics at the Nencki
Institute for Experimental biology (Poland)  **Deadline:** —
- PhD Position: Job Code: CF-06-2025  **Deadline:** 2026-01-11

POSTDOCTORAL AND OTHER POSITIONS

- HRDG- Nehru Science Postdoctoral research Fellowship**

 **Deadline:** —
- Maria de Maeztu Postdoctoral position in Gravitational Waves Astronomy at the ICCUB**

 **Deadline:** 2025-11-30
- Post Doctoral Position at Institute of Physical Chemistry, Polish Academy of Sciences**

 **Deadline:** 2025-12-31
- Postdoctoral position (m/f/d) | High-redshift galaxy / black hole evolution**

 **Deadline:** 2025-12-17
- Research Engineer – Software Development or DevOps (m/f/d)**

 **Deadline:** 2025-11-30
- Postdoctoral positions | Computational Relativistic Astrophysics**

 **Deadline:** 2025-12-21
- Postdoc position (m/f/d) | Development and Application of an Ultra-Bright Coherent Soft X-Ray Beamline**

 **Deadline:** —
- Doctoral (PhD) and postdoctoral position (m/f/d) in Computational Biology | Biomathematics | Biosystems Engineering**

 **Deadline:** —
- Associate/Full Professor Tropical Meteorology, Dept. of Geography, University of Georgia**

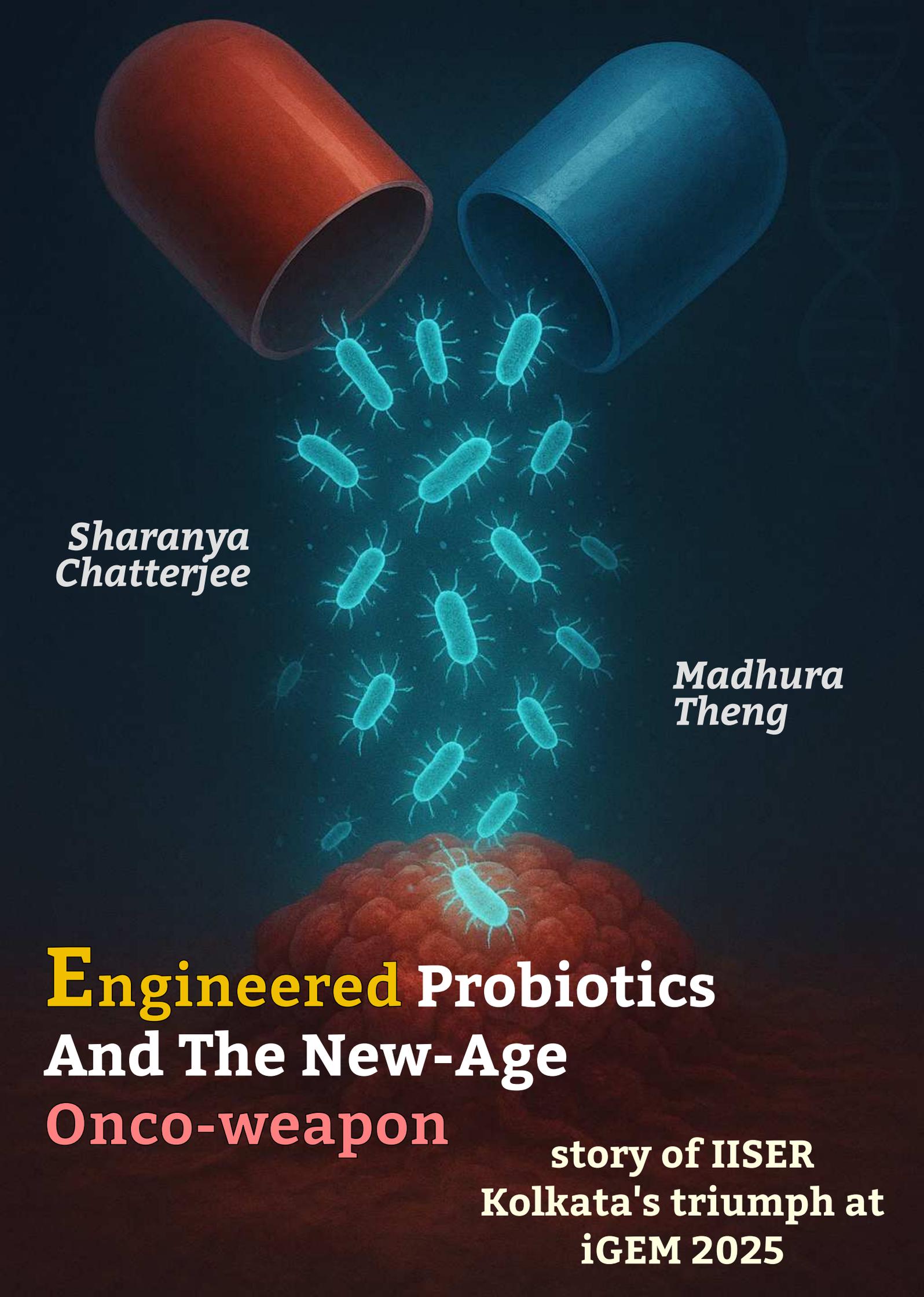
 **Deadline:** 2025-12-12
- Assistant Professor - Geomorphology of Ocean Islands**

 **Deadline:** 2026-01-12
- Associate or Full Professor, Weather Ready Texas Cluster**

 **Deadline:** 2025-12-12
- Director, School of Earth and Space Exploration**

 **Deadline:** 2025-12-12
- Postdoc/Research Scientist in the Reproductive Ageing Research Group (m/f/d)**

 **Deadline:** —



*Sharanya
Chatterjee*

*Madhura
Theng*

Engineered Probiotics
And The New-Age
Onco-weapon

story of IISER
Kolkata's triumph at
iGEM 2025

IISER Kolkata's iGEM 2025 team has engineered ReSET, a probiotic-based theranostic system that senses tumor-specific cues to deliver an anti-CD38 nanobody while simultaneously reporting therapeutic activity through a simple biosensor readout. Blending synthetic biology, mathematical modeling, and community outreach, the project pioneers a tumor-selective, safe, and accessible approach to cancer therapy, earning the team a Gold Medal at the iGEM Grand Jamboree in Paris.

EDITED BY: Archita Sarkar



Madhura Theng and Sharanya Chatterjee are 23 MS students in the Department of Biological Sciences, driven by a shared fascination for synthetic biology and its potential to solve real-world problems. Sharanya (right) previously represented her institute as part of the gold winning iGEM team in 2024 and her research focus lies in neuro-immune crosstalk. Madhura's (left) academic focus lies in neural circuitry, behaviour, and the cellular mechanisms that underpin them.

The red and blue probiotic pills on your bedside table could be the newest therapy for cancer! Unbelievable right? Well a bunch of college kids are here to make your eyes pop with an innovative take on the most ravenous disease of all time — cancer.

iGEM: The Global Stage for Synthetic Biology

iGEM (International Genetically Engineered Machine) is a World Expo of Synthetic Biology held every year where people from all over the world come together, be it government organisations or your scientist-next door, for a celebration of synthetic biology at large. Fast-paced and boisterous, iGEM is home to your coolest Ad-Hocs, the most promising green energy businesses and some of the finest biologists of the world.

And keeping the banner flying high, the newest endeavour of IISER Kolkata in the form of its iGEM Team 2025 brings forth the talk of today - a fusion of therapy and diagnostics — a true theranostic approach – ReSET. A team of ten undergraduates guided by some of the most passionate scientists of IISER Kolkata and high-facility labs can only smell of success!

The project idea grew from a fascination with the concept of the tumor microbiota, how bacteria can naturally colonize tumors and potentially be reprogrammed to fight cancer. **The team was excited by the possibility of using genetically engineered bacteria as living therapeutics within the tumor microenvironment.**

Targeting Regulatory T Cells

Just as Mary Brunkow, Fred Ramsdell and Shimon Sakaguchi turned the Nobel Prize of 2025 in their hands, defining 'peripheral immune tolerance', the iGEM team of IISER Kolkata visualised a therapy which deployed the very same key-players – the regulatory T cells (Tregs) — cells that are normally protective but, within tumors, become co-opted to suppress immune responses.

This led them to Dr. Shilpak Chatterjee's work on CD38, an ectoenzyme highly expressed on intratumoral Tregs, which depletes NAD⁺ and dampens effector T-cell activity. His paper led them to realize that targeting CD38 could 're-heat' cold tumors (those resistant to immunotherapy) and restore immune surveillance.



FIG 1 : IISER KOLKATA iGEM Team. From Ground Left : Iishaan Pyne , Asmi Mhatre , Anjali Mishra, Gautam Menon, Deepanshu. Top left : Sattwik Pradhan , S Nandita, Albin Ajesh, Shankha Shuvra Chattopadhyay, Sagnik Jana, Amrik Das.

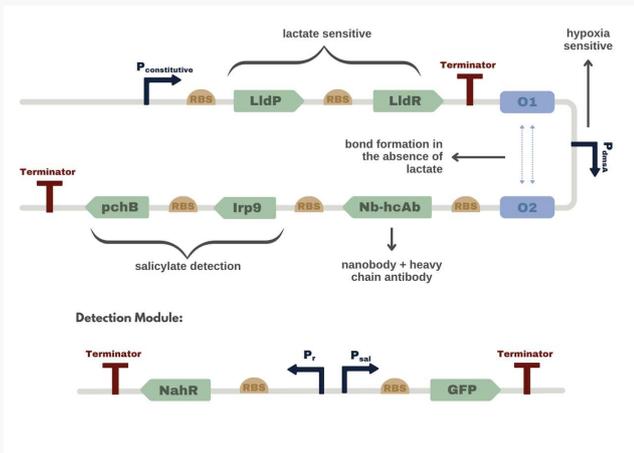


FIG 2 : Gene Circuit created by the team.

System Design: Tumor-Specific Activation via Synthetic Circuit

Combining these ideas — bacterial tumor targeting, the immunosuppressive role of CD38⁺ Tregs, and the concept of localized therapy — the team conceived ReSET, a probiotic system that senses tumor cues and releases an **anti-CD38 nanobody** specifically within the tumor while also enabling non-invasive monitoring of therapeutic activity.

While most cancer treatments are either therapeutic or diagnostic, **ReSET proposes to do both**: it treats tumors by locally blocking CD38 and reports its activity through the secretion of salicylate, a harmless metabolite easily detected using a low-cost paper strip.

Core Technology: Control with an AND Gate Biosensor

At the heart of ReSET lies a **biosensor circuit** engineered to function as an AND gate, adapted from the lldPRD operon. This core module ensures that gene expression is activated only when both lactate and hypoxia — the hallmark conditions of the tumor microenvironment — are present, to prevent off-target killing. The LldR/LldP system acts as the lactate sensor, where high lactate levels lift LldR-mediated repression, while the P_{hmsA} promoter drives expression specifically under hypoxic conditions. Together, these inputs tightly **regulate downstream**

expression, ensuring precise tumor-restricted activation and eliminating off-target effects.

Downstream of the AND gate, two key modules operate in parallel — the therapeutic module, encoding the anti-CD38 nanobody-Fc fusion, and the diagnostic module, comprising Irp9 and PchB, which synthesize salicylate as an externally detectable biomarker. In addition to the probiotic system, they also designed a **hardware-linked sensing circuit** featuring a bidirectional promoter responsive to salicylate. This interface allows the bacterial signal to be translated into a measurable output on the paper-strip-based detection platform, completing the loop between biological computation and real-world monitoring.

Tumor-Selective Targeting

You furrow your eyes and murmur “Target killing?”, but Team iGEM has got you covered. Specificity in RESET is ensured at multiple levels. First, the chassis — *E. coli* Nissle 1917 — was chosen for its natural ability to **selectively colonize tumor tissues**, a property that provides an inherent layer of spatial targeting. Second, the biosensor operates through an AND gate that requires both lactate and hypoxia signals for activation. These two conditions rarely overlap in healthy tissues but are defining features of the tumor microenvironment, ensuring that the therapeutic module is expressed only within the tumor. Finally, the therapeutic nanobody targets CD38, a marker highly specific to intratumoral regulatory T cells (Tregs). By focusing on this subset, they **prevent off-target effects on peripheral Tregs** and reduce the risk of triggering autoimmune responses.

Mathematical Modeling that helps predicting Efficacy

The project’s mathematical model comes in to enhance precision and robustness. *From kinetically modelling the inhibition of the hydrolase activity of CD38 by the nanobody-CD38 interaction to stochastic stimulation of the AND gate in the genetic circuit.* At tissue-level they **analysed tumour-growth models** to integrate tumour-immune dynamics. At the cellular level, they modeled the tumor cell cycle phases to understand how NAD⁺ restoration and Treg depletion affect tumor proliferation and apoptosis dynamics. By integrating CD38 activity inhibition with cell cycle checkpoints, the model **predicted a shift toward**

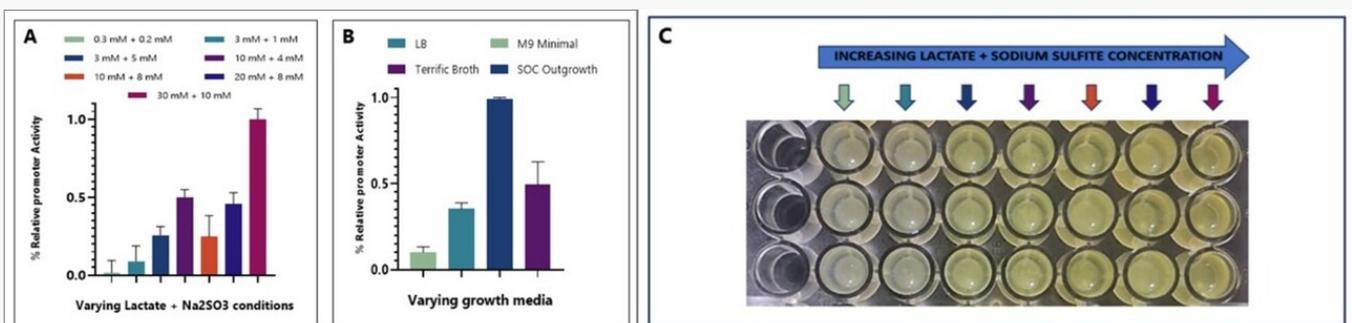


FIG 3 : Optimization of promoter activity under varying lactate and sodium sulfite concentrations and growth media. (A) Relative promoter activity increased with higher inducer concentrations. (B) Comparison of promoter strength across different media. (C) Visual representation of the experimental setup showing color variation with increasing inducer concentration.

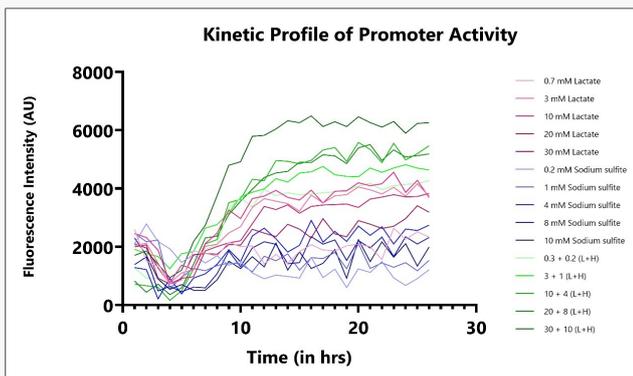


FIG 4 : Kinetic profile of promoter activity showing fluorescence intensity over time for different concentrations of lactate, sodium sulfite, and their combinations. Co-induction with both substrates led to the strongest and most sustained promoter activation.

cell cycle arrest and increased sensitivity to immune-mediated killing.

It is now that you wonder how safe is ReSET as a therapy? As the team themselves say, what sets their approach apart is its precision, safety, and accessibility.

Tumor-Selective Approach

Traditional cancer treatments like chemotherapy, radiation, or surgery are invasive, systemically toxic and often non-specific, harming healthy cells alongside cancerous ones. In contrast, **ReSET is non-invasive and tumor-selective**. It deploys engineered *E. coli* Nissle, a safe, well-characterized probiotic, that naturally homes to the colon, where it senses tumor-specific cues and secretes the therapeutic module precisely within the tumor microenvironment.

Biocontainment: Advanced Kill Switches and Scalability

Additionally, the bacterial system, a **GRAS** (Generally Recognized As Safe) strain with a long record of human probiotic use, is programmable, cost-effective, and easily scalable, unlike monoclonal antibodies that require expensive production and intravenous administration. To further ensure safety, the team implemented a **dual-layered lysis-based kill switch** inspired by advanced biocontainment systems for engineered probiotics. This circuit employs a *ccdB* toxin fused to a *ssrA* degradation tag, which keeps the toxin inactive within the host. Upon escape to external environments, cold-shock promoter activation triggers TEV protease expression, which cleaves off the *ssrA* tag, stabilizing the *ccdB* toxin. The now-active toxin inhibits DNA gyrase, leading to rapid self-lysis and **ensuring that the bacteria cannot survive outside the anaerobic tumor core or colon**.

Outreach : Making Science Accessible

ReSET stands out as a radical leap in cancer therapeutics — living and self-aware, a protector who talks back. However, science without striving for the community is just indulgence, so team iGEM's outreach philosophy began with a simple belief — science should speak a language everyone understands.

They began by listening. Conversations with cancer survivors, caregivers, onco-psychology experts, and the NGO Life Beyond Cancer grounded our project in the lived realities of cancer — the emotional toll, financial burden, and stigma that often remain unseen.

Partnering with schools, NGOs, and prominent educators like **Mr. Subhanath Chattopadhyay**, the iGEM team launched **Biology Beyond the Microscope** — a series of workshops that combined storytelling, hands-on experiments, and games to make biology intuitive and fun. From colour-changing chemistry and good-vs-bad bacteria activities for primary students, to demonstrations on genetic engineering and biosensing for high schoolers, every session aimed to spark curiosity and make science inclusive — especially for neurodivergent and special-needs learners.

Another collaboration with the **Breakthrough Science Society** and the **Satyendranath Bose Science Learning Centre** allowed them to reach hundreds of students through interactive science exhibitions and bilingual (English-Bengali) educational materials.

At the community level, they conducted cancer awareness drives during Durga Puja (a regional festival), held blood donation camps, and hosted public sessions at NGOs such as Ashar Alo, where even specially abled children participated in playful learning activities. These efforts were featured in *Anandabazar Patrika*, a regional newspaper, and led to widespread creation of awareness through the social media handle reaching people in thousands.

A cup of instant coffee in hand, missing protein ladders, and PCRs gone wrong, as the team raced to catch the last campus bus, they discovered that research isn't just about spreadsheets of success — it's about resilience, laughter, and teamwork.

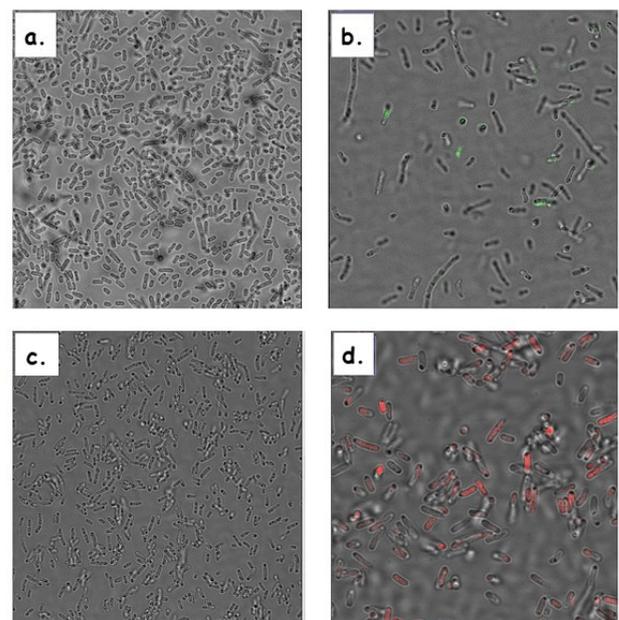


FIG 5 : Fluorescence microscopy of engineered *E. coli* under varying induction conditions. (a) Uninduced control, (b) cells showing GFP fluorescence upon lactate induction, (c) sodium sulfite induction, and (d) co-induction with both inducers resulting in RFP signal, confirming dual-input promoter responsiveness.



FIG 6 : Ishaan Pyne, one of the team members, conducts a school outreach session to introduce students to the fundamentals of synthetic biology and its real-world applications.



FIG 7 : From classrooms to labs — inspiring the next generation of bioengineers through interactive discussions and fun activities.

Innovating for India's Future

The blistering population of over a billion in India stands today saying “Cancer? A disease too complex to understand and too expensive to fight!” This quirky, bright team of IISERites takes a chance for millions across the globe, to innovate and protect. For as Buckminster Fullerene had once said, “The best way to predict your future is to design it!”

On November 1st, at the prestigious International iGEM Jamboree held in Paris, the IISER Kolkata team was awarded the coveted Gold Medal in the oncology village which is the most popular and has the highest competition. This recognition celebrates the team's innovative contributions to cancer therapy and diagnostics, marking a noteworthy achievement for undergraduate level in synthetic biology on a global platform



FIG 8 : Gold glory for Team IISER Kolkata! Months of innovation, teamwork, and passion paid off at the iGEM 2025 Jamboree at Paris.

The Physics Of Forgetting

Tanmoy
— Pandit
(QMill)

when
information

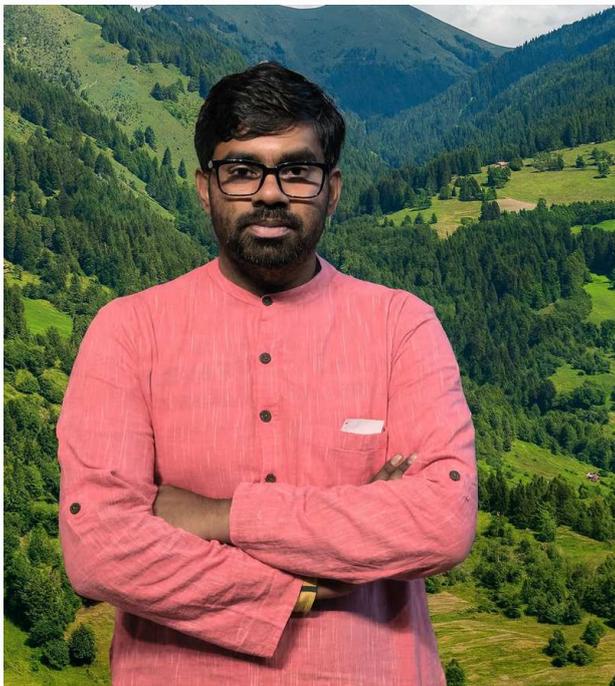
becomes
heat



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Every act of remembering, measuring, or deleting information leaves a scar in the fabric of the universe by releasing heat. This connection, known as **Landauer’s Principle**, bridges two of greatest intellectual adventures—computation and thermodynamics—and reveals that information itself obeys the laws of physics.

EDITED BY: Archita Sarkar



Tanmoy Pandit is a Quantum Algorithm Scientist at QMill (Espoo, Finland), focusing on quantum error mitigation, quantum noise characterization, and algorithms for NISQ devices, alongside large-scale simulations of open many-body quantum systems. Beyond physics, he switched from Quantum Algorithm to music—violin and piano—and he’s committed to scientist activism and public-interest science through the India March for Science – Abroad Chapter (IMFS-A) and the Breakthrough Science Society (BSS) – Abroad Chapter.

This article draws inspiration from: T. Pandit, G. Paul, A. Misra, and P. Chattopadhyay, Landauer Principle and Thermodynamics of Computation, *Rep. Prog. Phys.* **88**, 086001 (2025).

A Whisper of Heat

When you delete a file from your personal laptop, it vanishes from your screen. But in a deeper sense, it doesn’t disappear—it transforms. In 1961, physicist Rolf Landauer made a bold claim: erasing one bit of information must release a tiny but unavoidable amount of heat into the environment. The minimum possible cost is

$$Q_{\min} = k_B T \ln 2$$

where k_B is Boltzmann’s constant and T is the temperature of the surroundings. At room temperature this is only 2.9×10^{-21} joules per bit—too small to notice, but large enough to impose a fundamental limit on every computer that has ever existed or will ever be built.

Landauer’s insight turned information from an abstract concept into a physical quantity. Knowledge, it seems, comes with a price tag—paid not in dollars, but in entropy.

The Demon who Cheated the Second Law

The idea traces back to one of physics’ most famous thought experiments. In 1867, James Clerk Maxwell imagined a mischievous being—a “demon”—who could sort fast and slow gas molecules using a tiny trapdoor between two chambers. By letting only the fast ones through one way and slow ones the other, the demon could create a temperature difference out of randomness, apparently defying the second law of thermodynamics:

$$\Delta S_{\text{total}} = \Delta S_{\text{system}} + \Delta S_{\text{environment}} \geq 0$$

If such a demon existed, it could create useful work for free, making a perpetual-motion machine of the second kind and this was century old unsolved problems.

Szilard’s Brilliant Simplification

Half a century later in 1929, the Hungarian physicist Leo Szilard gave the demon a more concrete stage. He devised a *Gedankenexperiment* that distilled Maxwell’s paradox to its purest form: a box containing just a single molecule of an ideal gas in contact with a heat reservoir. His “one-molecule engine” proceeds in four conceptual steps:

- a) Insert a partition to divide the box into two equal halves of volume $\frac{V}{2}$. The lone molecule lands on one side or the other.
- b) Measure which side it’s on. That act of observation gives the demon exactly one bit of information.
- c) Attach a frictionless piston to the correct side. The molecule pushes the piston outward, expanding isothermally and doing work

$$W_{\text{out}} = k_B T \ln 2$$

- d) Remove the partition and reset the system. The demon is ready to start again.

At first glance, Szilard’s setup appears to defeat the second law: the demon extracts work from random motion without any apparent cost. The catch lies in the demon’s memory. To repeat the cycle, it must erase the record of which side the molecule occupied. According to Landauer,

$$S = -k_B \sum_i p_i \ln p_i = k_B \ln 2H$$

They are not just mathematically similar—they are the same concept in different units. Every bit of information corresponds to a physical entropy of $k_B \ln 2$.

Whenever a computer deletes or erases data from its hardware chip, it is not merely rearranging symbols on silicon chip of your computer; it is converting structured information into heat that diffuses into the environment. Or as Landauer famously said, “Information is physical.”

From Thought Experiment to Real World Technology

For decades, Landauer’s limit was a theoretical curiosity. Today, it defines the holy grail of low-power and quantum computing. Modern transistors waste billions of times more energy per operation than this bound, largely because real devices operate far from equilibrium. But as engineers shrink circuits to atomic scales, and physicists manipulate qubits that are easily disturbed by heat, Landauer’s principle becomes not just elegant but essential.

Recent experiments have even erased information using **angular momentum** instead of energy, and verified quantum versions of the principle using superconducting qubits. Each test confirms the same conclusion: there is always a thermodynamic price for forgetting.

The Universe Keeps its Books

From Maxwell’s demon to Landauer’s principle, the message is clear: there is no free lunch, not even for information. Every act of learning creates order; every act of forgetting restores disorder. The heat from your laptop, the power consumed by data centers, and the entropy of black holes are all governed by the same equation.

In a sense, we are all demons—tiny processors in a vast cosmic engine. And as we compute, think, and erase, the universe quietly tallies our debts in units of heat. To know is to order. To forget is to warm the world, ever so slightly.

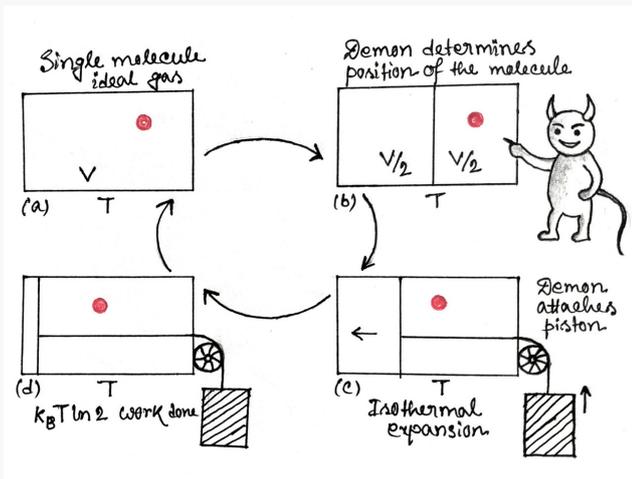


FIG 1 : Schematic of Szilard’s gedanken experiment. The demon inserts a partition, measures the molecule’s position, and allows isothermal expansion to extract work $k_B T \ln 2$. To repeat the cycle, the demon must erase its memory, dissipating the same heat

that act of forgetting releases exactly the same energy gained earlier:

$$W_{\text{erase}} = k_B T \ln 2 = W_{\text{out}}$$

Balance restored—the second law follows. The demon can’t win, because the universe always collects its entropic cost.

When Bits Meet Atoms

This simple realization changed how scientists view both computation and nature. In Shannon’s information theory, uncertainty is measured by the Shannon entropy

$$H = - \sum_i p_i \log_2 p_i$$

while in statistical physics, the Boltzmann entropy reads



FIG 2 : In 1867, J C Maxwell imagined a tiny being that could seemingly outwit the second law of thermodynamics. Decades later, Leo Szilard transformed the paradox into a single-molecule engine, showing that information and energy were inseparably linked. In 1961, Rolf Landauer closed the loop, proving that erasing information carries a fundamental thermodynamic cost.



Where Curiosity meets Experience! Prof. Arvind Anand Natu engages students in an inspiring interactive session.

Guiding the Next Generation of Thinkers: An Interaction With Prof. Arvind A. Natu

Swarnendu Saha (IISER Kolkata)

From a financially humble childhood, doing odd jobs to fund his education, to becoming a scientist shaped by Germany, industry, and decades at NCL, this interview with Prof. Arvind Natu brings out the inner self of the current top most office holder of IISER Kolkata, the chairperson of the Board of Governors. Team InSight feels this interview would showcase life lessons, humour, and practical advice from someone who has seen science, institutions, and people grow over decades.

[Also available online, at \[scicomm.iiserkol.ac.in\]\(https://scicomm.iiserkol.ac.in\)](https://scicomm.iiserkol.ac.in)



SS: Hello sir. I am Swarnendra Saha from Team InSight and today I came here to interview you. I hope you are okay with it.

AAN: Oh yes.

SS: Okay, Let's start from the very beginning. How did you get here? By that I mean the point where you sit today.

AAN: Okay. I come from a very very normal family with a lower middle class family of the country and from the age from all my college days I had done my education of my own because my parents had never seen the doors of the school.

SS: On my own means?

AAN: I mean I earned money.

SS: From school days?

AAN: No. From my college days.

SS: Tuition Parathey the aap? You gave tuition ?

AAN: Tuition parathe nahi, I did anything you can imagine, you know; Labour, paper and everything else that is possible.

SS: Okay.

AAN: So I did that because somehow I wanted to learn. And I told my father that I'll be on my own. When I came to Pune, I took admission in the college. Four years I passed basic chemistry with distinction and then I joined Pune University and passed out the MSc. This is all I was doing while I was working.

SS: So you are from a Marathi background?

AAN: Yes, yes. Marathi is my mother tongue.

SS: Okay, and you are around Pune?



FIG 1 : Prof. Natu completed his MSc in Organic Chemistry at Pune University, while he was working.

AAN: No, my hometown is in Belgium, which is on the border of Maharashtra and Karnataka.

SS: Okay.

AAN: So and then after my MSc, there was a high, very high pressure on me that I must adopt a job and all. So I must do the job. But in between I met a girl who insisted that I must do PhD and that was my wife. I got married at a very, very early stage and when I was just 21.

SS: Sorry?

AAN: When I was just 21, I hardly passed MSc. But in those days that was a girl's marriage age. So I married at a very early stage.

So my journey on the family front is very smooth. I became a grandfather at the age of 45.

SS: What? Really?

AAN: Yeah, and may become a great-grandfather maybe in another one or two years.

SS: So by 60 when you are at the retirement age...

AAN: ...My both daughters got married.

SS: Wow. So you have a very big family.

AAN: No, my wife, me and two daughters. Okay. That was my family. And my bigger family was father, mother, his son, a brother and a sister. My parents took care of their education. I said I'll take mine. And thus I wanted to do it, I was in a bit of a shift. But my wife insisted that you must do a PhD. There is no alternative for me. So I got a job in AFMC actually.

SS: AFMC?

AAN: Armed Forces Medical College, as a lecturer after my MSc.

SS: But you did your...



FIG 2 : Prof. Natu worked as a lecturer at the Armed Forces Medical College (AFMC), right after his MSc.



FIG 3 : *National Chemical Laboratory (NCL), where Prof. Natu completed his PhD and spent over three decades of his career.*

AAN: Masters in Organic Chemistry, but still I was offered a job in AFMC.

SS: How?

AAN: That is the trick of the army. So I worked there for some time and then I joined NCL, National Chemical Laboratory. I was drawing 300 rupees as a fellowship which is unimaginable today.

SS: But in those days it might be a good amount of...

AAN: Oh, maybe, maybe to some extent. My wife took up a job and we started both.

SS: She was also in academia?

AAN: No, she was my classmate, but she was a teacher.

SS: School teacher?

AAN: School teacher. And then we started our journey. In another first year after the marriage, my daughter was born. So when I was studying for my PhD, first paper, my daughter was already born. So it's very, very unheard of nowadays, you know. But that is the thing. Then after doing all this business, I managed to get my PhD after a little bit of a long time because I was working all over there. And when I was there, I had no idea where to go. Generally people used to go to the US at that time for postdocs. Somehow I had some special love for Germany from day one. So I applied for a fellowship. In all over India there were 700 applications, out of which 9 were to be selected.

SS: Only 9?

AAN: Only 9.

SS: 10 minus 1, 9?

AAN: 10 minus 1, 9. And I was, my number was 2 in the merit list. So I could get wherever I wanted, you know. So then I went to Germany. I went to West Berlin. In those days it used to be called West Berlin because of East and

West. The division was there. So I studied at Technical University Berlin, TU Berlin. But one thing, when I first went to Germany, there were three obstacles. Number one, I was a complete vegetarian fellow.

And there was no concept of vegetarian food. Forget about availability. No concept of what people eat if they can't eat meat. Then, regular water was not available. If you ask for the water in the hotel, they'll tell you that you have to take medicine. No regular drinking water. The concept itself was not there.

SS: But people, biologically, do need water to drink, right?

AAN: Yeah, soda, water and in Germany they say carbon dioxide, carbon. But no normal water, hardly anybody will drink. Then, and third was the worst language. Now everybody speaks English everywhere. In those days, no English. The place where I was staying in a small village, I was the only fellow who could speak English. This was a small village near Geneva. And I decided if I had to study in this country, my language has to be strong. So I spent four months of my life studying language, thorough language, regularly going to school, studying there. And what others could not achieve, I achieved. Three courses in four months. Generally, people finish first. So there was that I could finish. And then I joined as, by the time I went to Berlin, I could speak German and talk and all. Because I was not, I was knowing, although in the lab, you can manage with English.

SS: Do you remember the language tutorial?

AAN: Today? You can take my interview in German. Because, that is because my ties to Germany in my life are very, very strong. Then I took up a, after finishing my postdoc, and then I got the extension again.

SS: Your postdoc was in TU Berlin ?

AAN: TU Berlin.

SS: Where was your PhD?

AAN: NCL. NCL.

SS: And in AFMC, you were a lecturer.

AAN: Yes. And then when I finished, I got twice the extension also. For four years I did postdocs. And then my professor asked, what you like to do? Would you like to go back? I thought, let me take the experience in industry.

SS: Industry ?

AAN: Industry. And that complete interview, I gave it in German language.

SS: Complete interview?

AAN: Complete interview. A to Z. And there was not a bit of a problem. And I managed to get the job as well. But I realized after six months, it's better to come back

mainly because we are not accepted in European society. Especially in German society, which was war, war born, I can say.

SS: Racism?

AAN: Yeah, it's racism. And I tell you one thing, today also it is accepted. Today it also exists.

SS: In Germany?

AAN: Everywhere in the world. Let me tell you. You are respected only because of your brain and all of that. But when you enter into social life, ...

SS: ... You're an external person, still out.

AAN: Yeah, yeah, still out. In India also it is the case. So that kind of thing is there. So I decided to come back by thinking, let me have, what do you say, let me have first class citizenship in the second class country, but not the other way around. So I came back, applied for a job in NCL again, and fortunately then I continuously served for more than 30-35 years in NCL.

SS: So your major part of your working life lies with NCL.

AAN: Yes, NCL.

SS: And then how did you come to Pune? I mean, IISER Pune?

AAN: I'll just tell you some stories about my NCL life. That is also equally important. In the beginning, I started working on several things, natural products, synthetic chemistry and what not.

One day I met a gentleman who gave a completely different direction to my life. His name was Dr. Merchant. I was talking to him and we were coming in flight and then he asked me, my dear young man, what are you doing?

Then I was bubbling with enthusiasm, I did this, I did this and all of that. And then very calmly he said, my dear young boy, if you cannot use organic chemistry for either medicine or biology, it's of no use. In this sentence he said, that opened up my eyes.

And I started learning biology, using biology textbooks at the age of 34 or something like that. So because I realized that for organic chemistry, biology is highly necessary, complementary, then you will be able to design your molecules properly and so on and so forth. So I took up, I took up for the so-called bio-organic chemistry, maybe DNA-based, protein-based, I worked on the diagnostics and several things.

And last, how the circle completes, I gave a complete course on biology and chemistry of DNA and RNA for PhD students in biology and chemistry in a German university, Bielefeld University.

Of course, I didn't give that course in German. Maybe the first 20-15 minutes, but later on it was difficult, because it was a 28 lecture course. So I said, I learned biology late, but



FIG 4 : Technical University of Berlin (TU Berlin), where Prof. Natu pursued his postdoctoral research.



FIG 5 : Prof. Natu later taught a full course on the chemistry and biology of DNA and RNA at the **Bielefeld University, Germany.**

completed this circuit to teach biology to German students in a university called Bielefeld University.

In between I had visited several universities and all other things in Germany, Europe, everywhere practically, to give talks and all of that. Its corollary is that chemistry, knowledge of chemistry must be used for societal needs. And that is where I entered into the pharma business.

SS: Pharma?

AAN: Pharma - pharma companies. I specialized myself in pharmaceuticals, synthesis, process development, all other things, impurity analysis, what not. So I was a director, board of directors of public pharma companies for three different companies.

SS: So you mean PSU companies?

AAN: No, no, regular private companies. I was a member of the board of directors in three pharma companies, and as a consultant to many national and international companies. Frankly speaking, I cannot remember how many companies I was a consultant for. Because later on, at the end of the day, I realized that if it is, our knowledge is not used for societal needs, then where is the point? The difference is, what is the difference between this theoretical or what we do is, first we create a nice problem, or we design a problem, and then try to solve it. Instead of that, can we take up a ready-made problem that is required, and then try to solve it.

According to me, the second way is preferred, because of course, some, all high science, technology needs high science, there is no doubt about it. So I worked for the pharma industry, I worked in antifungals, I used several things, including one Japanese and one Hungarian firm. I was also a consultant. So I spent my life in NCL fully, I enjoyed my life.

And then after that, in the last few years, there was one Dr. Ganesh, who was the first director, I said, we were sharing the lab, we were sharing the office, everything in NCL. And then we were discussing this project with students, how they don't know anything, MSc, first class, *kuch malum nahi hai* (they don't even know the basics). So there we took an essence that we must do something for that.



FIG 6 : Prof. K.N.Ganesh, founding director of IISER Pune and a key mentor during the institute's early years. He and Prof. Arvind Natu shared the laboratory and the office during their days at NCL.

And it initiated, of course, that we were very small fish the whole time. Then there were great people like C.N.R.Rao, and all of the people joined, they inculcate a great tendency to develop eye service for this thing, mainly with two USPs. One is the inculcation of research at the graduate level, which is a really very good point.

And second, we also follow all the interdisciplinary teaching, research, maybe it is a biological, mathematics or mathematical physiology or molecular biophysics, or nanoscience, biocomputation, whatever. So these were the two USPs. And we had a lot of problems, it was not a very smooth life. The year 2006, when we started, we were given four months to start a so-called World Cross University, four months only. February 2006-08, 1st of August, ministry order, your institution must start on 1st of August. 24 students, four faculty members, with which we started, and a 10,000 square feet lab.

Today, 10,000 square feet is just a corner of some lab. But we started with that. Then slowly through many transitions, mainly because of the teamwork. And Dr.Ganesh had one - I must appreciate his leadership. Once he tells you something, you will never intervene. It's a complete freedom you have. You can make a decision, you can do anything you like. He said, if you fail, I am responsible. So that kind of team spirit we enjoyed in bringing up IISER.

See, why I'm telling you this specifically, today, you might think that everything has come just on its own, you know, whatever you see today. But it's not the case. We have learned it in a very hard way.

We went to the transit campus, after the transit campus, we came to the main campus, and now we are more or less settled. I can give you a small example. When we took up the land, it was completely stony with snakes, scorpions, bamboo jungles, big stones, and there was Nala, everything was there. And we had built up one building, somehow managed to get, which will take care of everything. Laboratories, classrooms, lectures, offices, everything together in one building. The hostel was also there.

But in the night, students used to be afraid. What we were doing, you know, we used to come in the night to sleep



with the students in the hostel, just to give them courage, you are not alone, we are here. So like that, we developed that culture, the students-teachers relationship, and everywhere. And that's why the Pune IISER is there. So that was one of the transits.

We took a lot of effort to develop that culture from day one. Number two, you might be surprised to get a faculty, it was a very difficult thing. Good faculty, because every faculty that will come will have one IIT offer, one IISc offer. So how to attract faculty? So we said you are the pioneer of the institute, you can do whatever you like. So like that we collected. You know, you might be surprised, in the beginning we went abroad to get good lectures, assistant professors. I went to Oxford, Boston, everywhere people went, and they tried to sell IISER Pune to the young postdocs who would like to come back. What else could we have done? If they didn't come to us, we had to go to them. So that way we acquired very good faculty, that is for sure. And then from day one, our goal was to get the best infrastructure. Today in IISER alone, I think more than 200 students in IISER Pune. And this was possible because of the exact leadership and team spirit. This went up to recently, and then in 2019, I got a call from the ministry.

They said, we would like to have a BOG chairman for IISER Kolkata. There was nobody apt. So would you like to have it?

To be frank enough, I did not know what to say. Of course I knew, because there were several BOG chairmen who came and all. I was not sure of the exact nature of the job. Then I learned, I talked to many friends, and with their consultation, I felt that they said, you will be able to do the job. And from that day, just now today only, February 2019, as of today, I am carrying out this, my job. Many directors, interaction, everything.

And then slowly, slowly, this news spread. And then they said, oh, since you are taking Kolkata, why don't you take Thiruvananthapuram also? So now, as of today, I am the BOG chairman of four IISERs.

SS: Four IISERs?

AAN: Yeah.

SS: Which ones?

AAN: Kolkata, Trivandrum, Berampur, and Bhopal.

SS: So even this month, you are traveling all the IISERs for convocation?

AAN: Just now I received an email from Berampur. Their convocation is also coming up.

One more facet of my whole thing, as I said, is I was involved in a lot of Indo-German collaborations. Educational institute, industry, science, everywhere. So four years back, I was awarded the Cross Order of Merit. This by a German president, which is the highest civilian award given to a foreigner.

SS: And you got that?

AAN: I got it. See, why I am telling you this, not because I am some great or anything, but people also should

learn that besides research, you need to develop several things. For example, I must have translated more than 900 German pages in English. Translated several thesis, because that was my hobby. You should have some hobbies also. I had translated several theses, patents, everything.

So that was one of the things that I, that is very, which is very close to my heart for my collaboration efforts. Thus, nobody knows how the people are selected. Even the candidate doesn't know that his name is being considered or anything.

You don't have to submit any bio-data for anything. It is at that level. And in our country, all civilian awards if you get, you have to go to Delhi and get it. This is the only award where the German president's man will come to open it. At three o'clock in the afternoon he came. He left at nine o'clock by giving me that honor and all other things, medal, everything.

Forty minutes program and then he left. This is the, I thought I'll just share this. This is exciting. Besides that I got several lifetime achievement awards and all other things. That is okay. This is a part of it. But this is something really. And I have been research ambassador, German research ambassador from 2007 onwards to facilitate the Indian students to go to Germany. We had the scheme.

I don't know whether you know it. There was a one wise-scheme we developed where the third year or fourth year students from ISER can go to Germany for three months and take up that. Take up, they can, they're to and fro fare and they'll be paid some 700 euros per month. I have sent a minimum 13, 14 students every year from IISER Pune. This is a completely different passage from my chemistry administration and German.

Therefore I enjoy speaking German. If you ask me to give an interview, many times I also translate my e-mails in German and read it. Because then I'll get practice.

SS: Sir, in continuation of your things, there are a couple of things that came up in my mind. Firstly, you yourself have come up, not from a very lucrative family. But you have built yourself up. In that light, today, in today's scenario, IISERs



FIG 7 : The highest civilian honor given by Germany to a foreign national, the **German Cross Order of Merit**, was awarded to Prof. A.A.Natu.



do have students from various backgrounds. And keeping aside everything linguistic and others, only one parameter that becomes very strong is finance, economic background. So we have a good chunk of students from economically weaker sections. However, if we see the Fees structure, EWS students don't have much respite. So my question to the BoG chair is, can there be any way to provide respite to those particular students whose sole criteria is nothing else but the fact they come from an economically weaker section?

AAN: And merit.

SS: Of course, merit. Yes.

AAN: So, now I tell you, I look after this. In the beginning, when we started IISER, we were following the INSPIRE scheme. That means top 1% in-state votes are only entitled to join IISER. So we're selfish. We thought we don't have to pay anybody, because if it is 1%, INSPIRE Fellowship, they'll get 5,000 rupees. But then slowly I realized one thing. Only money cannot attract us. I must confess, I thought in the beginning money will attract everybody to IISER. Then we realized, no. And slowly we got rid of it. And then the question is, still our boys are good. So 70% or 60-70% they get the INSPIRE Fellowship.

Although it's not much, it is 5,000 rupees. Then I will tell you how we solve the problem. There are several government schemes. For SC there is something, and all other schemes through which I got the fellow to IISER. And I said, please tell the students how to apply, what to do, and all that. So in IISER Pune, at least 80-85% students, they get the money.

But then we have Corporate Social Responsibility also. For example, we told Infosys that you pay for 30 students. So they paid. This way, we adjust. And if suppose amongst that somebody is not, in spite of doing this, he could not, then we take care. For example, I said that if it comes to that, I pay for the students.

SS: Something cannot be done for Kolkata or other IISERs?

AAN: Why not? The West Bengal government has plenty of these schemes. There are plenty of schemes. Fact is, there is no proper coordinator. So somehow we have to make an effort.

SS: Yes, because I mean each batch has about 200 students in ISER Kolkata. So if from the institute or from the government or from some agency, if efforts can be taken, I guess 200 students can be accumulated somewhere or the other.

AAN: Yes, through CSR. You need to try several ways. You can't just sit at home and wait for this. Somebody has to coordinate with the West Bengal government. Our students' merit is so high. Their merit is so high. They don't get these kinds of people there.

SS: So the West Bengal government chief secretary is a part of BoG?

AAN: So being... But somebody has to go, approved from the office of the board of governors. And again, that fellow, that particular fellow, should have passion to do office. The problem is, if you don't have passion, you can't do it. We could build IISER only because we had just one passion, that we'll do it and show it. And we kept on accepting different people.

SS: No, my thing is that, at least if this point comes up in the BoG meetings.

AAN: Oh, surely. I'll tell you one thing. You don't have to wait for that either. A proper fellow, who is well connected with the West Bengal government, can approach. There is one social welfare department, Samaj Kalyan. Then there are departments for higher education. So there are several ways of doing it. Provided, if somebody has passion, that his children should get this. I did it in the beginning to start with. Now I don't do it. I have now put two, three fellows, faculty, similar faculty, who have some passion. They don't do it. I am told, this approach will work. It can be done.

SS: My next question is that, given the present scenario, present international scenario, I mean, do you, as a teacher, suggest students go abroad to pursue a PhD or step back and try in India?

AAN: Depends mainly on the subject. There are some subjects or some areas, which are really equivalent to an international scenario. For example, if you want to go to quantum computing, I don't think we have the real expertise.

All are theoreticians. Or there are many, many areas like this, where you have to go there. But in certain cases in biology and all, you can do it in India. Only you won't have a thappa, or seal, that your PhD from US or UK.

SS: Is it required or does it matter? The foreign tag matters?

AAN: The foreign tag many times matters, while doing the, while, when you go for the interview. It's a mentality issue. So if I say that, your PhD from IIT Kanpur, or IISc Bangalore, and you say, somebody else says, I'm PhD from Yale University, then they'll say, oh, yes. You may get the edge of having a seal and the brand value attached along with.

This is not always, it is very difficult to generalize, let me confess also. But I feel in certain areas, you can do very well in India, there is no doubt about it, but in certain cases, you have to go abroad. And people have one wrong notion, that if you go abroad and fast.

Basically, according to me, our BS-MS degree is ideally to build the capacity.

SS: Capacity? Of Students?

AAN: No. Analytical capabilities, nurture the creativity, presentation skills. These are all taught, according to me.

And at the end of fourth, or four and a half years, if you are well trained in this, you can accept any challenge you like, whether it is academics, whether it is industry, or some



other jobs. When I say some other jobs, I would like to draw your attention to two things. One, I have sent several boys to law.

SS: Law?

AAN: Yeah. Because we don't have patent attorneys in this country.

Ninety percent of our patents are in science and engineering, and our ten percent do not even have a science or engineering background. So many students are doing very well. This is number one.

Number two is content writing. Today everybody knows what content writing is. But before that also, many of our IISER students have joined content writing, and they are doing well. Because we don't have that kind of good content writing. We don't have people in science communication. We don't have. By the way, I don't know whether you know or not, two years back, the first student who stood first in CAT examinations was from IISER. He has joined, and I am among the first. So it's not that you should only.

You can join UPSC, you can join MBA, there are several ways of doing it. It depends on how you use your capabilities. You can join industry, you can join anything you like.

SS: So how do you think a science student from IISER will do well if joining an MBA? Because that can be done by any student with any background.

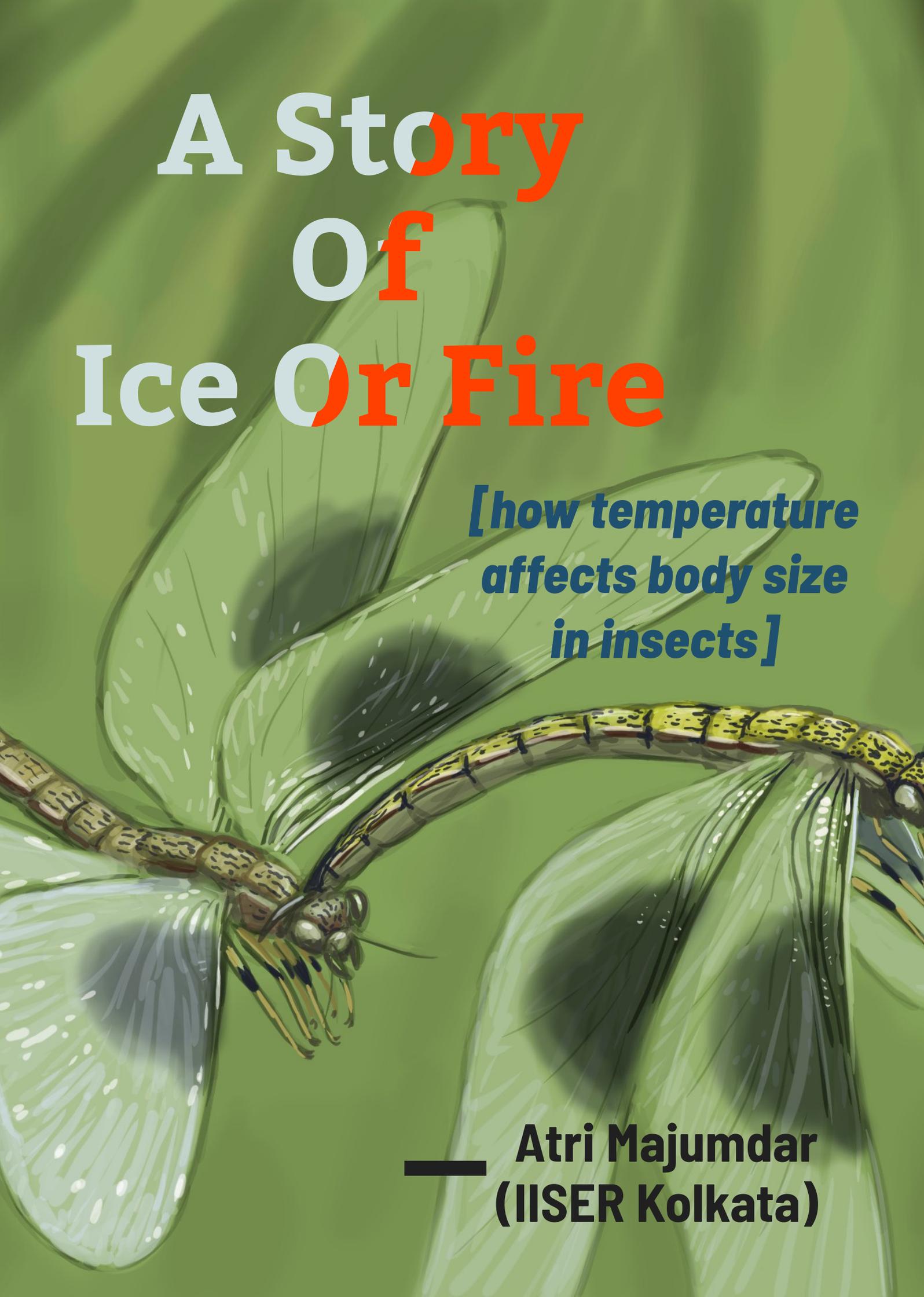
AAN: MBA with science background plays a major role in all other affairs. How? For example, now the pharma

industry, you take. Somehow I take examples all the time from the pharma industry. The pharmaceutical industry today needs youngsters with science backgrounds and MBA degrees. These three things: analytical capabilities, nurturing creativity, and presentation. And these capabilities you can use anywhere that you go in future. In any branch of science or any profession that you take. And I always encourage them if they say they would like to do this.

SS: Thank you sir for your time with us. We hope our present students will be inspired by your comments. Thank you.



FIG 8 : At the 12th Convocation of IISER Kolkata, Prof. Natu joins fellow BoG members in celebrating a new generation of scientists. His emphasis on foundational learning and academic freedom resonates through every graduating cohort.

The background features a detailed illustration of two dragonflies. One dragonfly is smaller and positioned on the left, while the other is significantly larger and positioned on the right. Both dragonflies have transparent wings with visible veins and segmented bodies with dark spots. The background is a solid, light green color.

A Story Of Ice Or Fire

*[how temperature
affects body size
in insects]*

**— Atri Majumdar
(IISER Kolkata)**

Take a walk through the Carboniferous, when dragonflies the size of hawks ruled the skies — and discover how oxygen, temperature, and evolution conspired to shape the rise and fall of these insect giants. This article dives into the deep-time data and modern models that reveal why ancient insects grew so large, and why they never did again.

EDITED BY: *Suddhajit Bishayee, Archita Sarkar, Swarnendu Saha*



Atri Majumdar is an undergraduate at IISER Kolkata with a primary passion for theoretical paleontology and macroevolutionary theory. He currently works in the IISER Kolkata paleobiology lab under Dr. Subhronil Mondal and is also part of a collaborative project between the University of Oslo (Norway) and Lund University (Sweden) exploring the evolution of dragonflies. Outside of geology, he is an avid bass player and performs with his band, Nakshattra Krittika.

Let's take a walk back in time. To be specific, let's go to 320 million years ago, to a period called the Carboniferous. At a cursory glance it would look quite similar to modern rainforests. Until you take a closer look at the trees and you realize that all of the "trees" are massive towering ferns. Ferns as big as modern seed bearing trees.

You are slightly lightheaded due to the significantly higher oxygen content in the air. A slight shiver sets in, it's quite cold as well. Much colder than what one would expect in a rainforest. There is a lot of movement in the shadows of the trees but the plants are too dense to make anything out.

Take a moment to get your bearings as your feet sink into the dense mulch covering the ground. There seems to be a clearing up ahead so you decide to go take a better look. No sooner than you step into the clearing something massive flies out from under the dense brush and startles you.

Expected a bird? Maybe one of those ancient flying reptiles? Instead it's something very familiar yet incredibly alien!

It's a dragonfly! but unlike the ones outside your house this one has a three foot wingspan. That's when you start to realize -all of the creatures that you saw before were insects, absolutely massive ones.

This was what insects were like in their heyday. The dragonfly described above was called *Meganeura* which was about the size of a hawk. But it was far from alone in the giants department. In fact most insects of this time period were record setting giants. The largest dragonfly of all time existed in the Carboniferous, at no other time period has any dragonfly grown large enough to even challenge this record. Surprisingly dragonflies are not the only record setters of the Carboniferous. Most insect groups have their largest recorded sizes in this time period which is quite a significant pattern.

Now we can make an obvious observation. These insects did not remain giants, since in modern times a dragonfly with a 3 inch wingspan would be considered large let alone 3 feet.

So why were they this big? Something must have driven them to attain these large sizes, biotic or abiotic.

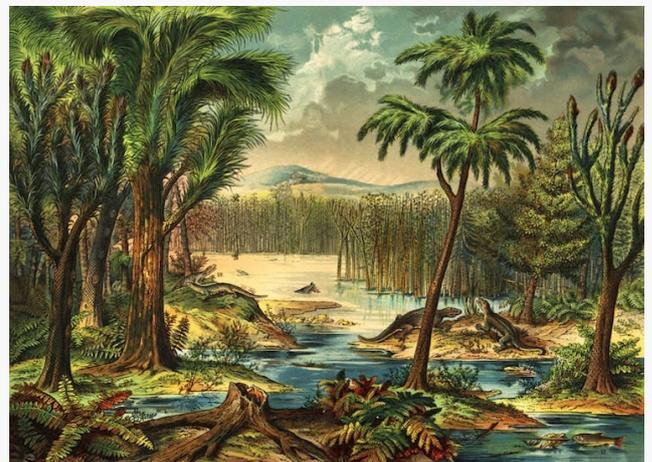


FIG 1 : *A Carboniferous rainforest with unidentified basal amphibians basking in the sunset.*
Art by: Mark Ryan

Paleontologists thrive for questions like these. Data where there is a possible pattern over millions of years. The specific field which deals with this is called Macroevolutionary theory. We deal with fossil data through huge windows of observation, either temporally or spatially.

First let's take a look at our dataset. In any form of Macroevolutionary work, it is very important that our data is as dense through time as possible.

So we must choose a model group that is commonly fossilized. We also have to consider that our model group's fossils must reliably represent the organism's body size. For example, if you want to construct a dataset of human height in a country. Using scalp hair as a metric would be flawed since there is no correlation between total height and hair length.

Taking these things into account we landed on the group Odonata. All these criteria are met by a few groups of insects, one of them being Odonates. These represent dragonflies and damselflies. Not only are their wings quite commonly fossilized but their wing size has a direct correlation with their actual body mass.

In geology there is a popular phrase : "The present is the key to the past".

Which is why our hypothesis should be grounded in phenomena we can observe in extant organisms. Since, we wanted to look at abiotic and biotic factors that might have affected body size in the past. We must first look at modern examples of factors that can affect body size.

For our focus group (insects) two main abiotic controls pop up.

- The Temperature Size Rule
- The limits of insect respiration

The Temperature Size Rule is a phenomenon observed in both insects and more complex organisms like mammals. It relates back to the physical law called the "Square Cube Law". An organism's surface area increases in squares, while its volume increases in cubes. This results in larger organisms having much higher volume than surface area. The issue with this is that the heat in a body is produced proportionally to volume of cells, but has to be dissipated

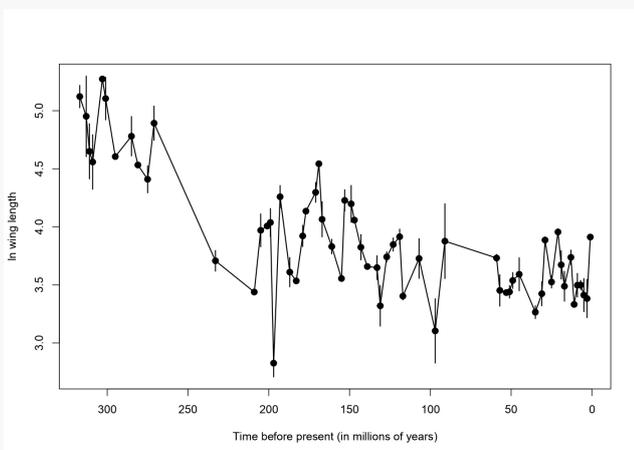


FIG 2 : Graph showing variation in Odonate wing size through time. Each dot represents a data point and the vertical bar represents variance in wing size data from that time point. We take log of wing size instead of raw values since it helps clear our noise.

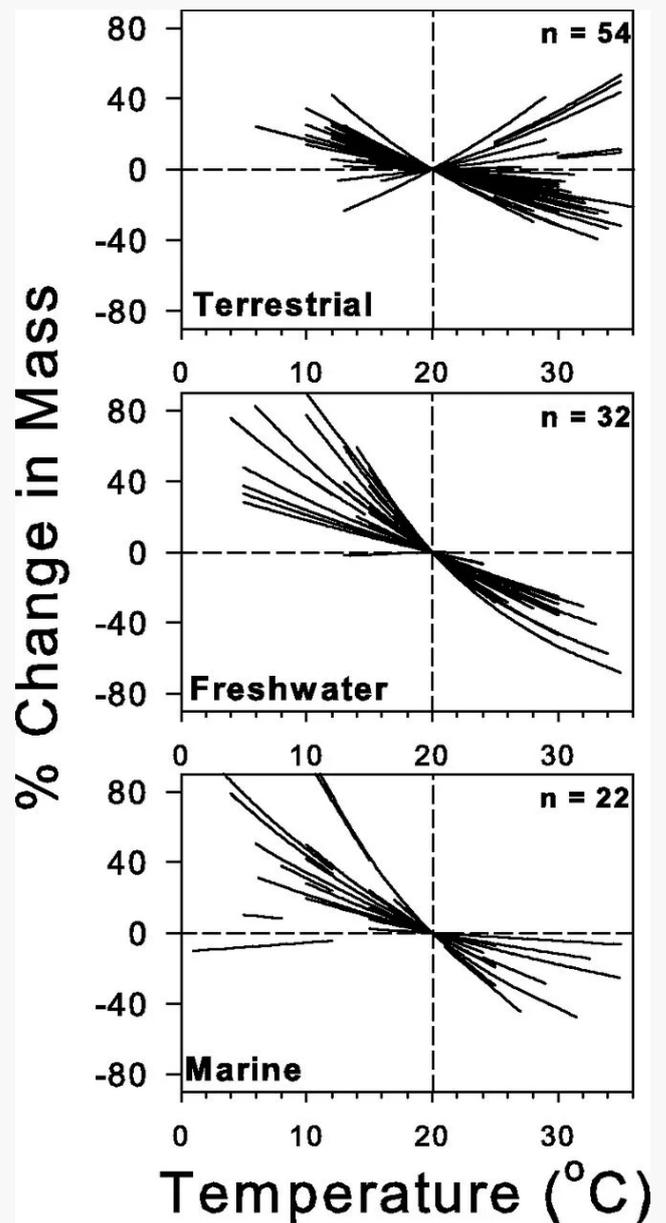


FIG 3 : Forster and Hirst 2012. This graph shows how body size of terrestrial, freshwater and marine species responds to temperature. Size changes are expressed as a percentage change from the organism's size at 20 °C; each line represents a single species. n, number of species. We can see that positive change in mass happens at lower temperatures.

by the lower surface area. The resultant effect is bigger animals trapping much more heat in their bodies. This is not ideal in hotter climates but perfect in colder climates.

The basic principle of the temperature size rule rests on this. Colder climates almost always result in larger animals since they need to be bigger to preserve heat.

Hence we construct our first hypothesis : "Colder temperatures lead to larger body sizes being preferentially selected"

Now we take a look at the second point. Unlike us, insects have open respiratory systems. Which means that they do not have a pressurised circulatory system to carry gasses through their body. This results in their overall gas exchange being very inefficient compared to mammals or reptiles.

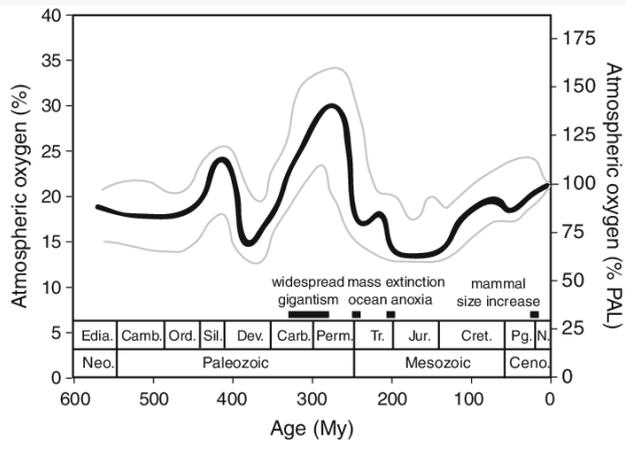


FIG 4 : Payne et al 2011. This graph represents atmospheric oxygen concentration through time. We can see that the highest values on the y axis appear during the “Carboniferous” and late “Permian”. We can compare them to current day O2 saturation by looking at the y axis value when age is 0 in the graph (this point represents present day).

For an abnormally large insect to not suffocate, there needs to be an abnormally high amount of oxygen in the air. Luckily in the Carboniferous, oxygen content was in fact very high, 35% to be precise. If we look at pO2 concentration throughout the Phanerozoic, the Carboniferous is the point of highest O2 content. Coincidentally it would seem that the largest insect sizes were attained at this time.

So we can construct our second hypothesis stating that: “Oxygen content in the atmosphere has a proportional control on insect body size.”

Looking into literature we can see this hypothesis has been considered by Clapham and Kerr 2012. They worked on this problem and found a positive correlation between oxygen saturation and insect body size.

They also tested correlation with temperature and came up with sub par values implying bad to no correlation. This is an interesting result since theoretically, there is a strong indication that temperature should play a role in body size control. Secondly, by looking at the graph we can see that O2 saturation recovers past 100 mya but there is a continued downward trend in insect body size. If O2 saturation was the only control on insect body size, then we should have seen an upward trend past 100mya.

All of these clues point to the fact that there is more to this story than just O2 saturation.

In our study we tested the correlation between temperature and odonate wing size through time. We did this by analyzing multivariate time series models. The two main models used are URW (unbiased random walk) and OU (Ornstein Uhnbleck). The Unbiased Random Walk (URW) model describes how several traits can change together over time purely by chance, like multiple variables drifting randomly without any preferred direction. Each trait changes at its own rate. Some traits may tend to change together if they are correlated. The Ornstein Uhlenbeck (OU) model adds another layer by including a “pull” toward certain preferred values, representing evolutionary or environmental constraints. In this model, traits still fluctuate randomly, but they tend

to move back toward an optimal set of values instead of drifting endlessly. In simple terms, URW models show random and unconstrained evolution, while OU model’s evolution is guided toward stable, adaptive targets.

In multivariate modelling, we see whether one time series is affecting another time series in any way. For URW models this means whether one time series is influencing the random walk to another time series. For OU models this means whether one time series is affecting the optima of another time series, after properly parameterising all our models.

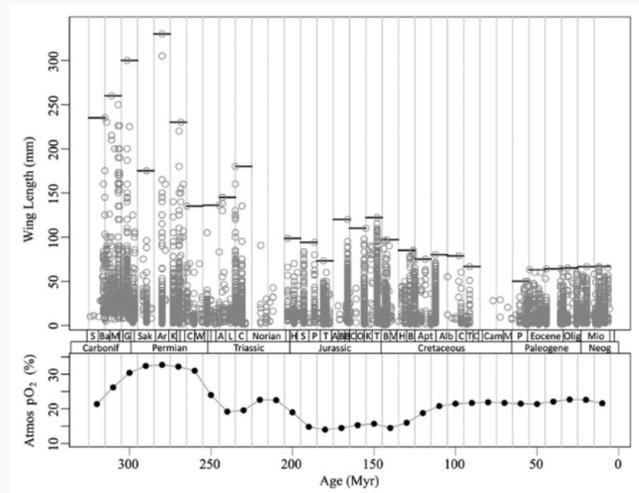


FIG 5 : The top graph shows raw wing size variation through time and the bottom graph shows oxygen concentration variation through time. The timeline has been divided into 10mya intervals. The maximum wing size in each interval is marked with a horizontal black line. The two graphs are oriented like this so we can visually see the similarities in the variation of wing size and oxygen concentration. We can see that both graphs peak and plateau at similar points of time hinting towards correlation.

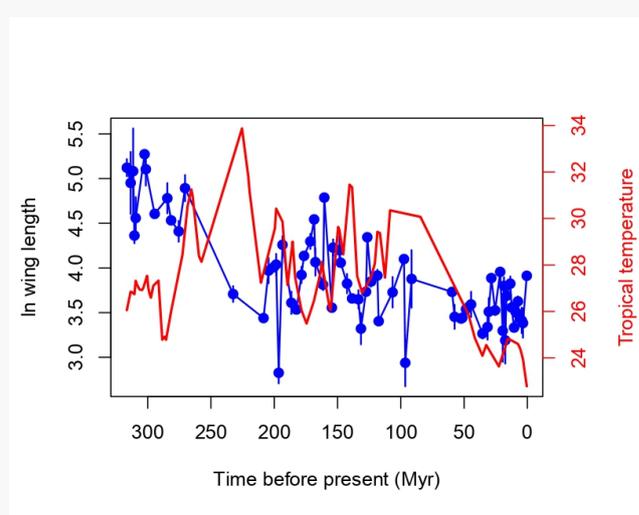


FIG 6 : Odonate wing size and tropical temperature through time. The blue line represents wing size (log in mm) and the red line represents temperature in degrees Celsius. Both datasets are overlaid over each other so that we can visually see the negative correlation between them.

Before delving into the model data we can first take a glance at our raw datasets. Visually we can see that there appears to be some negative correlation between our two time series which is very promising.

Looking at our model results we can see that OU2 offers the most support. Which means that our best supported model is an Ornstein Uhnbleck process. When temperature is reaching an optima of some kind it is also pulling wing size towards a peak.

As per our work the output matrix of the model produces a negative slope. This supports our observation that there is a negative correlation between temperature and body size. Our model data overall supports our hypothesis of temperature affecting body size negatively.

MODEL	K	LOG-LIK	AICC	Δ AICC
URWdiag	0	-52.54092	113.6972	23.27788
URWsym metric	0	-51.70938	114.3563	23.93698
OU1	8	-44.64526	107.6512	17.23188
OU2	9	-34.70966	90.41932	0.0
OU3	9	-39.21412	99.42824	9.00892
OU4	11	-35.77253	98.09679	7.67747
OU5	8	-136.2054	290.7714	200.35208
OU5 param	9	-39.54269	100.0854	9.66608

Table 6 : Multivariate OU and URW results (wing size of odonate modelled alongside temperature). Log-lik and AICc are internal scoring systems that the models have. They simply represent how good of a fit each model is compared to the other models. For log-lik a bigger value is better (less negative) and for AICc a smaller value is better. Delta AICc shows the difference between the best scoring model (OU2) and the rest. Delta AICc score allows us to easily determine the ranking of the model scores.

This confirms our suspicions that O₂ saturation alone is not controlling body size of insects. The Carboniferous period had the lowest temperatures and the highest O₂ saturation. This led to odonate body sizes reaching an all time high. Following that we observe a sharp drop in body size. At this time there was a rapid increase in temperature due to the Permian extinction accompanied by a decrease in O₂ saturation. In the Mesozoic (252 to 66 mya) we see that temperatures shift to lower values similar to the Carboniferous (359 to 299 mya) a few times but there isn't a proportional response in insect body size. This is likely due to the fact that the mesozoic was plagued by low O₂ saturation values.

In the Cenozoic despite O₂ values being relatively high and temperature dropping to levels lower than the average in Mesozoic there is no real response in body size of insects.. Predation pressure can play a big role in the evolution of a lineage.

Our current hypothesis is that the evolution of crown birds in the paleogene creates predation pressure on insects as a whole. Further quantitative studies are needed to make this more concrete but it is a theoretically plausible hypothesis.

Conclusion

In nature it is very rare that only one variable controls an entire system. We observe this very frequently in modern ecological studies. Any biotic or abiotic factor in an ecosystem, if perturbed, can disturb the whole system. Applying this same principle to paleontological studies has yielded very promising results. This study is just one of many macroevolutionary trends which are being re-examined with a multivariate lens. Perhaps one day we will invent a time machine and go back to the mesozoic to know exactly why insect body size reached stasis. Until then our best bet is studies like these.

My Journey With The Fruit Fly



[decoding
neurodegeneration
in lysosomal storage disease]

— APURBA DAS (IISER Kolkata)



In this story, Apurba Das chronicles her PhD journey uncovering how lysosomal defects trigger neurodegeneration in Mucopolysaccharidosis Type VII using the humble fruit fly as a model. Her work not only reveals how restoring the cell's self-cleaning process can rescue brain function but also points toward affordable, brain-targeted therapies for rare diseases.

EDITED BY: Ayan Biswas, Debanuj Chatterjee



Apurba Das is a recent PhD graduate from Lysosome Biology and Related Disease lab at Department of Biological Sciences, IISER Kolkata, under the guidance of Prof. Rupak Datta. She is interested in understanding neurodegeneration, lysosomal storage disorders, and rare diseases.

I am Apurba Das, a recent PhD graduate from the Indian Institute of Science Education and Research Kolkata, India. I have always enjoyed biology classes since school, largely due to my love of nature. I had a childish imagination – as if a tiny version of me could sit inside a cell and watch the processes happening, like watching city traffic, people walking on roads, or workers keeping the city alive. Later, I realised this would require sub-micron visualisation, possible only through microscopes that reveal the cell and its components like the nucleus, lysosome, mitochondria, and proteins. This fascination with the unseen world led me to pursue a PhD – an intuitive choice after my master's. My core interest was to study human diseases, to understand them better and contribute new knowledge.

My research – Mucopolysaccharidosis Type VII, a Lysosomal Storage Disease

After joining the programme, I was offered a project to study Mucopolysaccharidosis Type VII (MPS VII) using the **Drosophila model** – yes, those tiny fruit flies you see around in your home. We utilized the power of flies owing to their remarkable advantages: their genes are easy to manipulate and study, they have shorter lifespan which makes ageing research faster, and many of their basic biological processes work in the same way as in humans. Research needs model organisms with genes and processes conserved in humans, as human subjects cannot be used for experiments due to ethical and practical limitations.

MPS VII is an ultra-rare genetic disorder affecting about 1 in 250,000 people, caused by mutations in the β -glucuronidase (β -GUS) gene 1. It belongs to a group of disorders known as lysosomal storage diseases (LSDs), which occur when lysosomes – the organelle responsible for breaking down cellular waste using hydrolytic enzymes fail to degrade materials. When an enzyme or lysosomal protein is missing or dysfunctional, undigested substrates accumulate in the lysosomes, leading to cellular failure and disease.

Our lab generated the **first Drosophila model of MPS VII** by deleting the CG2135 gene, human homolog of β -GUS. The fly had 70% reduction in β -GUS enzymatic activity and mimicked features like MPS VII patients 2. Mammalian system like mouse models of MPS VII exist, however, their severe disease manifestation creates difficulty for molecular studies. Hence, simpler, and cost-effective models like flies are invaluable.

MPS VII also known as Sly syndrome was first described by **Dr. William S. Sly**, Professor Emeritus at Saint Louis University, in 1973 (3). He reported that certain patients had distinct facial features, enlarged heads, protruding abdomens, and slow growth. His investigation revealed elevated glycosaminoglycans (GAGs) in urine and presence of granulocytes in blood and bone marrow samples. Dr. Sly identified β -GUS deficiency leads to accumulation of undegraded GAGs which are negatively charged polysaccharides found in connective tissue.

Dr. Sly's passing on May 26, 2025, marked the loss of a pioneer in lysosomal biology. Beyond MPS VII, he made seminal contributions to understand carbonic anhydrase deficiency, hereditary hemochromatosis, and the discovery of the mannose-6-phosphate receptor – crucial for directing lysosomal proteins to lysosomes

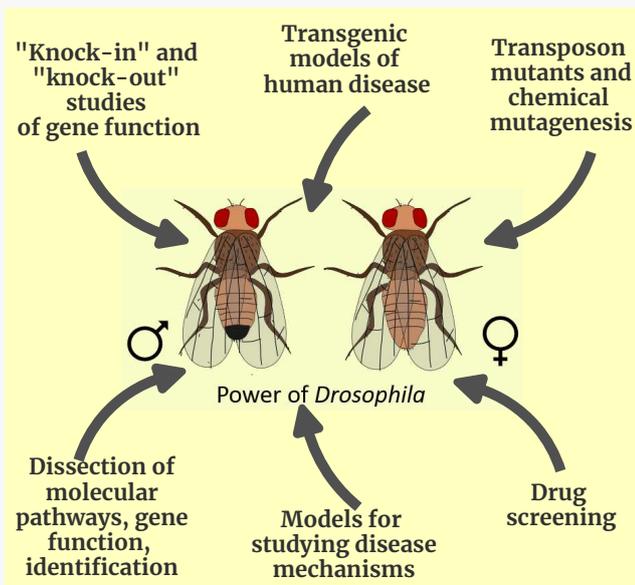


FIG 1 : *Drosophila* as a model organism. Flies have genes homologous to human diseases, which can be mutated to study their function. *Drosophila* are used for studies related to understanding disease pathogenesis, gene functions, and screening drugs.

alongside Prof. Elizabeth Neufeld. Their discovery later enabled the development of **enzyme replacement therapy (ERT)** for MPS VII. Prof. Neufeld once reflected on how a small technical oversight had made her miss the receptor in her earlier experiments 4, teaching me that science often hinges on details - a lesson that shaped how I designed my experiments.

To appreciate their contribution, let us take a step back and ask a question, **how does a protein “know” it belongs to the mitochondria or lysosomes?** The answer is a signal tag (like postal code) that guide proteins to their destinations. Lysosomal enzymes, for instance, are tagged with mannose-6-phosphate in the Golgi apparatus and delivered by vesicles to lysosomes containing the corresponding receptor. These insights not only transformed cell biology but also laid the foundation for targeted drug delivery in modern medicine.

The PhD Problem - Can we correct neurodegenerative symptoms in MPS VII?

When I first learned about MPS VII, I was struck by **how devastating it is**. The babies with defect in β -GUS gene mostly do not survive birth because of a severe condition that causes their bodies to swell with fluid before delivery also known as non-immune hydrops fetalis. Additionally, those who survive show clinical manifestation like stunted growth, skeletal abnormalities, enlarged liver and spleen, hernias, recurrent infections, cloudy corneas, and joint stiffness. The multi-organ failure is the major cause of mortality, with a median lifespan of MPS VII patients only about 3.5 years.

MPS VII is also a neuropathic disease, affecting cognition and neuromuscular coordination. About 80% of patients show **neurodegenerative symptoms** - intellectual disability, delayed speech, hearing loss, and restricted movement 1. Neuropathological studies have

revealed GAG accumulation, brain vacuolation, and skull enlargement - a system slowly collapsing under its own burden 5,6.

The first and only FDA-approved ERT, Mepsevii™ (vestronidase alfa), developed through Dr. Sly's collaboration with Ultragenyx biotech company, was approved in 2017 7,8. ERT supplements the missing β -GUS enzyme and benefits MPS VII patients, yet it fails to cross the blood-brain barrier (BBB), **leaving neurological symptoms untreated**. I noticed that since its first discovery, only a handful of studies have reported on neurodegeneration in MPS VII. However, mechanism of neurodegeneration remains unknown while development of therapy which can restore it, are in preliminary stages. Additionally, ERT can cost around \$200,000 annually. This amount is beyond the reach of economically underdeveloped countries like India. This highlights the urgent need for affordable, brain-targeted alternatives.

Drosophila models of MPS VII developed by our group has pitched its importance in the field and was extremely helpful to understand the molecular mechanisms of neuropathology in MPS VII.



FIG 2 : Dr. William Sly, Emeritus Chair and Professor of Biochemistry, described the first patient with MPS VII, and also conducted research throughout his career based on finding a treatment for this very rare disease. The results of his research on enzyme replacement therapy led to the development of this treatment. [biochem.slu.edu]

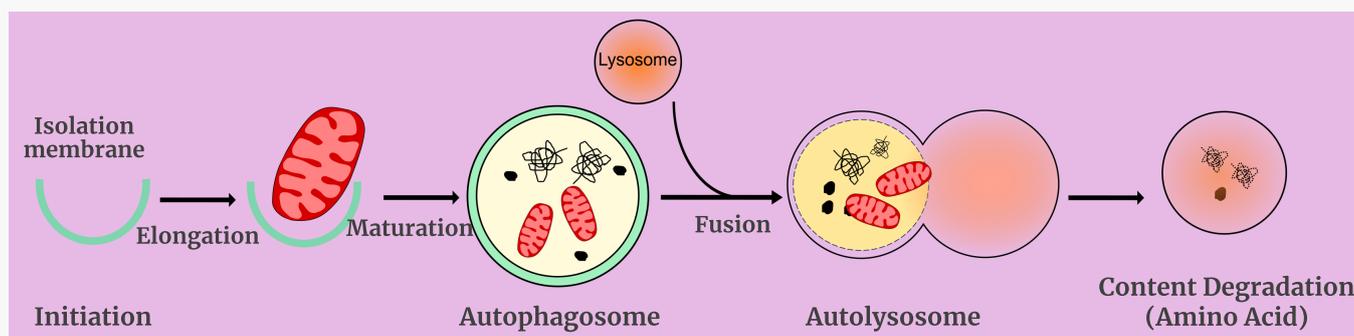


FIG 3 : Scheme showing steps of autophagy pathway.

Small molecule based therapy - solution for neurodegenerative MPS VII

When I joined the lab, our newly published study on MPS VII fly model showed shorter lifespan, low hatching rates and the flies had drastically reduced ability to climb vertical surfaces known as climbing index. The reduced mobility indicated **defect in neuromuscular coordination** as our muscle movement depends on the signalling from brain. This prompted us to investigate the tissues, where we found signs of muscle degeneration, loss of dopaminergic neurons, and accumulation of engorged lysosomes, mitochondria, and undegraded proteins in the brain 2. However, the mechanism of development of neurodegeneration in MPS VII was still poorly understood.

We asked a basic question: Why is there accumulation of mitochondria, undegraded proteins, lysosomes in MPS VII brain? Is there any defect in clearance system of the brain? Cells keep themselves clean by removing the unwanted proteins and damaged organelles using pathways like autophagy. **Autophagy**, a word which has gained popularity after the 2016 Nobel Prize in Physiology or Medicine to Prof. Yoshinori Ohsumi, is explored by number of pharmaceutical companies for its benefit in anti-ageing effect. The recent trend of intermittent fasting is based on the concept that when we fast or limit calories our body breakdown stored fat or glucose to supplement cells. During this process autophagy is activated, where cells breakdown proteins and get rid of worn out organelles like mitochondria and keep our cells especially neurons healthy. The autophagy process starts by formation of a vesicle known as autophagosome which takes up the materials to be broken down, and autophagosome fuses with lysosomes. The lysosome degrades the dumped materials into amino-acids, units of lipids etc which is supplemented to the cell for its use (Fig. 3). Thus, starvation has beneficial effect but beyond a certain threshold our body may not cope with nutritional deficiency.

Accordingly, we first investigated if **autophagy is defective in MPS VII flies**. We studied them in different age groups and distributed flies into early age 4 days old to late age 45 days old. When the MPS VII flies were deprived of food, we found severe decrease in their lifespan whereas normal flies had longer lifespan indicating they can cope the stress better. These data indicate that MPS VII flies are unable to compensate for nutritional deficiency due to an autophagy defect. I was excited after my first experiment and was happy that my hypothesis got a lead.

Next, I delved deeper and systematically dissected the autophagy process, checking all its steps and found significant reduction in genes and proteins related to autophagy in 30-45 days old MPS VII fly brain 9. **An autophagy marker protein known as LC3 or Atg8 was found to be downregulated in MPS VII fly brain.** Atg8 is important for formation of the autophagosome, engulfing materials in the autophagosome, and fusing with lysosomes to dump the contents in them. Reduction in its level leads to autophagy defect ultimately triggering cell death in the neural cells. These findings clearly confirmed the underlying reason for neurodegeneration in MPS VII.

The crucial point in my research was observing the autophagosome in cells under an electron microscope. We found MPS VII had fewer autophagosomes compared to normal brain indicating functional autophagy. Moreover, MPS VII brain had significant presence of multilamellar bodies (MLB) - onion-like structures due to accumulation of undegraded materials in lysosomes (Fig. 4). **Reliving my childhood imagination, it was possible to see a nucleus, mitochondria with cristae like I have seen in textbooks, autophagosome - a double membrane structure with mitochondria inside it by using electron microscope.** This technique marked an advancement for our lab, as we were finally able to image brain tissues after overcoming several hurdles. This taught me to be persistent and patient, and to trust the process even when things take a long time without much explanation.

The final objective of my project was to **find alternative targetable molecules to restore neurodegeneration in MPS VII**. For this we turned our focus on using small molecules which can be synthetic or natural derivatives, have low molecular weight and have emerged as therapeutics, especially for neurodegenerative diseases like Alzheimer's, Parkinson's, and Huntington's, etc. They are used due to their versatility, ability to reach intracellular targets, and ease of oral administration, in addition to being cost-effective. We screened a few candidates and found two drugs with the potential to rescue neuropathology by activation of autophagy. We found that **trehalose**, a non-reducing disaccharide, and **resveratrol**, a polyphenol extracted from nuts and berries, when orally administered for 30 days, could restore the autophagy defect in the MPS VII brain and improve the climbing ability of the flies.

I also emphasized the idea of finding a drug that **can upregulate lysosome biogenesis along with autophagy**, so that activated autophagy does not get stalled due to the unavailability of functional lysosomes. This is like a city's garbage being collected by garbage collectors



(autophagy), but if it is not properly recycled or processed (by lysosomes), the city remains dirty. Thus, we looked for factors that can regulate autophagy like a switch. The transcription factor TFEB, also known as the master regulator of lysosome biogenesis, is that switch 10,11. It controls a vast circuit in cells related to autophagy, lysosomes, and the metabolism of lipids and amino acids. When the switch is off, autophagy remains inactive, but under starvation-like stress, it is activated to generate new lysosomes for degrading the cellular “garbage” carried by autophagy.

I found that these drugs can switch on TFEB expression, leading to the initiation of the autophagy and lysosomal gene circuit. **My research identified, for the first time in MPS VII, a novel circuit that could serve as an alternative therapeutic approach.** Consequently, the clearance of debris was enhanced, and cell death was reduced in the MPS VII fly brain. This restoration of neurodegenerative markers resulted in a notable improvement in the climbing index of MPS VII flies. Thus, my research paved the way for managing neurodegeneration in MPS VII where ERT failed to rescue.

We see how a deficiency of an enzyme (β -GUS) altered the cellular signalling and manifested pathogenesis in MPS VII. Lysosomes being more than a mere suicide bag, can cross-talk with other cellular components and take charge of the processes. We found how lysosome defect caused the imbalance in autophagy and metabolism. Compounds like resveratrol and trehalose, with their ability to cross the blood-brain barrier, offer a promising starting point for such combinatorial strategies. Ultimately, the goal is translational: to connect the molecular understanding of autophagy-lysosomal regulation with therapeutic development. The hope is that by enhancing the cell's innate capacity for renewal, we may slow or even reverse neurodegeneration not only in MPS VII but across a spectrum of lysosomal and age-related disorders.

Future perspectives and implications

Although MPS VII is rare, the cellular insights it reveals are remarkably universal. **Defective clearance and disrupted stress adaptation** are shared signatures across major neurodegenerative disorders such as Alzheimer's, Parkinson's, and Huntington's diseases. The activation of autophagy through TFEB illustrates that neuronal survival depends not only on efficient waste disposal but also on the fine-tuning of metabolic balance. These findings highlight that enhancing intrinsic cellular recycling capacity could serve as a valuable complement to enzyme replacement therapies. Moreover, this study underscores the enduring value of model organisms – *Drosophila*, though simple, continues to illuminate the fundamental biological logic.

Looking ahead, **translating these findings into mammalian systems** will be essential. I remain deeply curious about how small molecules might restore neuronal health and whether unexplored metabolites or gut-brain interactions could hold keys to crossing the blood-brain barrier. My hope is that this research contributes to the growing efforts to bring real therapeutic hope to patients with rare neurodegenerative disorders.

This PhD journey has been more than an academic pursuit – it has been a lesson in perseverance, curiosity, and gratitude. Behind every experiment were mentors,

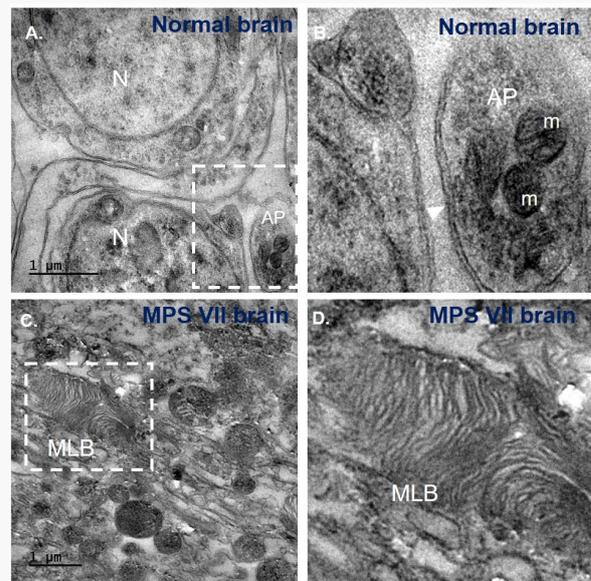


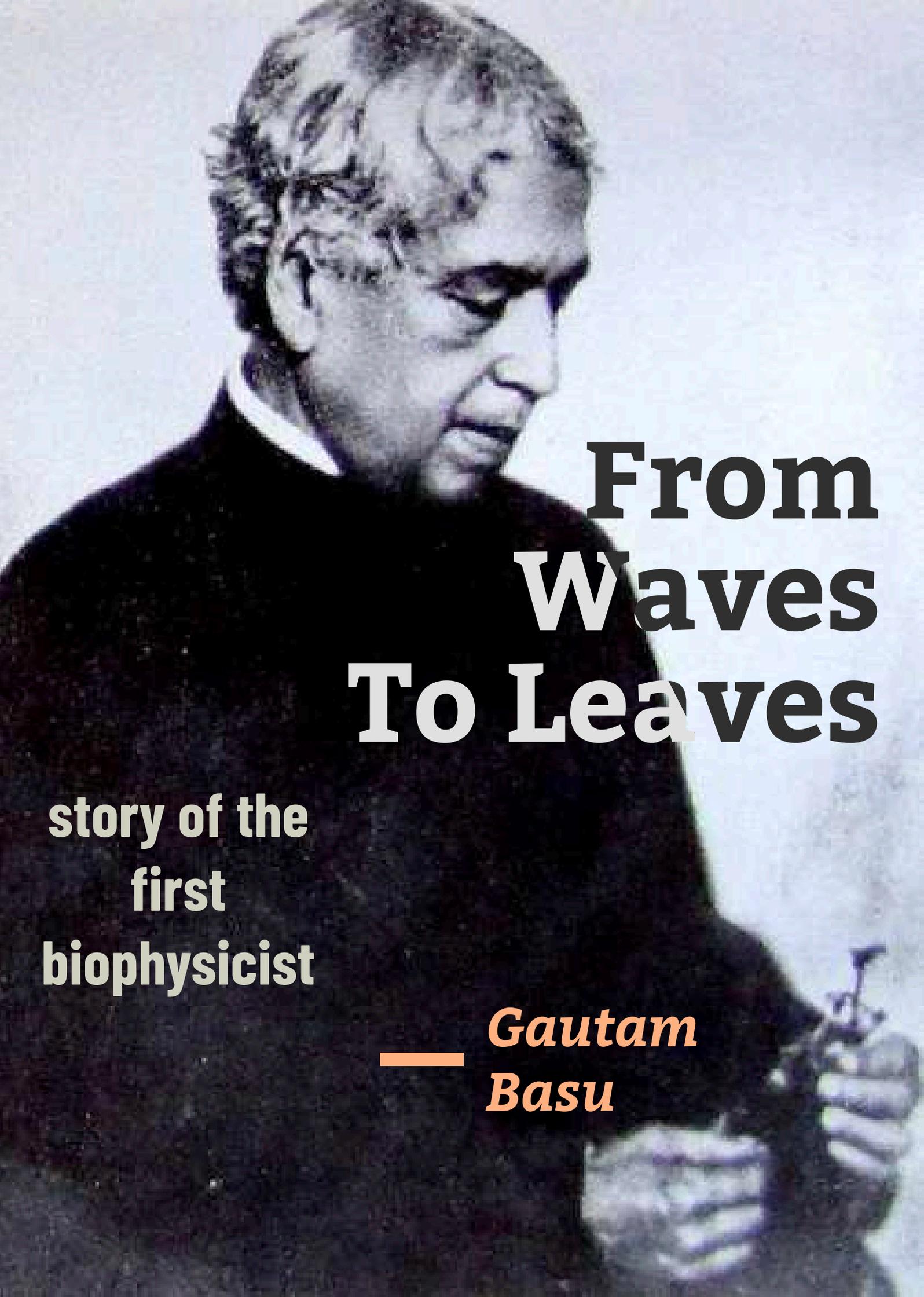
FIG 4 : Micrographs of ultrathin sections of normal and MPS VII fly brain taken under electron microscope. A) Normal brain micrograph. N=nucleus, AP=autophagosome, m=mitochondria. B) Magnified image of the inset showing autophagosome. Note the double membrane marked with white arrow. C) MPS VII brain micrograph. MLB-multilamellar bodies. D) Magnified image of the inset showing MLB. Note the onion like structures of MLB. [9]

collaborators, friends, and family who kept the spark alive. Science often begins with wonder, and I aim to carry that same sense of curiosity forward into every new beginning – continuing to ask questions, chase unknowns, and believe in the quiet power of keep learning.

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From Waves To Leaves

story of the
first
biophysicist

— *Gautam
Basu*

In this article, we trace Jagadish Chandra Bose's extraordinary scientific evolution—from pioneering wireless communication to founding the field of biophysics. His 1924 work *The Physiology of Photosynthesis* transformed plant science through quantitative, instrument-driven research, revealing early evidence of the C₄ pathway decades before its formal discovery and securing his legacy as a global pioneer in photosynthesis research.

EDITED BY: Ishita Bardhan



Dr. Gautam Basu is a Biophysicist and a former Professor at Bose Institute. Beyond scientific research, he is actively involved in science communication and has interest in History of Science. He is an elected Fellow of the West Bengal Academy of Science and Technology and the Indian National Science Academy.

Early Research in Electromagnetic Waves

The scientific pursuits of Jagadish Chandra Bose, a pioneer of Indian science, often shifted directions. In the very beginning, his research focused on electromagnetic waves. In 1895—ten years after he had joined Presidency College in 1885—he published his first research paper in the *Journal of the Asiatic Society*, on the subject of the polarization of electric waves. Following this, he published five more papers on the same topic, and in 1897, his lecture at the Royal Institution in London instantly established him as one of the world's foremost scientists. Thus began the scientific journey of Jagadish Chandra Bose, the trailblazer of Indian science.

Shift to Comparative Studies of Matter and Life

But soon that journey took a major turn. From 1895 to 1899, although he gained fame as a pure physicist working on electromagnetic waves, between 1900 and 1906 his research shifted to a comparative study of the responses of inanimate (metals) and animate (plants) matter under electrical and mechanical stimulation. During this period, his imaginative theory or hypothesis was that there is no fundamental difference between the inanimate and the living. At this time, he threw himself into experiments to prove his hypothesis.

In his own words [1]: “At that time, I was investigating the electric waves of the atmosphere and had succeeded in inventing and constructing a new instrument for recording messages transmitted from a distance. I observed that the writing of the instrument made of metal became weaker and weaker, as if the instrument were becoming exhausted... Just as human fatigue is relieved by rest, the fatigue of the instrument also disappeared after rest. Again, just as certain drugs stimulate us, I found a similar process occurring in the instrument made of inanimate matter... From this, I came to understand that the inanimate and the living worlds are governed by the same laws and are bound together by the same principles.”

But in his thinking—that is, in drawing correct conclusions through data analyses—there was a flaw. He had accepted the post-stimulus electrical response of inanimate matter as a sufficient criterion of life. But here, the distinction between “sufficient” and “necessary,” which appear similar yet are actually quite different, required precise application—a distinction he failed to make. Electrical response is certainly a necessary condition for life. But it is never a sufficient one. Unless several other conditions are also satisfied, the mere presence of electrical response does not allow one to classify inanimate matter as living.

Philosophical Influences and Scientific Isolation

It is worth noting here that during this period Jagadish Chandra had the companionship of Nivedita and Rabindranath Tagore. Inspired by Vivekananda, Nivedita held an unwavering belief in Advaita philosophy, while Tagore emphasized the relevance of ancient Indian idealist thought as an alternative to Western rationalism.



FIG 1 : During his research on electromagnetic waves, J C Bose's pioneered a 60 GHz microwave setup which is now kept at the Bose Institute in Kolkata, India. Along with a receiver, it contains a galena crystal detector placed within a horn antenna. Microwaves were detected using a galvanometer. [Biswarup Ganguly]

These influences, perhaps—even if only momentarily—blinded the scientist [2].

As a result, he reached a stage in his scientific career where Western science journals, raising various objections, almost stopped publishing his papers on this subject. Yet he did not stop his research. Encouraged and in large part assisted by Nivedita, he began publishing his research findings in the form of books. But books, unlike journal articles, were not validated by contemporary experts actively working in the same field. Consequently, his work of that period gradually became separated from the mainstream current of science.

Emergence as the First Biophysicist

However, this phase did not last long. He then entered a new chapter of scientific research (1907–1935)—one that was not only new for him but also an entirely fresh chapter in the history of world science: Biophysics. A letter he wrote to his friend Patrick Geddes (24 January 1917) is noteworthy, in which he said: “I do not belong to any particular camp—the physicists think I have abandoned physics and joined the botanists; the botanists again think I am a physiologist, and so on. However, the Royal Society is very kind in publishing my papers. Though, when I send them several at once, they are somewhat embarrassed, and as a result some of my papers remain unpublished.”

During this time, the central focus of his work was plant electrophysiology: the minute responses of plants to various forms of stimulation and their growth (his famous instrument, the crescograph, was developed during this period), the absorption of water by plants and its transmission from roots to great heights, the nervous system of plants, and plant intelligence. While much has been written about his scientific contributions in this period, there is one aspect of his work that has received very little discussion—Jagadish Chandra Bose's contribution to photosynthesis research.

In 1923, he published a paper on this topic in *Nature* [4]. There he wrote: “The possibility of ultra-measurable traces of certain chemical substances affecting assimilation is a matter of much importance in physiology. The carbon-assimilation of water-

plants affords an extremely sensitive process for the investigation of the subject. The usual method of counting the number of bubbles of oxygen given out by the plant under light is, however, most untrustworthy for quantitative determinations, since the size and frequency of the bubbles undergo spontaneous variation. This difficulty has been completely removed by a new device which I have been able to perfect, by which the evolution of equal volumes of oxygen is automatically recorded on a revolving drum by an electromagnetic writer; records thus obtained enable us to determine the normal rate of photosynthesis and its induced variations. I have also found that there is a definite relation between the evolution of oxygen and the formation of carbohydrate in the leaf. The automatic apparatus referred to can be so adjusted that the successive dots in the record represent the photosynthetic production of amounts of carbohydrate as small as a millionth of a gram. It is impossible in this short communication to give a detailed account of the apparatus, which will be found fully described in my forthcoming work, “The Physiology of Photosynthesis,” to be published by Messrs. Longmans.”

The book *The Physiology of Photosynthesis* [5] was published in 1924 by Longmans, Green & Co. Why did Jagadish Chandra suddenly immerse himself in photosynthesis research? The answer is clear from the preface of the book, where he wrote: “It would appear, therefore, that almost everything that can be known about photosynthesis has now been ascertained. It may be admitted that this is approximately true in the qualitative sense, but certainly not in the quantitative sense. The present volume is essentially a record of quantitative research in these various directions”

In other words, while information on this subject had been understood largely in a qualitative way up to that point, as a physicist he sought to present it quantitatively. In



FIG 2 : The crescograph, invented by Jagadish Chandra Bose in the early 20th century, is a precision instrument for measuring plant growth. Using a system of clockwork gears and levers, it could magnify movements up to 10,000 times, recording them on a smoked glass plate. Marks made at short intervals revealed how growth rates changed in response to different stimuli such as temperature, chemicals, gases, and electricity. [Biswarup Ganguly]

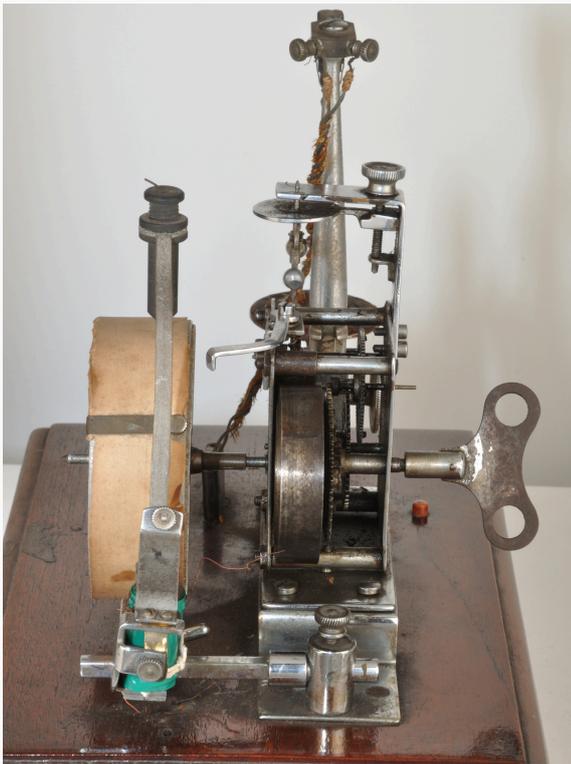


FIG 3 : *The Photosynthetic Bubbler made by JC Bose to record the rate of photosynthetic activity of aquatic plants. The bubbler is fitted airtight at the top of the plant vessel. As photosynthesis proceeds, oxygen accumulates and is periodically released through the mercury valve once a specific pressure is reached. Two platinum electrodes positioned near the valve close an electric circuit during each release, producing a dot on a moving drum via an electromagnetic writer—thereby providing a precise, continuous record of photosynthetic rate. [Biswarup Ganguly]*

the book, the words “quantitative” and “qualitative” were printed in italics. And here lies the key to his mindset as a researcher. At that time, biology was approached mainly from a qualitative perspective, whereas physics was grounded in a quantitative one.

This was the contribution of the world’s first biophysicist.

The book contains a total of 25 chapters. In the first chapter, he described the instrument he invented for measuring photosynthesis-induced bubbles (the Photosynthetic Bubbler), in which oxygen bubbles of varying size accumulate inside a closed container and generate air pressure. Once that pressure crossed a certain threshold, it produced an electrical signal, which was transmitted to an automatic recorder. This recorder could also measure time—the interval between two successive signals. In other words, by measuring the time taken for equal amounts of oxygen to be released, it became possible to determine the quantitative rate of the underlying biological process (in this case, photosynthesis). In other words, the instrument could accurately measure how quickly a plant released equal volumes of oxygen. Though simple, the device was undeniably innovative. Unfortunately, even today in Indian colleges, students are still taught to count oxygen bubbles released by plants, while Bose’s Photosynthetic Bubbler remains unused. Had it been otherwise, the Bose Photosynthetic Bubbler might not have remained so obscure.

Major Findings and Innovations

After the first four chapters, describing the apparatus and the precautions required during experiments, the next nine chapters recorded experiments using this device: the effect of increased light intensity on photosynthesis (Ch. 5), the relationship between light quantity and photosynthesis (Ch. 6), physiological factors in photosynthesis (Ch. 7), changes in photosynthesis under stimulants, anaesthetics, and poisons (Ch. 8), the effect of infinitesimal amounts of chemical substances on photosynthesis (Ch. 9), the electric response to light (Ch. 10), the initiation of photosynthesis when plants are transferred from darkness to light (Ch. 11), the effect of continuous light on photosynthesis (Ch. 12), the role of carbon dioxide supply (Ch. 15), and oxygen production in the complete absence of carbon dioxide (Ch. 16).

Bose demonstrated that the aquatic plant *Hydrilla* stopped photosynthesis in winter (neutral pond water) in absence of CO₂ but in summer (acidic pond water) they continued to evolve oxygen in the complete absence of any supply of CO₂. The discovery of this quite new pathway later turned out to be the C-4 pathway (now the well-known Hatch & Slack Pathway). Further, this unique pathway turned out to be an example of non-Kranz single cell C₄-pathway, operating in aquatic angiosperms.

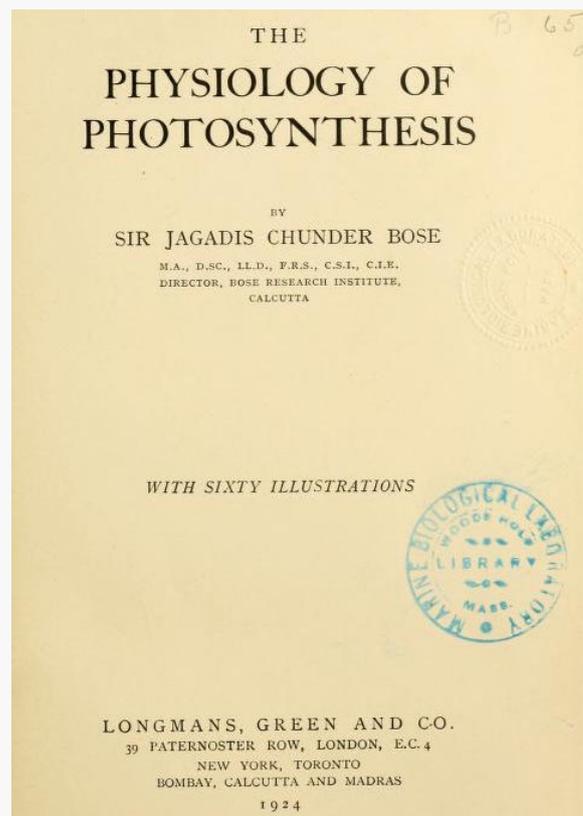


FIG 4 : *Jagadish Chandra Bose’s 1924 monograph *The Physiology of Photosynthesis* marked a turning point in plant science. Introducing quantitative, instrument-based measurements through his innovative “Photosynthetic Bubbler,” Bose transformed photosynthesis research from descriptive biology into experimental biophysics. His observations on *Hydrilla* even anticipated the C₄ pathway decades before its formal discovery, establishing him as a global pioneer in photosynthesis research.*

With slight modifications to the original bubbler, he described further experiments across four chapters: the effect of temperature variation on photosynthesis (Ch. 17), the influence of season and stimulus (Ch. 18), diurnal changes in photosynthesis (Ch. 19), and the efficiency of photosynthesis under different colors of light (one of the earliest photosynthesis action spectrum) (Ch. 20).

The book also introduced several new instruments. Chapter 10 described work on the electrical response of plants to light using a photoelectric cell. Chapter 13 explained the construction of an automatic radiograph with a selenium cell. Chapter 14 introduced a new electrical photometer for measuring light intensity.

In addition, many other kinds of work were recorded: the determination of energy distribution across different wavelengths of the solar spectrum using a magnetic radiometer and carbon disulfide prism (Ch. 21), the efficiency of spectral rays in photosynthesis (Ch. 22), the measurement of weight increase in plants due to photosynthesis using a torsion balance (Ch. 23), the simultaneous measurement of sugar production in plants during photosynthesis using two independent methods—a torsion balance and a chemical balance (Ch. 24). Finally, the efficiency of photosynthesis in storing solar energy was measured using another innovative device (Ch. 25).

Legacy and Global Recognition

The sheer volume of research contained in this one book is so great that it could easily provide the material for four or five PhD dissertations. But what about the quality of the research? For that, let us listen to a specialist in photosynthesis. According to Professor Govindjee, a pioneer in photosynthesis research (particularly Photosystem II) and Emeritus Professor of Biochemistry, Biophysics, and Plant Biology at the University of Illinois at Urbana–Champaign [6]: “Sir J. C. Bose made some remarkable observations on the physiological aspects of photosynthesis. While measuring the dependence of photosynthesis in the aquatic plant *Hydrilla* on external agents [carbon dioxide], he discovered in 1924 that during summer the efficiency of photosynthesis was not only much higher than in winter, but that the plants also produced malic acid (malate), which supplied carbon dioxide for photosynthesis; thus, no external carbon dioxide was required. This newly discovered pathway was later proved to be the C-4 pathway (now well known as the Hatch and Slack pathway). Moreover, this unique pathway

turned out to be an example of the non-Kranz, single-cell C-4 pathway functioning in aquatic angiosperms. He also discovered another phenomenon: the stimulatory effect of nitric acid on photosynthesis.”

It is noteworthy that almost thirty years after Bose’s work, in 1960, Karpilov was able to trace radioactive carbon atoms into malate and aspartate molecules in maize leaves—work that Hatch and Slack later used, in 1966, to describe the C₄ photosynthetic pathway in sugarcane leaves. Thus, Govindjee has no hesitation in declaring: “Therefore, Jagadish Chandra Bose was not only a pioneer of photosynthesis research in India but also one of its pioneers worldwide.”

Summary

In the 1920s, Jagadish Chandra Bose turned to photosynthesis, publishing *The Physiology of Photosynthesis* (1924), a 25-chapter monograph. He devised the Photosynthetic Bubbler, an innovative instrument that enabled precise, quantitative measurement of oxygen release during photosynthesis, overcoming the limitations of simple bubble-counting methods. Using this and other novel devices, Bose investigated the effects of light intensity, wavelength, temperature, seasonal and diurnal changes, as well as chemical stimulants and inhibitors. His most significant finding was that *Hydrilla* plants produced malic acid to supply internal CO₂ for photosynthesis—an early recognition of the C₄ pathway, decades before Hatch and Slack’s 1966 discovery. He also observed the stimulatory effect of nitric acid on photosynthesis. Modern scholars, including Govindjee, regard Bose as not only a pioneer in India but also a global trailblazer in photosynthesis research.

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FIG 5 : Sir JC Bose demonstrating “Plant autographs and their revelations” at the Evening Discourse, Royal Institution, London (May 1914). [Bose Institute Gallery]



Science, Systems, Success: Interview with a Distinguished Scientist

Swarnendu Saha (IISER Kolkata)

From the evolution of Science education in India, to the role of premier institutes, and the changing dynamics of student choices across disciplines, Prof A.K. Tyagi, dean of HBNI shares his view with our member Swarnendu Saha on India's growing global scientific workforce, and how institutions like BARC function differently from universities. The conversation also touches on research culture, opportunities for young students, regional representation, and broader issues such as employability, educational changes, and student politics.

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SS: Good Morning sir. This is Swarnendu Saha, your host for the day. Welcome to IISER Kolkata.

AKT: Thank you Swarnendu. Thank you for having me here today.

SS: So, my first question is - how do you see, as a teacher and a researcher yourself, the changing nature of science and research education in India ?

AKT: We have a heritage and age old tradition of strong education in India. Then, with the coming of western, European education newer universities were established in the presidency cities like Calcutta, Bombay and Madras, and then in Allahabad, Lahore etc. I myself come from one such conventional university only. There also things have changed rapidly. However, with time, these institutes were not able to cater to the growing needs and aspirations of the youth student community of the country and different systems of education institutes like IITs and AIIMS started being established.

Things have rapidly changed in premier institutions also. First and foremost, you are yourself from IISER Kolkata. You know, in the last two decades or so, the government has set up several new premier institutions.

During my time, mainly we had five old IITs and some AIIMS like this only. But now we have got several IISERs. The number of IITs has also gone up to 20 plus. So is AIIMS, we now have 23 AIIMS. Several IITs have come. So the research ambience has changed there as well. Right from their UG program to PG program, many of them offer integrated MSc. So integrated MSc has got components of BSc as well. The students are exposed to state-of-the-art laboratories, which may not be the case during our time, 40 years back or so. So I see a positive development all over India, be it conventional universities or central universities or premier institutions.

I do see an upward trend in the research component. Now students are much better exposed to research compared to earlier days. And this is going to increase only in coming years. So this is my response to this question.

SS: Our Dean of Academic Affairs, when our previous batch was going out had shown a study that over years, the number of girls graduating from IISER

Kolkata is quite low compared to the number of boys. This part of the country - Kolkata and the surrounding region, doesn't suffer significantly from casteism or other similar factors, so I don't think that acts as a barrier to discourage girls from joining the institutes.

The situation is particularly dismal in subjects like mathematics and physics. From the point of view of a teacher, how do you see this?

AKT: Yes, first and foremost, I should really appreciate this question. For that matter, the number of female students has increased in the last several decades. Every decade, you will see that the number of female students in premier institutions and university categories also is going up slowly, but definitely steadily.

So the situation is going to improve in the coming years. Now coming to their preference for certain subjects, you will be surprised to know, even during my time, 40-45 years back also, it was more or less the same. Maximum girl students were opting for biology.

Second was chemistry, followed by physics, and mathematics was least preferred. And not to make this mistake, never ever, that they don't have temperament for mathematics and physics, I will not agree with this argument. Some people may make this kind of argument also.

But that's not correct at all. In fact, girl students are quite well equipped to handle mathematics complex problems as well as physics complex problems. Somehow, for some other reasons, either because of family, they see family members, or because of other reasons, they have more fascination for biology followed by chemistry.

Traditionally, it is true abroad also. So I will not be able to pinpoint any strong reason, except that probably this also goes by word of mouth. Sometimes many things happen by word of mouth.

A group of students from the present generation may see, say 10 years back, their family members or their other neighbors and all, what they did. And they realize that these people have done MSc in chemistry or MSc in biology. So they also get tempted. So this could be one reason, an indirect reason, but there is no direct corollary which one can establish for not finding enough number of girl students in mathematics.

SS: No, see, as a part of this question, the fact is that if biology as a subject is very intensively fieldwork based and weight lab based, yes, these days computational biology has also gained space and that's required, but biology itself is a very field based, very weight lab based. In contrast, we don't require mathematics to go in the field and then do some calculations. If they have that zeal and temperament with a pen and paper, and now it is a high competition, they can do stuff.

So had that been the requirement of physical abilities, though I don't mean to say any other thing. But anyways, physical abilities or safety or anything first, the person who has to go for other forest trips or field trips or who has to do a direction



FIG 1 : Prof. A. K. Tyagi was formerly the Director of the Chemistry Group and Bio-Science Group at the Bhabha Atomic Research Centre (BARC). [Source: barc.gov.in]



of frogs, I mean, or butterflies, is more prone to take mathematics because it's a much safer, much calmer life. So how.....

AKT: No, no, no, there can be counter opinions on this discussion. I would say that excites them more, going to a garden to make herbarium. I know herbariums, I don't know whether you know or not, herbariums were made by students. In BSc we used to make herbariums. We had to go to the botanical garden and make some leaves, press them, put them into paper, then they used to write the botanical names. I think all these things excites young students in general and probably female students in particular.

Maybe, it is not the comfort of sitting in one corner on a desk and doing mathematics that would attract her. That has its own charm. But in my opinion, by nature, girls are more focused, that is a universal fact.

Multiple tasking wise also they are superior. I think there are well defined reasons for this. So probably it is this ability of having tremendous focus, I am not saying boys don't have focus, but in comparison my personal assessment is that girls definitely have more focus and perhaps less diversion compared to boys.

Again I will have a disclaimer, that not that all the boys have diversion, but relative fraction could be more. That is what I think you also, your generation also will agree. These could be the reasons that they want to go for these kinds of subjects which are much more diverse compared to sitting in a corner.

I think multiple tasking ability is one reason and fascination for colors, fascination for good smell, you know fragrance which a botany student is exposed to compared to mathematics student could be one reason on lighter side.

SS: My next question is - have you ever felt, the number of PhD students from and in India has seen a rise or fall ? You have connections abroad, you have been abroad, means let's assume East Asia, mainly Europe, Australia and US, this part. There is a much more fraction of Indians doing a PhD compared to the other group that I mentioned.

Have you ever felt that or never?

AKT: No, no, no. I think it is not correct to give any geographical angle to those PhD students who are following. I think it is just a question of the inclination of one student.

Chinese, for example, do a lot of PhDs. I think the maximum number of students come from China. So one may again counter argue that it is maybe an Asian trait, that's not correct here.

I think a number of students are there in Germany as well. I have been there several times, and they also have a good number of PhD students. So I don't think it will be correct to pinpoint any regional preference and in India of course I must say that within India there could be some reasons people from the eastern part of the country have more liking for science subjects and for research compared to let us say northern part. That again does not mean that northern part students do not have.

I myself come from that part of the country. So I think it is just some aberration that could be there but a little bit of difference definitely could be there. You yourself are from West Bengal if I am correct.

SS: Kolkata.

AKT: So, people from this part of the country definitely have a fascination for basic sciences.

SS: No, why I asked you this question is that I have seen some of my friends, immediate seniors go abroad for PhDs. The fact is that one of my close friends has always got this, in a lighter mood, that you are a young kid doing a PhD, why are you in such a hurry? And their lab is filled with mainly Indians or Asians rather than Germans. She is doing her PhD somewhere in West Germany towards the border of France and Switzerland. So there is a pattern.

They have said that in the US also, they are more prone to go to work at an earlier age compared to Indians who prefer to stay more as a student as long as possible doing a PhD, doing post-doc. From that point of view, I ask this question to you.

AKT: I understand. Also let us not forget that India and China are two of the most populous countries in the world. So their absolute number will always be more than the number of any other country.

But you have to see the number divided by population. Then I don't see that there is a vast difference. After all, the population of these countries, many of which you are referring to, is equal to that of a single state in our country.

So absolute number wise, Indians and Chinese definitely will be dominating, I believe, in any field.

SS: Let's move to the next point. About a few months ago, the Prime Minister of New Zealand was in India for the Raisina Dialogue talks. So that's a political, geopolitical stuff where the government has called other guests, other dignitaries, other government officials. My point is that the New Zealand Prime Minister was a guest of honour and in his speech he has said that India is the second largest producer and supplier of educated laborers to New Zealand.



FIG 2 : Prof. A. K. Tyagi did his post-doc in Max Planck Institute for solid state research, Stuttgart, Germany from 1995 to 1996. [Source: springernature.com]

Here, my question is - As a person who is involved in human resource development, how do you see this comment?

AKT: This is a very encouraging comment and I am pretty sure not only the Prime Minister of New Zealand, but many other heads of the states also would echo the same sentiments.

Because definitely we are producing a large number of highly educated young generation colleagues here. And many of them go abroad and contribute to their economy and they contribute to our economy also. You know India gets a very decent amount of foreign exchange, I am not able to quantify exactly.

By remittance. So these people contribute in a significant way. And Indians are there, not only educated, other spectrum of the workforce also, Indians traditionally have done very well. They are hardworking people. Let us admit that Indians by nature are hardworking and they are respectful to the system as well. All these things are there which any employer would like.

There is a reason for the large number of Indians, because the Indian diaspora is probably second largest. If I am correct, you may cross check it incidentally. After China, probably our diaspora is the largest in the world.

SS: Yes. But don't you think had they been in India and their ability, their capabilities have been in workforce in India, India would be far more better benefited than benefit it has from the remittance?

AKT: There is a truth in your statement that if they were full time in India, definitely their contribution to our economy would be more. Obviously. Because here they spend more time towards their employee and department.

I fully agree with you that compared to working abroad, they only have remittance kind of support to the economy. If they are full time here, definitely they will better integrate with the economy. But at the same time, let us remember that we talk about global order these days. We are all talking about global villages. The entire world is one and borderless trade we talk about. So in such a scenario, it is not a bad idea in my personal opinion to see our fellow citizens go to different parts of the world and do some good work there. Then when they come back, they become much better equipped to handle the problems of the nation. So it is not a bad concept at all. If they go there, they may settle as per their choice or they spend let us say a couple of years, come back.

So either way, the country is the gainer. Don't think that country is the loser.

SS: My next question now to you as a scientist, exactly what is your domain of research?

AKT: In my domain of research, I started my career in solid state chemistry. So we are into the development of different types of materials for various applications. In my group, we work on fundamental science. We also work on applied science. And considerable work has been done in the nuclear sector as well. So these are my 40 years of research in the most brief way I can summarize.

So basically development of materials, processes and products is something I have done during my career.

SS: So your lab is in BARC or HBNI?

AKT: No, HBNI doesn't have any lab. As I mentioned, it is a university degree awarding university. It is a central office. Labs were always in BARC only.

SS: So you now balance your work between the two places?

AKT: No, now I am a full time employee of HBNI. So BARC I go only occasionally.

SS: So your lab runs on its own?

AKT: No, no, no. No lab can run on its own.

SS: How does the system work then? Because in IISER, I see the same professor who is the director or dean. Sometimes they do administration work and the rest of the time they are teaching or research purposes.

AKT: No. BARC is a different system altogether thanks to Dr. Bhabha's grand vision. So here, you know, we have got our younger colleagues. So even if one person retires or he shifts somewhere else, projects continue. So our projects don't depend on one or two individuals. So we have got the next generation of colleagues who take over. This system works extremely well, especially for mission mode projects. This kind of system which Dr. Bhabha envisaged almost 70 years ago. It is a time tested system. It works very well. So I may or may not be around. Someone else will take over and carry forward the pattern.

SS: Okay. So as in institutes like IITs or IISERs where the PI of the lab is there and he is the top boss of that particular lab and everything runs under his or her guidance. That doesn't work with the BARC model.

AKT: No. In BARC, we have some people who work in this fashion also. Very small projects they will work on separate individuals. But primarily, remember, ours is a mission mode organization. So we work on large projects



FIG 3 : Prof. A. K. Tyagi has been working as a Senior Professor (Chemistry) at HBNI since 2022 and as Dean of HBNI since 2024. [Source: maps.google.com]

which are not, you know, dependent on one person coming and going. These projects are very regularly formulated and there are a battery of people who work on a given project in different age groups and so on. And we also plan.

We know now when we are going to leave the organization. So a couple of years before that, we start to think about who will take over this particular project. So the system is time tested.

SS: As a scientist, what do you feel is your greatest contribution as a scientist?

AKT: This is a question for which the answer can be very long, especially for me who has spent so much time in science. I will give some answers. Of course, first and foremost, an organization like BARC provides a lot of opportunities. You can do different types of work. I think this is an organization where there is a scope of contributing to many projects of national importance. That is something which definitely I was part of. And it also allows you to do basic research. You can develop products for applications. You can also develop futuristic materials. So my journey, I would not hesitate to say, was quite fruitful and enjoyable.

SS: And which part of the research do you think is your greatest contribution?

AKT: As I mentioned, I am a materials scientist. So development of materials is something which definitely I can say is my... If you ask me a single line answer, development of different types of materials is my contribution which I am proud of.

SS: Currently, what research are you doing?

AKT: Yes, as I mentioned that I shifted to HBNI. So some research I continue, of course, with the help of collaborators. And I continue to have students who are working in BARC. I must thank the BARC administration for permitting me, for permitting these students to work in BARC.

SS: And how do they work? Say, they work under your guidance.

AKT: Of course. I am the guide of these students. And then some other mid-career colleagues are co-guide. So that they can get day-to-day guidance.

SS: So you are the PhD guide of them. PhD guide of them.

AKT: Yes. And for these students, as I mentioned that I have also requested some mid-career colleagues to act as co-guide.

SS: Have you ever thought of joining institutes like IISERs or regular universities, shifting from BARC?

AKT: Frankly speaking, the answer is no. Because right from the beginning, I was busy and working at that satisfaction level. Job satisfaction level also was high. And

the department allowed me to work on varied types of projects. So I think that thought of shifting never came to me.

SS: How much independence do you have as a scientist?

AKT: This is an organization where nobody has any excess control over others. This organization gives you enough independence within the confines of rules and regulations. Now, that is without saying, independence comes with responsibility also. You agree with me that more independence, more responsibilities. So with this concept, I would say this is a very nice organization.

SS: No. My point is that during chats with my professors, be it my department or any department, all are my professors, teachers. So they have said that in these institutes like IISER in general or IISER Kolkata in particular, what danger is that they don't have any top boss on them as far as research is concerned.

So it is they who decide what to do, how to do it. Yes, responsibility falls and then they have to acquire the funds and all. But it is their thing.



FIG 4 : Prof. A. K. Tyagi was conferred the Vigyan Shri Award in Atomic Energy by the President of India, Smt. Droupadi Murmu, during the inaugural Rashtriya Vigyan Puraskar ceremony at Rashtrapati Bhavan on August 22, 2024. [Source: incers.org]

But in BARC, you have been told that projects go on. You only join that at a point in your career. You add to it. It adds to you and then you leave. The project still goes on. It is like a river. You just join somewhere and leave it. So from that point of view, I ask this.

AKT: Your question is well taken. See, both the models have merits and demerits. I am not saying. So this model works very well in academic institutions.

SS: Which model?

AKT: The model of independence in terms of selecting problems and getting funds from funding agencies, which you mentioned in IISERs and IITs. This model, I am not denying that it is bad. Never ever. But the kind of projects in which DAE is engaged in need this kind of arrangement where we have large projects, mission-oriented projects. So there we need to have a certain hierarchy also where one can get work done from others. So again, one more thing I say is that when you have responsibility for large projects, you also need to have authority. Higher responsibility also calls for some authority as well. So there are different models and both are required in science. Depending upon organization, both the models are required.

I am not saying that one should have only the mission mode kind of model or the other model. Depending upon which organization you belong to, both the models have to exist.

SS: My next question as a student is, if someone wants to join BARC, what kind of preliminary training from their end they should do? And what are the requirements for joining BARC?

AKT: Yes, this is a good question. See, there are two ways of joining DAE. One is after MSc - the pathway I used to join.

After MSc, the main entry point is training school. I must share with you that in the training school of BRC, in basic sciences, in physics, chemistry and biology, we have quite a good number of TSOs, training school officers right from early days from the West Bengal area. So, people are lacking, as you also know that they are lacking for basic sciences.

So, a good number of our brand students come from West Bengal. For cracking training school, there are two things. One is that you have to appear in a national level examination or you have some valid grade score.

That way you can come for the interim directly. For cracking written tests, you should be thorough in all subjects of chemistry. Your questions will come from different branches of chemistry.

Physical, organic, inorganic, radiochemistry and you know, radical chemistry and so on. Then, once you qualify the written exam, you are called to Mumbai for an interview. The interview is held in Mumbai. Written exams are held all over India. Kolkata is one of the biggest centers for our written exam. In an interview, the interview is a different ball game.

In an interview, the written exam and interview are two different things altogether. If you do well in the written

exam, it does not mean you will do well in the interview also. The interview panel goes quite deep and you need to really have good concepts here.

So, for interviews, I always say the best way is to know everything and something of everything. You understood? It means a couple of topics, some 8 to 10 topics, you must be very thorough.

And for other topics, you should have good knowledge. So that you can face questions from a wide range of topics.

SS: So, it's a strike and balance between jack of all trades and master of some.

AKT: Not none, but precisely. And this applies when you get a job also. It's very important to have a wide knowledge base, but deep in your domain.

You are deep in your domain and wide otherwise. And otherwise, suppose if you do PhD, then also there is a possibility of joining DAE. We have a scheme called the KSKRA Fellowship - KS Krishnan Research Associate Fellowship, KSKRA Fellowship. There one can join after PhD, but the number of positions is a bit small and frequency also is not annual.

SS: Okay, my next question is that as a scientist in BARC or DAE, how much fund do you get for yourself? Yourself means your personal research or your any either we take data in ARF funds. And are you allowed to go Europe for, Europe means abroad for conferences and stuff like that?

AKT: Yes, Of course. I think our department in general, and BARC in particular, has schemes for sending people abroad. We have a special scheme where one can go abroad once every 4 years.

SS: Once in 4 years?



FIG 5 : Prof. A. K. Tyagi received the prestigious Fellowship of The World Academy of Sciences (FTWAS) at a ceremony in Rio de Janeiro, Brazil, on September 30, 2025. [Source: smcindia.org]

AKT: Yes. Once in 4 years fully funded and partial funding anyone can get. So, I have myself gone to many, many conferences abroad.

SS: But, what if you want to attend one each year.

AKT: No. Let us admit one in each year is not possible in other institutions also. After all, it costs a lot of money to the treasury. So, in my opinion, one conference every year is fully paid by the government, I think it is slightly on the higher side of expectation. You should get some annotations which are paid for by others. I have got a good number of annotations in my career.

I mean when I was mid-career and where my visits were at no cost to the department.

SS: The external?

AKT: Yes.

SS: They funded?

AKT: They funded everything, my stay, my travel, everything. So, you should come to that stage that everyone will invite you, people will invite you and offer you everything. As I said in the earlier part of the interview, to expect money from the government all throughout is equivalent to expecting money from father for whole life. A day should come when we support our father.

SS: So, at which point of the career should we expect more from the government?

AKT: Asking early career to mid-career, definitely you should expect more funding from the department. But after mid-career when you become senior, mid-career means let us say about 40. So, for the first 15-20 years I am sure people will not offer you full paid visits.

And at your age definitely you must look for support. But as you grow further once you are in your mid-40s or so, your situation should definitely be such that anybody should be proud to invite you at low cost to your department.

SS: Today's BSc or MSc students do some bit of research as a part of their curriculum or internships. Let us assume a student has gone to you for some MS thesis or internship and that person has done a considerable amount of work. So, when he returned to his own institute, he maintained contact and there were occasional meetings and the project is finally successful and they got a paper out of it.

Now that student wants to go abroad to present his work. In that case, do they have any funding for those students? If yes, what are those? Because those are not readily available from the schemes from CSIR, DST, etc. If not, do you think there should be schemes to support those then? And in the process, how?

AKT: See, this is also a very good question. This is almost a policy type of question. Let us have one thing that a

student who is in MSc, after BSc, he is in MSc part 2 - let us say, second year.

Let us assume I am that. Okay. So, at this age, I think you are too young to, you know, make a presentation in a very big international conference.

Maybe you can make a postal presentation. So, for that, there are exchange schemes here.

I fully agree that MSc students also should be exposed to a foreign country to an overseas work culture. But for that, this is not the only model where, you know, they do some research, they want to present a paper. That comes as, you know, you have rightly pointed out to senior PhD students. Usually, SRFs are given funding for going abroad. In HBNI also, incidentally, we have got a scheme of funding each and every PhD student to go abroad once during his PhD. Fully funded. But that is done after three years are over. After that only when they are in fourth and fifth year, then only we give them funding and for the right reason. Because a very young person, if first year PhD leave alone MSc, may not be, if not almost, may not be mature enough to, you know, to withstand that kind of, you know, scrutiny is not the right word, that kind of, you know, question answer session, this, that, all. And his data also may not be sufficient.

In six months of internship as an MSc student, I don't think I can have that kind of data that becomes presentable in international conferences abroad. But for young MSc students, the government has got schemes of exchange visits.

SS: What are those?

AKT: So, let us say, they are bilateral agreements in other countries. The government sends a group of young students to Europe to interact with Nobel laureates of the given year. So, all these schemes are there. So, DST has a number of schemes for MSc students also. But our MSc student number is very large. To expect that each one of them will go also is, you know, beyond the possibility of implementation. But at the same time, their time will also come. My first visit abroad for a post job was in 94. Eight years it took. Doesn't matter. And, it was not too long. It was worth waiting. After 80 years, I was mature enough in terms of my knowledge, whatever I had those days. My PhD is over. I got two promotions. I was, you know, reasonably mature enough, strong enough to do work internationally. So, I think too early is also not desirable.

SS: Have you been to the North East?

AKT: Manipur and all? I have had a very sincere plan for the last several years. And I have a very close colleague who comes from Manipur. So, he is promising me to arrange a visit to Manipur University and all that. Somehow it never happened. So far I could not go. And this is against my wish. I have been thinking for at least 10 years of being deported. So, I do plan in the coming years. I have very strong working relations with several people in the North East region.

SS: Have you ever felt that the representation of people in science from the North East is not up to the mark?



AKT: No, there can be many reasons for this. But now it is really progressing well. And I see North East students are really doing well. I may share with you my own experience with these students. They are very hard working students. Extremely hard working students are from this area. My own colleague comes from Manipur. And, you know, you can bang on him for anything. This kind of commitment is there. So, in the coming years they are definitely going to shine. And if assuming that there is under representation of these people as of today. That won't be the case forever.

SS: No, the fact is that many times, if not my personal opinion. Many times in various sectors, we feel our statistics do come out. India's North East remains under-represented. They may have to work harder to be in the same place where I am. Had there been more access to resources and facilities. They could have been more at a better place. Every state to the West of West Bengal, and including Bengal has one IIT. And, the whole of North East has one IIT. I accept every, or almost all the north-eastern states I believe have one NIT. But again, one medical college in the whole of Nagaland. And that too has been established very recently. And the medical colleges in some other states had to reserve seats for the students of other states. So do you feel or would like to say regarding this. .

AKT: I will answer very briefly like this. While all you say could be correct. But believe me, the Government of India is very serious on this matter. North East states are definitely giving a lot of consideration. And a lot of improvement will happen in the coming years. So not that the Government is turning a blind eye on this issue. Definitely not. The situation is going to improve. They may have geographical disadvantages. But this disadvantage cannot stop them any longer. So there is a sign of reversal of this trend. Be assured in the next 10 years or so. You will see their very decent representation everywhere. And I may also say in my group, in BARC in our division. We invite a number of faculty members from the North East region. And a large number of young PhD students. They come for our conferences from the North East region. And this, I will ensure that it is going to increase only. In our conferences especially. So there is an upward trend.

SS: Okay, so we are more or less towards the last part of the interview. So how do you see the changes in your times? And how do you see the changes in our times?

AKT: Changes in what? Changes in the development of science and how the students look towards academics ?

SS: I am from Bengal. My father is a businessman. When my father and mother were young, there was a zeal towards engineering. But people did take up basic sciences, as well as other subjects - in arts and science. Today, premier institutes in Kolkata, often less than 10 students got enrolled in a class that can accept 30 to 40 students. And this is right in the main city, and not in some remote part of the country. On the other hand, the number of private

engineering colleges is increasing. In your personal view, how do you think things have changed, compared to your times, your student days.

AKT: From my studentship days things have definitely changed. But let us also admit - Now there are many more options. I remember in the early 80s. When I was in B.Sc. or so. That time there were hardly any engineering colleges. We had 5 IITs. And we had some old engineering colleges. You could literally count all on fingers. Now, every nook and corner. You will see engineering colleges.

So, today's young students and their parents have a much wider option compared to let us say in the 70s, 80s and even 90s also. This is one development which has happened. I am not saying good or bad. But it has happened. And in a way it is good also.

Now, coming to students not opting for basic sciences. What you are referring to is legacy. West Bengal is a hub of legacy colleges. And universities. Some of the oldest colleges and universities of Asia are set up in West Bengal. In 1857, if you know, the three universities of British India were University of Calcutta, University of Bombay and University of Madras . Before that we had the Hindu College, what is today known as Presidency University. Then Serampore College in Hooghly, outside the ambit of British control but other European powers. Independent India saw the rise of ISI. They are also Shivpur B.E. College, today known as IEST. They are all very very old colleges.

So, in my opinion, the students not joining does not always mean these colleges as 40 years back does not put them on the wrong side. Of course, they also have to compete. Now, you cannot, you know, force anyone to take any particular stream. Suppose I have got the option of 10 dishes in front of me. I may choose the two best of. As per my liking. But if I have only three dishes. In front of me. Then you can imagine the probability of any dish to be picked by me is very high. So, this is the change in higher education also. Now, more options are available. And that's why students and parents. Also have a lot of other avenues to be explored which may not be the case during my time or generation before.

But definitely it is a matter of concern if many students are not going for basic sciences for MSc and other basic



FIG 6 : Prof. A. K. Tyagi serves as an Honorary Professor at the Jawaharlal Nehru Centre for Advanced Scientific Research (JNCASR), Bengaluru. [Source: ajatakcampus.in]



sciences degrees. We were discussing it with faculty members also. That is a trend. Could be in other parts of the country also. This is a matter of concern.

And definitely one has to work out and modify the syllabus in teaching. There are many students who could not come to MSc. Employability concerns are a big parameter to be taken care of these days. So, probably parents and students both think engineering makes them more employable. And that may be correct also. Since I am not an engineer. I cannot answer this question with emphasis. But this, you know. Let us admit. One has to take a job, support himself, parents and family. This is bound to happen. Which is going to come. So, it is an employability driven concept also. So, our MSc courses also have to evolve.

SS: And another question. Before I end. How do you see the influx of politics or student politics in the education system ?

AKT: See, whenever they are human beings, irrespective of the age group, they will assemble. There is a social fabric. There is a difference between homo sapiens and other species. That is true thousands of years back also. They could assemble. They could coordinate. Homo sapiens has survived a lot of crises. Recently you have seen COVID. Because of this. Coordination and cooperation. So, wherever there are a decent number of people, who are educated, who are ambitious; some of these kinds of elements are bound to come. And I think it is not a bad idea to have some people also have the opposite opinion. One is your opinion. But if there is a group of people who have some opposite opinion, let us listen to them as well. I always say. That we should be open. To the opposite view as well. So, student union and politics. It is inherent to human beings. Homo sapiens are born for this.

SS: But IITs, IISERs don't have them. But still they are functioning well.

AKT: No, this could be a local decision. I will not be able to comment on why they don't. And why others have. I will also not say which system is having more advantages. Definitely, there could definitely be other mechanisms. These days are the days of social media, zamana of social media. I don't think you need to have every formal union and all that. 25 people can have it. Lots of interaction can be there informally also. And do a lot of thinking, lots of exchange of ideas and all that. So, in that way I don't think human beings always need to either join hands or oppose each other. And let us respect that.

SS: My last question. What are your concluding remarks for students of IISER ?

AKT: Not only for students of IISER Kolkata. For all the students. I can say a couple of things right now. One is that - work hard and work smart. Working hard is important. But you can also include the element of smartness. Work hard and work smart in the right combination. It is extremely important for both your generation and for my generation. Remember, there is no shortcut to success. Some success may come by shortcut. In the long term, you have to really work as hard as you can. Third thing. I will say, no one is immune to failure. Don't think whatever you touch is going to become gold. That doesn't happen. There will be enough failures also in your career.

Many things don't go the way you think. So be ready for it. Not getting so encouraging results. To get some setbacks. And setbacks and failures teach you a lot. If you get some setbacks. If you get some failure. Be open. Do analysis. What went wrong in this project. These are the things I would say. A couple of more things I can say. Please, help each other.

Don't work only on your own. What you call. Don't think only about yourself. It is important that we think about others also. You will realize all these things after 40 years when someone will take your interview. So help each other. And, system you should take care. The system in which you are working. The system which has given you a job. I think it is very important. That we respect that system. We respect each other. We respect other cultures. We respect each other's language. We respect others' food habits. This is very important. And, I will also say at the end. While being local. Think globally.

SS: Thank you sir. That will be all.

Breaking The Ice

— comic by Arya Mhatre

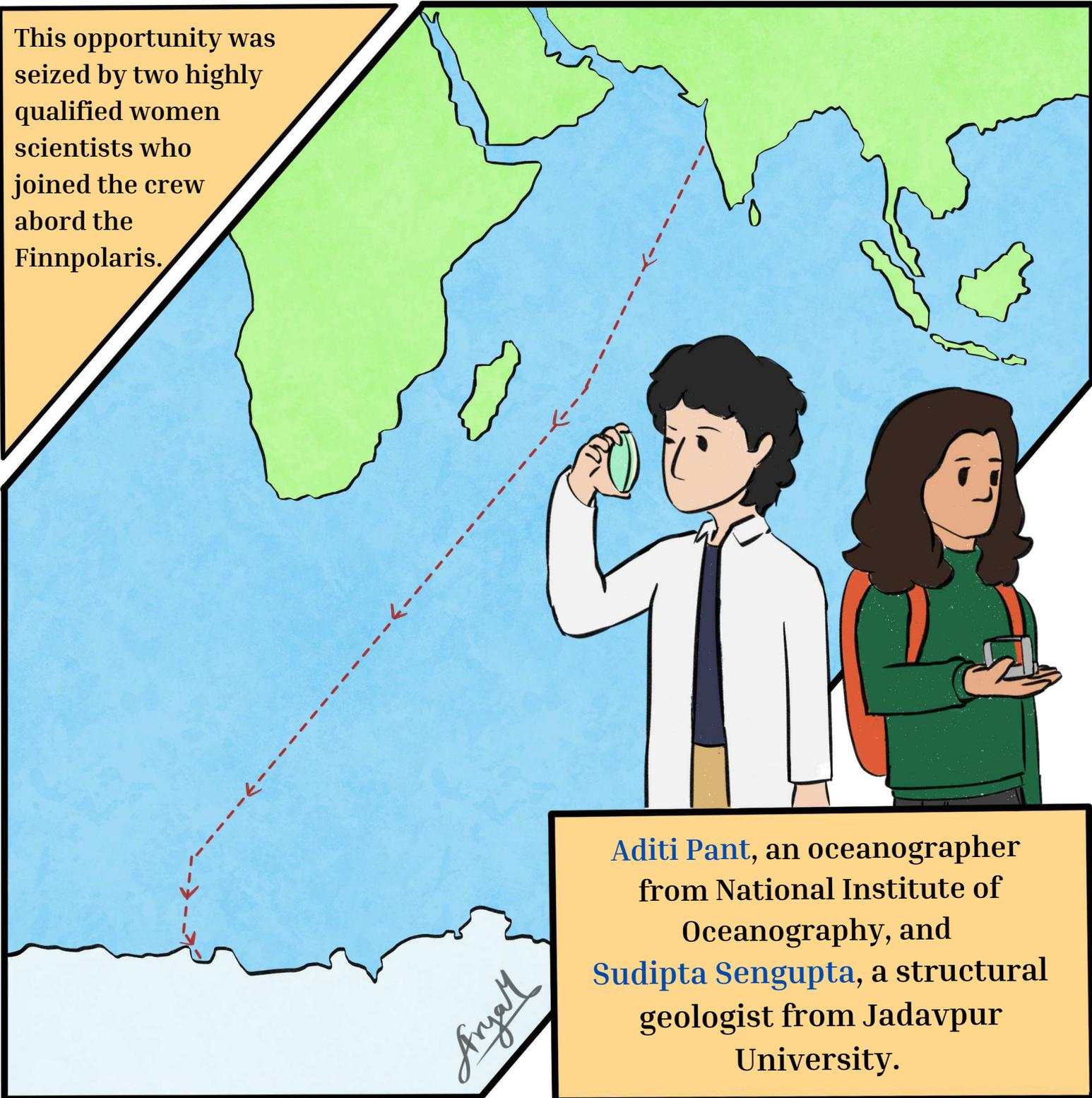


*India's **First** Women
in **Antarctica***



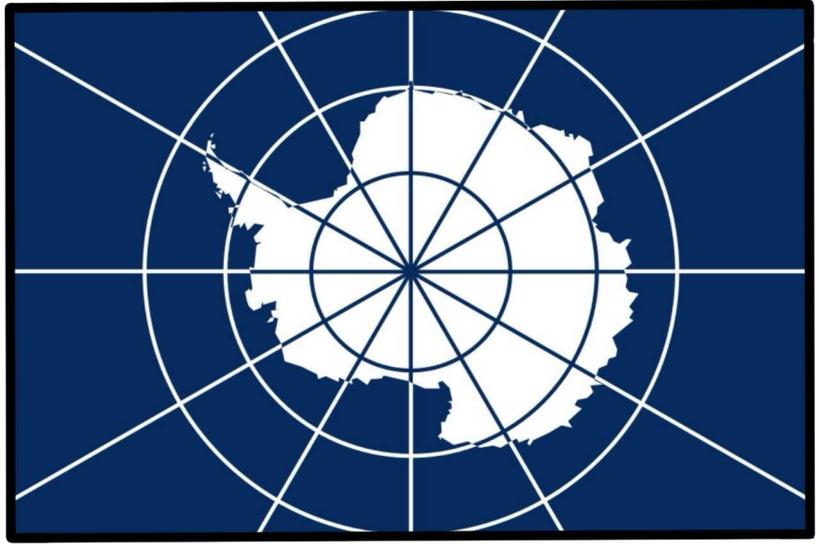
India's 1st Antarctic expedition was initiated by Prime minister Indira Gandhi in 1981. Women were allowed to join for the first time in 1983, for the 3rd Antarctic expedition.

This opportunity was seized by two highly qualified women scientists who joined the crew aboard the Finnpolaris.



Aditi Pant, an oceanographer from National Institute of Oceanography, and **Sudipta Sengupta**, a structural geologist from Jadavpur University.

India officially acceded to the Antarctic Treaty System on 1 August 1983. The program was started with the goal of initiating multiple fields of study in Antarctica. It was decided that a permanent station would be built during the 3rd expedition along with continuation of previous research on the continent.



Their journey began in December 1983. They set sail from Goa and after 1 month of continuous sailing, the team docked at the Schirmacher Oasis region. Dr Pant and Dr Sengupta became the first Indian women to set foot in Antarctica.



The expedition wasn't without its risks. The frozen continent provided quite a challenge to stay at and study. They had to face blizzards, freezing temperatures, and a sun that never set. There were also many technical difficulties during their voyage.



Sengupta



This was not the first challenge faced by the women scientists. Despite prevalent sexism, they had proven themselves through their achievements in research. Sudipta sengupta also had plenty mountaineering experience through previous expeditions.

Detailed geological and structural mapping was conducted across 35 sq km in the Schirmacher Range. Rock samples were also collected for analysis. Microbiological studies were conducted on the freshwater lakes. Researchers measured biological productivity, bacterial counts, and variations in microbial activity over time.



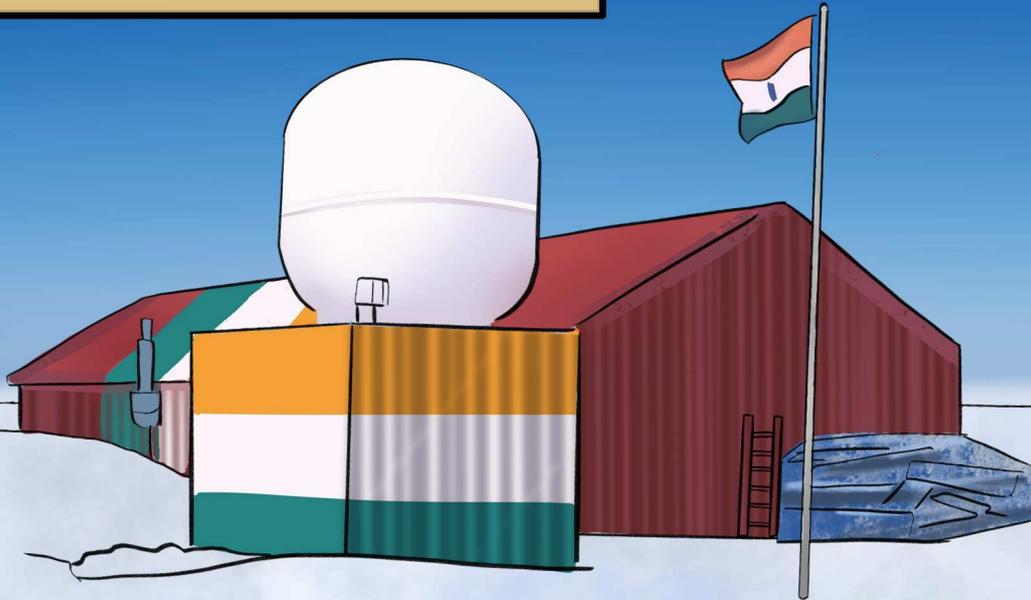
The marine biology program focused on sampling zooplankton, particularly krill, from different parts of the ocean to study their distribution and abundance.



Their male teammates took a while to be more accepting of their presence. Dr. Pant was primarily on the ship as a marine biologist while Dr. Sengupta did field work on the continent.



The expedition ended after 4 months of research-



-and creation of the Dakshin Gangotri station.



Their courage shattered stereotypes and expanded the horizon for women in science. Both scientists returned to Antarctica in future missions before continuing their research back in India. Even today they continue to teach and motivate young women to overcome their fear and explore research in various fields.

Till now more than 80 women researchers have participated in India's Antarctic program. Their work not only advances our understanding of Antarctica but also serve as an inspiration for future generations of researchers to explore new frontiers in science.





Arya Mhatre is a student at IISER Kolkata currently pursuing Earth Sciences. Beyond collecting cool rocks, she's also an illustrator and comic artist who wants to learn 2d animation.



Researchers have discovered a new kind of “memory” in phase-change materials, where a material can remember tiny temperature disturbances even under constant conditions. This finding links the physics of metastable states to future technologies in sensitive thermal sensors and brain-inspired computing. Read the writeup by *Aniket Bajaj* for more details.

Insight Digest

Fresh highlights from the frontiers of science

Aniket Bajaj Thermal-breach memory: Harnessing metastability for sensing to artificial neurons

Swarnendu Saha Listening to Rivers: How Stream flow Can Help Us Understand Rainfall Better

Suman Halдар What do the fundamental constants of physics tell us about life?

Ashish Ramesh NT From the Arctic to India: Understanding How Barents–Kara Sea Ice Influences the Monsoon

 Also available online, at scicomm.iiserkol.ac.in

Thermal-breach memory: Harnessing metastability for sensing to artificial neurons

Aniket Bajaj, Satyaki Kundu, Shikha Sahu, D. K. Shukla, Bhavtosh Bansal. *Appl. Phys. Lett.* 127, 021902 (2025)

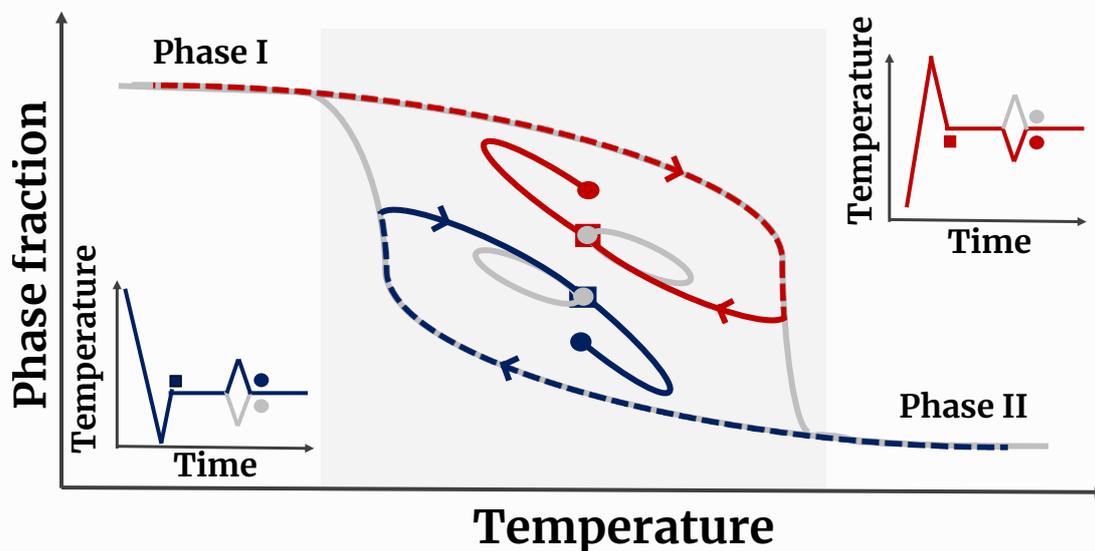
Contributed by Aniket Bajaj (Department of Physical Sciences, IISER Kolkata)

In everyday life, memories often surface in unexpected and seemingly random ways. Interestingly, various forms of memory have also been identified in the physical world—ranging from magnetic systems and shape memory alloys to emerging fields like neuromorphic computing. In these systems, “memory” refers to the dependence of a system’s current state on its history, often manifesting as multivalued or path-dependent behaviour. A system that has not yet fully relaxed to equilibrium can retain information about its creation or prior states, while one that has reached equilibrium loses all traces of its past—the act of equilibration effectively erases its memory.

Recently, our group, led by Prof. B. Bansal, has identified a novel form of memory in phase change materials, coined as thermal-breach memory. Initially, in collaboration with Prof. D. D. Sarma’s group at IISc Bangalore, we discovered this phenomenon in a well-known halide perovskite material (MAPbI₃) which has thermally-induced phase change at low temperatures (150 K). And later, by recognizing the broad potential of this memory effect; we collaborated with Prof. D. K. Shukla’s group at UGC-DAE CSR, Indore; to establish this fundamental concept for room temperature applications using another phase change material, vanadium dioxide (VO₂).

These materials exhibit a key characteristic during their phase transition—hysteresis—where the phase fraction follows different paths depending on whether the external parameter (in this case, temperature) is increasing or decreasing (see figure). Memory effects require the system to be in a non-equilibrium state which corresponds to the hysteretic (metastable) region. And we found that when the system is held within this coexistence region at a constant temperature the metastable phase becomes “frozen,” showing no further progression toward the stable phase. If some perturbation is given to these isothermal conditions, one can track the breach by monitoring the corresponding behaviour of the frozen phase because its response to the given perturbation depends on the history of its creation (prepared while heating or cooling, see figure). This distinct behaviour enables the detection of thermal breaches as small as one degree.

Thus, athermal states in phase change materials enable thermal-breach memory, by detecting small thermal breaches via distinct response of its phase fraction, offering stable, sensitive operation for sensor and neuromorphic applications.



Encoding-decoding of thermal-breach memory: Materials such as MAPbI₃ and VO₂ exhibit hysteresis during their phase transition, where the phase fraction follows different paths depending on whether the external parameter (here, temperature) is increasing or decreasing. This gives rise to a phase-coexistence region (as shown with shaded area). We found that when the system is brought into this region via heating (dotted red) or cooling (dotted blue) and held at a constant temperature, the metastable phase becomes frozen (red and blue square), showing no further evolution toward the stable phase. And further, upon introducing a small perturbation under these isothermal conditions, the decoding occurs: the response of the frozen phase depends on its thermal history. This history-dependent, distinct response enables detection of thermal breaches and highlights the potential of such systems for sensing and neuromorphic computing applications. Adapted from reference.

Listening to Rivers: How Stream flow Can Help Us Understand Rainfall Better

Dean, J.F., Coxon, G., Zheng, Y. et al. Old carbon routed from land to the atmosphere by global river systems. *Nature* 642, 105–111 (2025)

Contributed by Swarnendu Saha (Department of Physical Sciences, IISER Kolkata (20MS))

Understanding rainfall is key for managing water, predicting floods, and studying climate—but measuring it directly is tricky. Rain gauges and satellites often miss details or have errors. This paper explores a creative idea: can we use the water flowing out of rivers (stream flow) to better estimate how much rain actually fell in a region? In other words, can we trace rainfall backward from the river’s response?

This sounds simple but isn’t. Stream flow depends not only on rain, but also on evaporation, soil moisture, and groundwater—all of which mix together in complicated ways. Many different rain patterns can produce similar river flows, so working backward to find the exact rainfall is impossible. Instead, the researchers aim to estimate the average rainfall over a catchment, which is more realistic and useful.

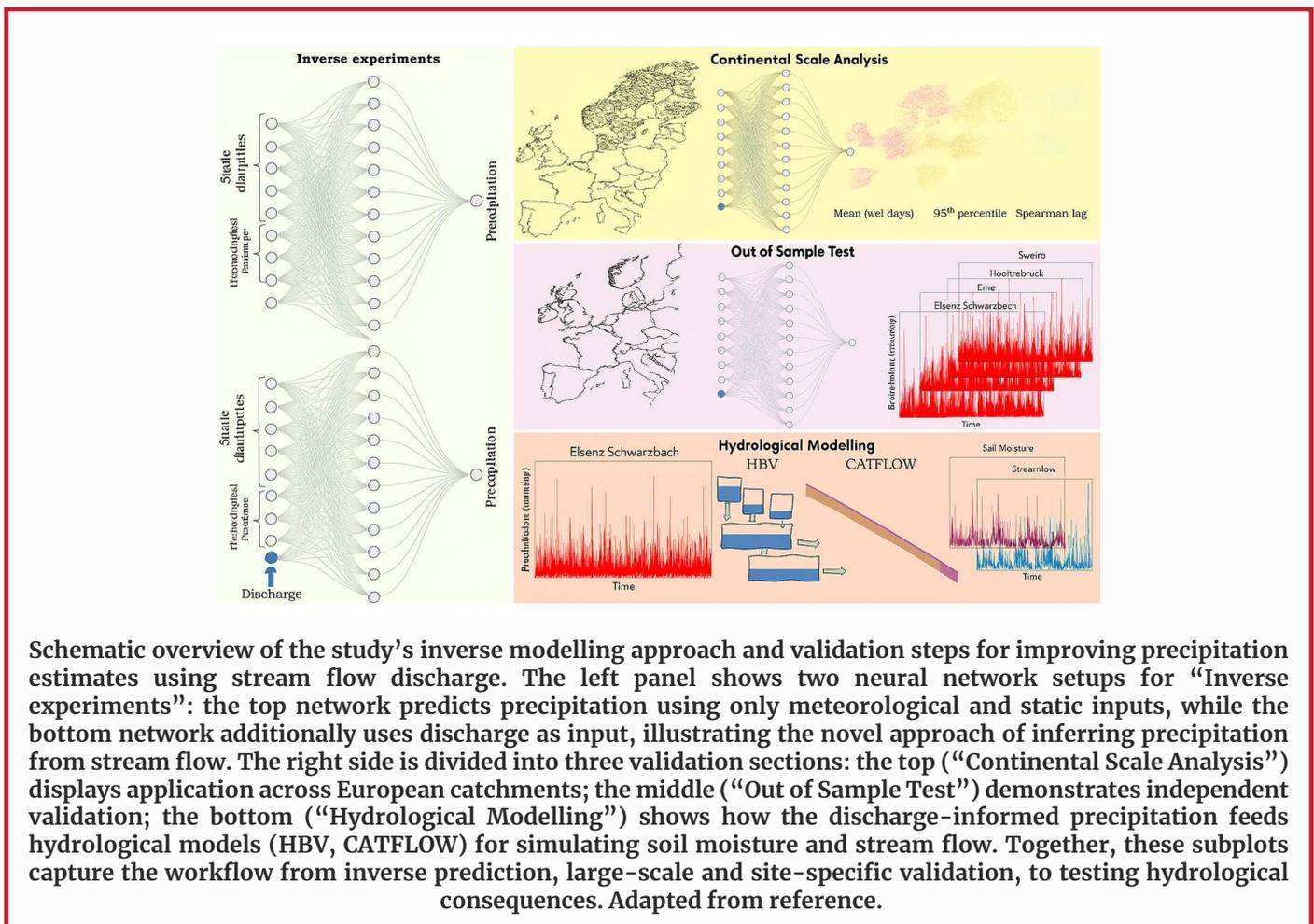
To tackle this, they use a type of artificial intelligence called an LSTM (Long Short-Term Memory) neural network. It’s good at handling time-dependent data, like how rivers respond to rain with delays. They train two models: one predicts rainfall using weather data such as temperature and humidity, while the other adds

river discharge information. Comparing the two shows whether including river data actually helps.

The results are promising. The model that includes streamflow performs about 20% better in estimating rainfall, especially in areas with good data. However, it slightly underestimates rainfall overall, meaning some adjustments are still needed. When these improved rainfall estimates are used in hydrological models they better match real-world observations of soil moisture and floods—showing that this method captures important water-cycle behavior.

The authors note that the approach relies on good-quality data and could benefit from newer AI techniques in the future. Still, their work demonstrates a powerful concept: using river flow (the effect) to learn about rainfall (the cause). It’s a fresh way of combining machine learning with hydrology—looking at the water cycle in reverse—to improve rainfall estimates where observations are limited.

In short, the study shows how “listening” to rivers can help us better understand the rain that feeds them offering a smart and practical step forward for water and climate science.



What do the fundamental constants of physics tell us about life?

Mehta, Pankaj, and Jane Kondev. What do the fundamental constants of physics tell us about life?. arXiv preprint arXiv:2509.09892 (2025).

Contributed by **Suman Haldar (Department of Physical Sciences, IISER Kolkata)**

In this extraordinary work by Pankaj Mehta and Jané Kondev, physics reaches toward the living world with the same audacity Weisskopf once used to estimate the height of mountains. Half a century ago Weisskopf showed that with just six physical constants— \hbar , c , e , m_e , m_p , G_n —the universe allowed one to estimate densities, mountain heights, stable matter. But life was missing from that program. This paper attempts the most radical extension: to put “life” itself inside the Weisskopf reasoning game. To ask: how much of biology can be read directly from quantum constants? How much inevitability is buried inside the Rydberg energy? How much universality does α , m_e / m_p impose on metabolism and replication?

Life on Earth is, fundamentally, electrons falling downhill toward lower energy states. Szent-Gyorgi called life a high-energy electron searching for a place to rest — this paper takes that statement literally and quantitatively. The authors argue that three essential biological numbers — growth yield, minimum possible doubling time, and the minimum maintenance power of dormancy — can all be derived from fundamental constants plus a few geometric/structural fudge factors. The Rydberg energy (13.6 eV) and Bohr radius (0.53 Å) define the quantum base units of chemistry. Thermal fluctuations ($k_B T \approx 25$ meV) are orders of magnitude lower — this gigantic asymmetry explains why chemistry is stable, why catalysts exist, why biological time must scale between these two worlds (quantum & thermal).

From this, they estimate the yield Y : mass (g) produced per Joule consumed. Using only α , R_y , molecular atomic numbers and bond fudge factors, they get 10^{-5} – 10^{-4} g/J — astonishingly matching microbes on Earth. This, they argue, may be universal, even for alien life, because it is not exponentially sensitive to activation energy — unlike kinetics.

Minimum doubling time emerges from the interplay of quantum-set minimum viscosity (Berg viscosity) and diffusion-limited kinetics. With Arrhenius activation barriers of 0.4–1.1 eV, one gets doubling times from seconds to geological years — perfectly spanning *Vibrio natriegens* (10 minutes) to deep-ocean microbes (years). And finally, dormant power — arises simply from thermally-opened membrane pores leaking charge requiring pumping — giving 10^{-13} – 10^{-15} J/s/cell, exactly the natural order biological measurements report.

The result is profound: evolution explores details, but the gross “possibility space” of life is already sharply bounded by physics itself long before chemistry, DNA or selection. The production of biomass, the speed of replication, the lowest energy to stay alive — are already written in the constants of nature. Growth yield is the least free, most universal property of life. This is not biology derived from empirical catalogs — this is life emerging almost poetically from \hbar , α , m_e , m_p . Physics gives life a skeleton before evolution gives life a story.

A

B

Self-replicating cells

$Y = \frac{\text{Mass}}{\text{Energy}}$

T_{\min} fastest doubling time

Dormant cells

$\text{Power} = k_B \frac{\Delta S}{\Delta t}$

entropy production

Characterizing chemical self-replicators. (a) Self-replication requires organisms to break down food molecules from the environment to extract energy and metabolic precursors (catabolism) and then use this energy to synthesize the complex molecules necessary for selfreplication (anabolism). **(b)** We focus on three properties of self-replication: (i) the mass per unit energy consumed needed to self-replicate, (ii) the time it takes for self-replication, and (iii) the energy per unit time a dormant cell must expend in order to stay alive and counter entropic forces. Adapted from reference.

From the Arctic to India: Understanding How Barents–Kara Sea Ice Influences the Monsoon

Sardana, D., Agarwal, A. Impact of spring sea ice variability in the Barents–Kara region on the Indian Summer Monsoon Rainfall. *Sci Rep* 15, 37790 (2025)

Contributed by Ashish Ramesh NT (IIT Roorkee)

The Arctic is warming faster than any other region on Earth, and one of the clearest signs of this rapid change is the steady decline of sea ice. Among the various Arctic seas, the Barents–Kara (B–K) Sea, located north of Russia, has been identified as a particularly sensitive region where warming and ice loss occur rapidly. This study explores how variations in spring sea ice in the B–K region influence the behaviour of the Indian Summer Monsoon Rainfall (ISMR), which is vital for the climate, agriculture, and economy of India.

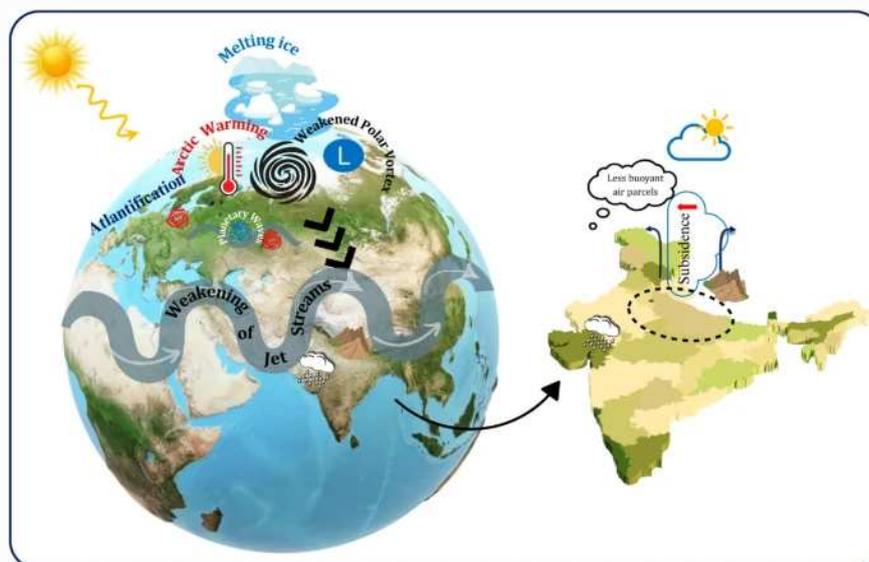
To investigate this link, the researchers examined climate data spanning more than six decades, from 1959 to 2021. They created a springtime sea ice index for the B–K region and identified years with unusually low and unusually high sea ice. They then analysed how the monsoon behaved during the following summer in each of these contrasting years.

The study found a clear and consistent relationship between spring Arctic sea ice conditions and the strength of the Indian monsoon. During years with low sea ice in the B–K region, the exposed ocean water absorbs more heat, warming the lower atmosphere and reducing surface pressure. This thermal and pressure imbalance helps generate disturbances that travel across continents as large-scale atmospheric waves. These waves modify the position and strength of the subtropical westerly jet stream during the Indian monsoon season. In low-

ice years, the jet stream shifts slightly southward and encourages sinking air over northern India, especially across the Indo-Gangetic Plain. This downward motion suppresses the vertical movement of moist air, limits cloud development, and ultimately weakens monsoon rainfall in one of India's most important agricultural zones.

In contrast, years with higher-than-usual spring sea ice show an opposite response. A colder Arctic surface supports higher pressure and different atmospheric wave patterns, which help strengthen upper-level divergence and promote rising motion over northern India. These conditions favour stronger monsoon circulation enhanced moisture transport and increased rainfall particularly in the Indo-Gangetic Plain and parts of Northeast India.

The findings highlight how tightly connected the world's climate systems are. Though India's monsoon is strongly influenced by tropical factors such as the Indian Ocean ENSO, and land–sea thermal contrasts, this research demonstrates that conditions in the faraway Arctic also exert an important influence. This has significant implications for water resources, agriculture, and long-term planning. The study suggests that including Arctic indicators in monsoon prediction models could help improve seasonal forecasts and deepen our understanding of global climate linkages.



This schematic shows how melting Arctic sea ice can influence the Indian Summer Monsoon. When spring sea ice in the Barents–Kara region decreases, the Arctic warms more quickly and more heat is exchanged between the ocean and atmosphere. This extra warming disrupts the polar vortex and changes the behaviour of large atmospheric waves and jet streams. These altered jet streams then move southward and affect the circulation over Asia. By the time this disturbance reaches India, it leads to increased sinking of air over the Indo-Gangetic Plain, which reduces upward motion and makes it harder for clouds and rainfall to form. Overall, the figure explains how changes in Arctic sea ice can indirectly weaken monsoon rainfall over northern India. Adapted from reference.



Marie Curie statue in Warsaw, Poland

Science Games

Quiz based on the earth and the moon.
Science Quiz

The theme for this issue is women in science.
Themed Crossword

Link each term with the next, and complete the science word chain!
Linked List

Can you guess the names of these scientists?
Who Am I?

Quiz: Earth and Moon

Q1. On February 14, 1990, a spacecraft turned its camera back toward Earth from a distance of about 3.7 billion miles (6 billion kilometers) from the Sun and captured the famous photograph known as the ‘Pale Blue Dot’. The image inspired the title of Carl Sagan’s book ‘Pale Blue Dot: A Vision of the Human Future in Space’, where he reflected on the fragility and unity of life on our planet.

- I. Voyager 1
- II. Voyager 2
- III. Pioneer
- IV. Cassini



Q2. Earth looks perfectly round from space, but due to its rotation and uneven mass distribution, its true shape slightly deviates from a sphere. Using data from ESA’s GOCE mission, scientists created the most detailed map of this ‘true’ shape, which represents Earth’s mean sea level affected by gravity and rotation.

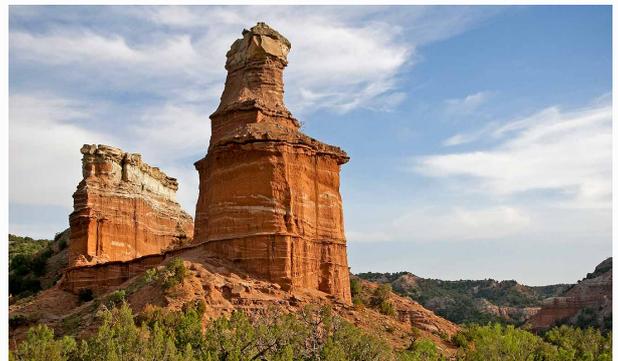
- I. Ellipsoid
- II. Oblate spheroid
- III. Geoid
- IV. Torus

Q3. The Moon is slowly drifting away from Earth at a rate of about 4 cm per year due to tidal forces. The Moon’s gravity pulls on Earth’s oceans, creating a bulge of water that, in turn, exerts a small gravitational pull on the Moon, causing it to move slightly farther away over time. This gradual drift also affects Earth’s rotation over millions of years.

- I. Changes in the Moon’s magnetic field
- II. Tidal interactions between Earth and the Moon
- III. Solar radiation pressure on the Moon’s surface
- IV. Expansion of Earth’s atmosphere

Q4. In Palo Duro Canyon State Park near Amarillo — the second-largest canyon in the United States, often called the ‘Grand Canyon of Texas’ — there stands a famous rock pillar that resembles a lighthouse. Formed over millions of years by erosion from the Prairie Dog Town Fork Red River, it can be reached via the popular Lighthouse Trail. What is the name of this iconic natural rock formation?

- I. Devil’s Tower
- II. The Lighthouse
- III. Chimney Rock
- IV. Cathedral Spire



Q5. Earth’s magnetic north pole isn’t fixed — it has sped up from drifting about 15 km per year to nearly 50–60 km per year, now moving toward Siberia. Data from ESA’s Swarm mission show this shift is caused by changes deep inside the planet.

- I. Solar wind effects on Earth’s magnetosphere
- II. Tectonic plate movements
- III. Changes in molten iron flow within Earth’s outer core
- IV. Shifts in polar atmospheric circulation

Q6. Life on early Earth may not have been green, but possibly purple, according to Shil DasSarma, a microbial geneticist at the University of Maryland. He suggests that ancient microbes used a molecule other than chlorophyll to capture sunlight — one that gave them a violet hue. This molecule, still found in halobacteria today, absorbs green light and reflects red and violet light, giving a purple appearance.

- I. Carotene
- II. Retinal
- III. Xanthophyll
- IV. Melanin

Q7. This region, located in Turkey, is world-famous for its otherworldly landscape of tall, cone-shaped rock formations known as “fairy chimneys,” formed by the erosion of soft volcanic rock over thousands of years. It is also known for its ancient cave dwellings and hot-air balloon rides over its surreal terrain.

- I. Cappadocia
- II. Pamukkale
- III. Santorini
- IV. Petra



Q8. Located in Tanzania, this massive volcanic crater was formed by the collapse of an ancient volcano about two to three million years ago. Now home to a rich diversity of wildlife, it is one of Africa’s most famous natural wonders and a UNESCO World Heritage Site. What is the name of this geological formation?

- I. Ngorongoro Crater
- II. Mount Kilimanjaro
- III. Lake Victoria Basin
- IV. Olduvai Gorge

Q9. This boundary layer between the Earth’s crust and mantle was discovered by seismic studies showing a sudden increase in the velocity of earthquake waves. It marks the transition from lighter silicate rocks above to denser peridotite below. What is this boundary called?

- I. Lithosphere
- II. Moho discontinuity
- III. Asthenosphere
- IV. Core-mantle boundary

Q10. This giant marine sinkhole, visible as a perfect blue circle from above, formed during past ice ages when sea levels were lower. It’s now one of the most famous diving sites in the world. Where is this geological wonder located?

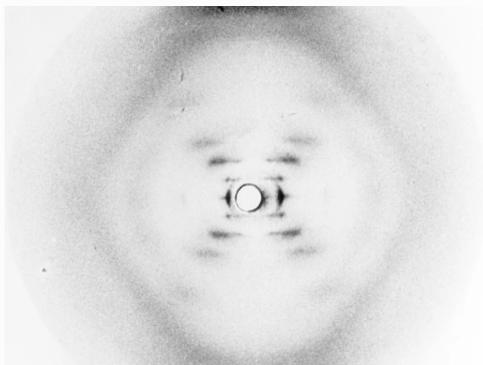
- I. Maldives
- II. Belize
- III. Bahamas
- IV. Australia



Answers can be found at the end of the issue. For an interactive version of the quiz, check out our [website](#)

Who Am I? – Scientists Edition

Guess the names of the scientists from the hints.

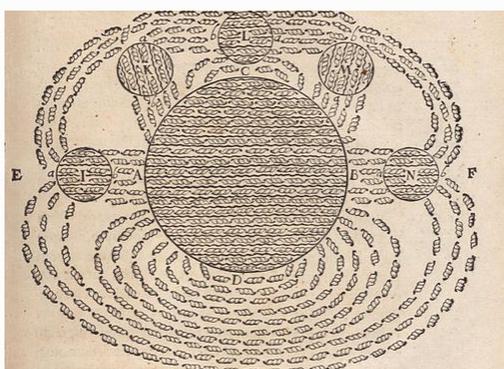


Which crystallographer am I?

- I was a British scientist in the mid-20th century, specializing in techniques that captured the hidden structures of molecules.
- My precise X-ray images provided critical evidence of a spiral form in the molecule that carries life's blueprint.
- Before my work with biological molecules, I studied the porous structure of coal, shedding light on its molecular makeup.

Which alchemist am I?

- I spent much of my career at a renowned English university, diving deep into mathematics and the mysteries of the natural world.
- In 1687, I published a work that mathematically proved the elliptical paths of planets, building on the ideas of an earlier stargazer.
- My curiosity extended to the nature of light, where my experiments with prisms showed how it could be broken into a rainbow of colors, revealing its hidden properties.



Which mathematician am I?

- I was a French thinker in the 17th century, blending mathematics with philosophy to unravel the mysteries of the world.
- A moment of inspiration, sparked by watching a fly move across a ceiling, led me to devise a new way to pinpoint locations using numbers.
- My work laid the foundation for a system that maps points in space with pairs or triplets of values, revolutionizing how we describe position.

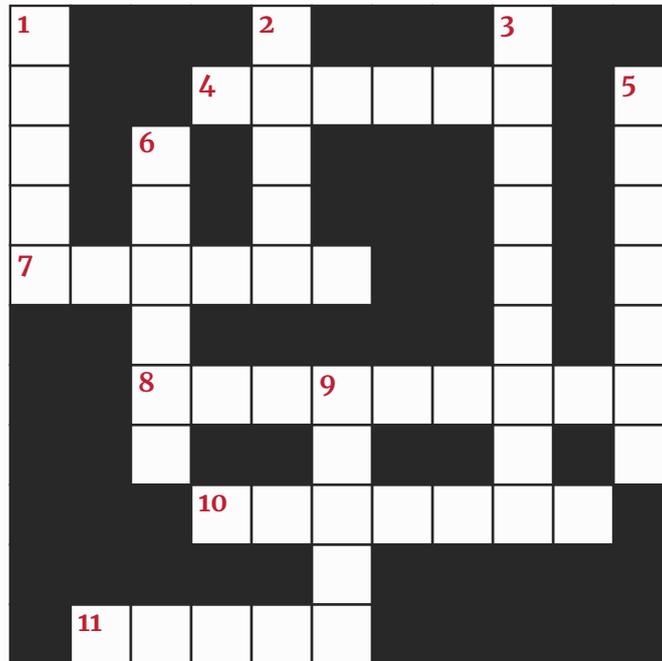
Which chemist am I?

- I was a German chemist in the early 20th century, driven to solve one of agriculture's greatest challenges through industrial innovation.
- By combining nitrogen from the air with hydrogen under extreme conditions, I developed a process that revolutionized food production for billions.
- My early experiments delved into the electrical properties of chemical reactions, but it was my use of a rare metal catalyst that changed the world.



Themed Crossword | Women in Science

This issue’s crossword is based on women who made pathbreaking contributions to science.



Across

- 4. Indian-American astronaut who spent over 300 days in space. (6)
- 7. English fossil hunter whose discoveries helped found paleontology. (6)
- 8. One of the first Indian women doctors; pioneer in medicine and women’s education. (9)
- 10. Austrian-Swedish physicist who co-discovered nuclear fission. (7)
- 11. Pioneering chemist and physicist who discovered polonium and radium. (5)

Down

- 1. Trailblazing Indian woman physicist who studied cosmic rays before independence. (5)
- 2. Astronomer who uncovered evidence for dark matter. (5)
- 3. NASA mathematician whose calculations guided Apollo missions. (9)
- 5. British chemist awarded the Nobel Prize for protein crystallography. (7)
- 6. Indian botanist who contributed to cytogenetics and plant breeding. (6)
- 9. American chemist who developed the first effective treatment for leprosy. (5)

Solution can be found at the end of the issue. For an interactive version of the crossword, check out our [website](#).

Linked List – Women In Science Edition

Linked List is a general science-based word game. The rules are straightforward:

1. The goal is to guess eleven words that have been drawn from science.
2. The first word (the seed) will be provided to you, and hints and number of letters will be provided for the remaining words.
3. You are also informed that the first letter of any word is the last letter of the previous word. So the first letter of the second word will be the last letter of the seed word, the first letter of the third word is the last letter of the second word, and so on.
4. This property goes all the way, so that the last letter of the last (eleventh) word is also the first letter of the seed word.

Find all the words!

Today's seed: **KADAMBINI GANGULY**

1. Rocket propulsion engineer who invented the satellite station-keeping thruster that revolutionized spaceflight stability (12)

Y

2. Physicist who explained the process of nuclear fission, contributing key insight that transformed atomic science (12)

3. Chemist and crystallographer whose X-ray diffraction image revealed the helical structure of DNA (17)

4. ISRO mission engineer who helped drive India's Mars Orbiter Mission through cutting-edge space navigation and systems work (16)

5. Mathematician who advanced applied probability and pioneered early work in the theory of plasticity—her calculations helped shape modern mathematical physics. (15)

6. Nobel-winning neurobiologist who discovered Nerve Growth Factor (NGF), uncovering how neurons grow, survive, and communicate. (20)

7. Indian gynecologist who achieved the country's first test-tube baby and pioneered the Gamete Intrafallopian Transfer (GIFT) technique. (14)

8. Chemist who created the first effective treatment for leprosy—the 'Ball Method' that transformed chaulmoogra oil into an injectable therapy. (10)

9. Professor of computer science at Brandeis University. Accredited with having coined the phrase "promise" when referring to the completion (or failure) of an asynchronous operation for the JavaScript programming language (12)

10. Cognitive scientist who revealed how babies learn through exploration—pioneering the 'theory theory' of child development and early learning. (13)

K

Solution can be found at the end of the issue. For an interactive version of this game, check out our [website](#).

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To showcase cutting-edge research, we publish short summaries (350–400 words) of recently published scientific papers. The summary should broadly outline the research questions and highlight the key findings. Submit your research stories [here](#).

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Alekhya Kundu
Sayan Saha

The Last Page

Crossword

Across

4. SUNITA
7. ANNING
8. KADAMBINI
10. MEITNER
11. CURIE

Down

1. BIBHA
2. RUBIN
3. KATHERINE
5. HODGKIN
6. JANAKI
9. ALICE

Who Am I?

1. Rosalind Franklin
2. Isaac Newton
3. René Descartes
4. Fritz Haber

Linked List

1. YVONNE BRILL
2. LISE MEITNER
3. ROSALIND FRANKLIN
4. NANDINI HARINATH
5. HILDA GEIRINGER
6. RITA LEVI-MONTALCINI
7. INDIRA HINDUJA
8. ALICE BALL
9. LIUBA SHRIRA
10. ALISON GOPNIK

Quiz

1. Voyager 1
2. Geoid
3. Tidal interactions between Earth and the Moon
4. The Lighthouse
5. Changes in molten iron flow within Earth's outer core
6. Retinal
7. Cappadocia
8. Ngorongoro Crater
9. Moho discontinuity
10. Belize

You made it to the end! While we cook up the next issue, here's a random photo dump.

Stride of Unity

A spirited celebration of National Sports Day as students and faculty joined together for the Freedom Run Marathon, embodying unity, health, and enthusiasm across the IISER Kolkata campus. *Credit: IISER Kolkata*



Checkmate Chronicles

Snapshots from the Chess Club Tournament — IISER Kolkata's chess enthusiasts showcasing strategic brilliance, camaraderie, and the thrill of mind games in action. *Credit: IISER Kolkata*

The Science Carnival

An exciting water rocket event from Inquivesta where engineering ingenuity, teamwork and pure excitement meet. *Credit: Inquivesta*

