VIGYAN 2047

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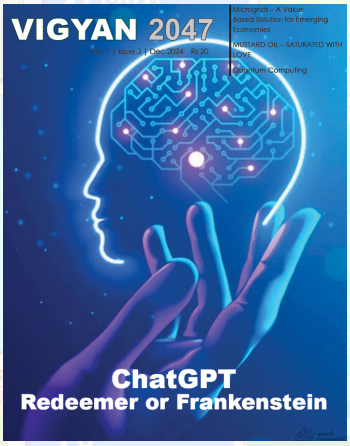
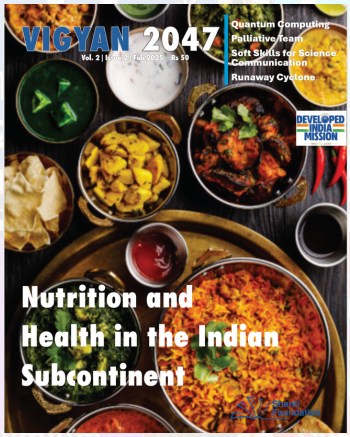
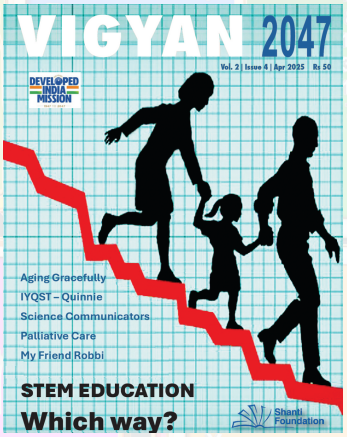
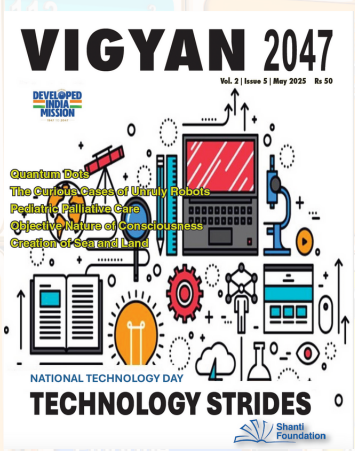
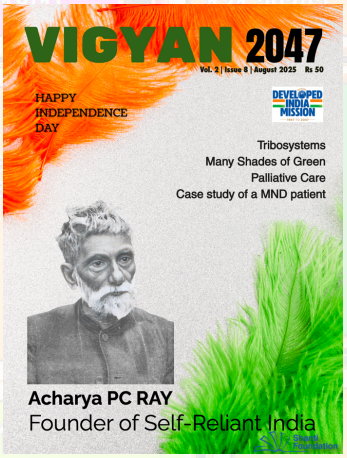
ANNIVERSARY ISSUE











VIGYAN 2047

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Shanti Foundation
(www.shantifoundation.global)
UG-17, Jyoti Shikhar
District Center, Janakpuri
New Delhi 110 058 INDIA
E: nakul@shantifoundation.global
T: +91 11 4036 5723

www.shantifoundation.global

In This Issue

Editorial

SCoPE still has scope

India, Sri Lanka, Maldives, Bhutan, Nepal, and Bangladesh share more than borders: monsoons and mountains, dense populations and youthful demographics, fast-moving economies and fragile ecologies. That common ground demands a common priority—scientific awareness—not as a side project but as public infrastructure. If the region is to convert its demographic surge into a dividend, curb health myths, and adapt to climate shocks, science must become everyday knowledge.

For decades, "science communication" meant fairs, one-off conferences, and souvenir volumes. Worthy, yes; impactful, rarely. In the age of smartphones and short attention spans, **Science Communication, Popularization & its Extension** (**SCoPE**) must evolve. The mission is the same; the medium has changed. Money should move from token events to content pipelines that reach citizens where they are: on WhatsApp, YouTube, Instagram, community radio, and local-language news.

South Asian governments should earmark bigger, ring-fenced budgets for two tracks: first, research and development in priority sectors such as climate resilience, public health, agriculture, clean energy, and AI for public good; and second, communication and uptake—the translation of science into trusted, local-language content and classroom practice. Communication is the last mile of science: it must be funded predictably, evaluated rigorously, and integrated with national education policies.

There are several high-yield, social-media–first moves that can be implemented quickly. Weekly local-language micro-explainers of 60–90 seconds can be created on topics such as food safety, vaccines, drought preparation, cyclone warnings, and AI basics. These should be published in local languages and paired with infographics for easy sharing. Teachers, nurses, agri-extension workers, and young scientists can be trained as community creators, supported with micro-grants and fact-checking, and recognized with badges and leaderboards. A myth-buster series with positive framing can replace scolding with "try this instead" cues, using trusted figures like faith leaders, sports icons, and regional artists. Crisis-ready channels should be prepared with templated alerts for floods, heatwaves, and disease outbreaks, distributed instantly through FM, YouTube Shorts, and IVR calls. Finally, open repositories of scripts, icons, animations, and datasets should be created so schools, NGOs, and newsrooms can freely reuse and adapt.

A long-term strategy requires a **Regional SCoPE Mission** with annual targets for reach, languages covered, and themes prioritized, along with **SCoPE Labs** at universities to co-produce content. Media literacy and inquiry-based science should be embedded in curricula, and teachers offered modular training. Tactically, within the next 90 days, a weekly "Science Minute" can be launched across public broadcasters, a rapid review cell can fact-check viral claims within 24 hours, and pop-up "Science on Wheels" kiosks can bring short explainers to markets and bus stations.

Success must be measured not by volume of content but by reach, retention, and behaviour change—whether vaccination rates improve, whether families adopt heat-safety steps, whether communities act on flood warnings. Dashboards should be published, and programs adapted based on what works.

The subcontinent now welcomes the festive season -- a season of renewal, and with it comes an opportunity to sow the seeds of a scientific temper too. Happy festival greetings to all.

Nakul Parashar, PhD
nakul@shantifoundation.global

Letter to the editor

Dear Editor,

Heartiest congratulations to you and your team for bringing out such an informative and engaging magazine—and for securing an ISSN. That recognition is well deserved and speaks to the publication's quality and credibility.

May I offer one suggestion as an enthusiastic reader? Please consider expanding the magazine with a few additional pages in each issue. In particular, a dedicated page for everyone—students, teachers, and curious readers—featuring crisp fact-boxes on the what, why, when, and how of major scientific discoveries would be invaluable. A consistent "Discovery Desk" (or similar) could present short, verified explainers with references, timelines, and everyday applications. Over time, this section would become a handy archive that people return to for quick, trustworthy science facts.

Thank you for your tireless efforts to promote scientific awareness. I look forward to every new issue and to seeing the magazine grow in depth and reach.

With appreciation and best wishes,

Abhinandan Jha

Nagpur

Shanti Sandesh is the Quarterly Report of Shanti Foundation

Shanti Sandesh

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WORK DONE THIS QUARTER (JULY-AUGUST-SEPTEMBER)

Education

- Government School Adoption through Vidyanjali Completed
- Government Sarvodaya Kanya Vidyalaya (GSKV), Janakpuri, New Delhi, adopted
- Three-Month Faculty Development Program at GSKV, Janakpuri, New Delhi completed
- 20 Wall-mounted Educational Posters at GSKV, Janakpuri, New Delhi installed
- Two Water RO Systems at GSKV, Janakpuri, New Delhi installed
- Five Shanti Devi Scholarships at RKMVCC, Rahara, WB commenced
- Five Lab Equipment at SKC, Sivakasi, Tamil Nadu delivered
- Twelve Laptops for Students at RKMVCC, Rahara, WB delivered
- STEM Education: Three issues of Vigyan 2047 published and circulated on time
- STEM Education: Three issues of Bangla Bigyan Katha published and circulated on time
- Vocational Training of a deaf & mute person in New Delhi
- Midday Meal for School Students in NCR through Annamrita

Healthcare

- Medicine distribution camp at Mayawati, UK conducted
- MoU with OVIHAMS signed to propagate about Motor Neuron Disease (MND) & support patients
- Published three articles on MND in Vigyan 2047 as a part of MND

PROJECTS-IN-PROGRESS (OCTOBER-NOVEMBER-DECEMBER)

Education

- STEM Education: International Year of Quantum Science & Technology Events
- STEM Education: Publishing monthly popular science magazines in English & Bengali
- STEM Education: Akhil Bhartiya Bangla Bigyanik Sammelani at RKMVCC, Rahara, WB
- Lab Upgradation of RKMVCC, Rahara, WB
- Heavy Duty RO Systems for RKMVCC, Rahara, WB and GSKV, New Delhi
- Shanti Devi Scholarships at RKMVCC, Rahara, WB and SKC, Sivakasi, TN
- Faculty Development Programs for Border Area Colleges in North 24-Parganas, WB with RKMVCC, Rahara, WB
- Twenty Laptops for Students at RMT, Vishakhapatnam, AP
- Adoption of Schools for Destitutes in Jalgaon, Maharashtra

Healthcare

- Medicine distribution camp at Mayawati, UK
- MND Awareness & Patient Support Programs with OVIHAMS, New Delhi
- Palliative Care Awareness Programs with RMT, Vishakhapatnam, AP

FCRA: 231661925
U/S 12AA: DEL SR26851-0602218
U/S 80G: DEL SE28327-0602218/9634
MoCA/GoI (CSR Registration): CSR000129571
PAN: AAOTS1073R
DARPAN: DL/2018/0193571

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IFSC: AUBL0002635
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In The News

Quantum Internet brought to commercial fiber

Researchers at the University of Pennsylvania have successfully demonstrated the first quantum communication over a live commercial fiber network using a specialized chip called the Q-Chip. This chip can transmit quantum signals while correcting for noise, and routes quantum and classical data together using standard internet protocols. Installed on Verizon's commercial fiber, the system showed high fidelity (over 97%) across a one-kilometer link between two buildings. Quantum particles are fragile—measuring them destroys their state—so traditional network routing can't be used. To solve this, the Q-Chip sends a classical signal just ahead of the quantum signal. This allows routing and error correction without disturbing the quantum data. Like a train engine guiding sealed cargo, the classical signal guides the quantum payload. The chip is silicon-based and mass-producible, enabling future scalability. Unlike lab environments, real-world fiber faces weather, vibrations, and temperature shifts. By observing changes in the classical signal, the chip infers necessary corrections for the quantum data. Though long-distance scaling still requires new technology, this demonstration shows that a quantum internet can work with today's infrastructure—paving the way for secure communication and future quantum computing networks. ◆

"Gold Quantum Needles" for sharper bio-imaging

Researchers at the University of Tokyo—Shinjiro Takano, Yuya Hamasaki, and Tatsuya Tsukuda—have directly imaged how gold nanoclusters form at the earliest stages of growth. Using unique synthesis conditions and single-crystal X-ray diffraction, they captured structural snapshots of nanoclusters just as they were forming—something rarely achieved. Under these conditions, they discovered a new, unexpected structure: elongated nanoclusters shaped like tiny pencils, composed of triangular and tetrahedral gold atom units. The team named them "gold quantum needles" because electrons within them show quantized behavior—a quantum effect where electrons occupy only specific energy states. These gold quantum needles also interact strongly with near-infrared light, making them promising for sharper biomedical imaging and efficient light-energy conversion. Gold, while often associated with luxury, is a key nanomaterial due to its unusual and tunable properties at very small scales. However, precise control over nanocluster formation has remained a major challenge. "Our goal was to open the black box of how these clusters form," said Tsukuda. The team now aims to refine their synthesis techniques and collaborate on applying these structures in cutting-edge technologies.The findings were published in the Journal of the *American Chemical Society*. ◆

Hidden Climate Driver Heating Antarctica

A new 30-year study has found that East Antarctica's interior is warming faster than its coasts, driven by shifting ocean conditions that transport warm air deep into the continent. Led by Naoyuki Kurita of Nagoya University and published in *Nature Communications*, the research links this rapid warming to changes in the Southern Indian Ocean, where intensified ocean fronts influence atmospheric circulation. Previously considered a climate "blind spot," East Antarctica holds about 70% of the world's freshwater in its ice sheets. Most temperature data came from coastal research stations, leaving the interior poorly monitored. To address this, scientists analyzed records from three unmanned weather stations—Dome Fuji, Relay, and Mizuho—active since the 1990s. These stations showed warming rates of 0.45–0.72°C per decade, faster than the global average. The cause is a new atmospheric "dipole" pattern: low pressure in mid-latitudes and high pressure over Antarctica. This high-pressure zone pulls warm air southward. While coastal stations haven't shown significant warming yet, that could soon change. This discovery suggests that current climate models may underestimate future Antarctic ice loss, with major implications for global sea level rise. ◆

Holograms to Your Phone

Researchers at the University of St Andrews have developed a breakthrough optoelectronic device that could transform holographic technology in areas such as smart devices, gaming, communication, and augmented reality. Published in Light: Science and Applications, the study combines Organic Light-Emitting Diodes (OLEDs) with Holographic Metasurfaces (HMs) to create compact, cost-effective holograms—without the need for bulky lasers. OLEDs, widely used in phone and TV displays, emit light across flat surfaces and integrate easily into small-scale systems. HMs are ultra-thin layers made of nanoscale structures called meta-atoms, engineered to precisely manipulate light. Together, the OLED-HM system can produce detailed holographic images through light interference. The team's key achievement is projecting a full holographic image from a single OLED pixel, a major simplification over traditional displays requiring thousands of pixels. This innovation enables miniaturized, high-resolution holographic systems. "Holographic metasurfaces are among the most versatile tools to control light," said Professor Andrea Di Falco. The research opens the door to next-generation holographic displays, with potential impacts across virtual reality, biophotonics, and optical communication. ◆

VIGYAN 2047 Volume 2 No. 10 October 2025 Pages 8–13

OUR FIRST YEAR OUR SECOND YEAR...

Science is not only about laboratories, equations, and research papers. It is about people–their ability to ask questions, to seek answers, to innovate, and to live informed, empowered lives. Yet, science cannot fulfil its true purpose unless it reaches the very heart of society. In India, with its vast cultural and linguistic diversity, this means science must speak in the many tongues of our people.

Sadly, in recent years, the closure of nearly twenty popular science magazines in Indian languages left a gaping void. For years, these magazines had been the primary bridge between scientists and society, between research and relevance. Their absence was felt most deeply in the very places where science communication was needed the most–schools, small towns, villages, and among communities where English is not the first language of thought.

It was in this moment of silence that we resolved to act. Science communication could not be allowed to fade into obscurity. The voice of science had to be revived, reimagined, and reinforced. This was not just a project for us–it became a mission.

Thus began our journey to strengthen SCoPE (Science Communication Popularization & its Extension).

Why Indian Languages Matter in Science Communication

India's strength lies in its linguistic plurality. From the rhythm of Bengali poetry to the philosophical depth of Tamil, from the elegance of Hindi to the vast spectrum of India's regional tongues–each language carries with it centuries of thought, emotion, and imagination.

For science communication, this means:

Accessibility: Knowledge in one's mother tongue reaches further, is understood more deeply, and remains more memorable.

Cultural Connection: Concepts of science become relatable when explained through local metaphors, idioms, and narratives.

Democratic Knowledge: English-language science magazines often serve an elite audience. But when science is shared in Indian languages, it democratizes access and empowers every section of society.

We believe that science is not complete unless it is shared widely, inclusively, and in the language of the people.

Our First Steps: Filling the Void

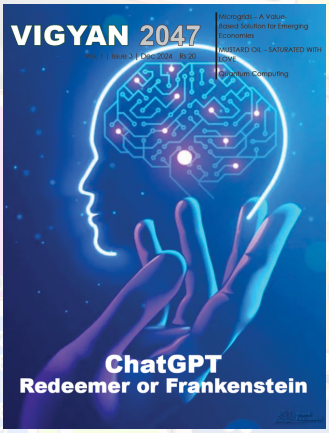
When the space was left empty by the closure of earlier science magazines, we knew the revival had to begin somewhere–and begin soon. With determination, we launched three flagship initiatives:

Bangla Bigyan Katha (Bengali)

From its very first issue, Bangla Bigyan Katha captured the imagination of readers. Written in simple, elegant Bengali, it offered not just science news but stories, insights, and explanations that brought complex subjects closer to the common reader. Today, with pride, we celebrate the fact that Bangla Bigyan Katha has crossed its 24th issue, marking two years of consistent publishing.


VIGYAN 2047
International Year of Quantum Science & Technology
Palliative Care
Sixth International Conference on Sustainability Education
RKMVCC
50 YEARS & COUNTING
Inaugural Issue


VIGYAN 2047
The Exciting world of Quantum Science
Data Science
Autism Spectrum Disorder
Nobel 2024
AI enabled this time


VIGYAN 2047
Microgrids – A Value-based Solution for Emerging Economies
MUSTARD OIL – SATURATED WITH LOVE
Quantum Computing
ChatGPT
Redeemer or Frankenstein


VIGYAN 2047
Quantum Electronics
Palliative Care
Vivekananda & Science
DEVELOPED INDIA MISSION
University
Global
Rankings


VIGYAN 2047
Quantum Computing
Palliative Team
Soft Skills for Science Communicators
Runaway Cyclone
DEVELOPED INDIA MISSION
Nutrition and
Health in the Indian
Subcontinent


VIGYAN 2047
DEVELOPED INDIA MISSION
Satyajit Ray's SciFi
Dark Matter
QUANTUM
INTERNET
Futuristic Communication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DEVELOPED INDIA MISSION
Aging Gracefully
IYQST – Quinnie
Science Communicators
Palliative Care
My Friend Robbi
STEM EDUCATION
Which way?
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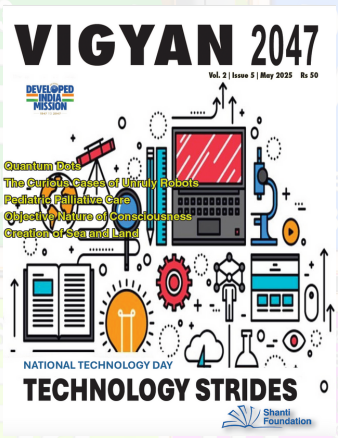
VIGYAN 2047
DEVELOPED INDIA MISSION
Quantum Dots
The Curious Cases of Unruly Robots
Pediatric Palliative Care
Objective Nature of Consciousness
Creation of Sea and Land
NATIONAL TECHNOLOGY DAY
TECHNOLOGY STRIDES
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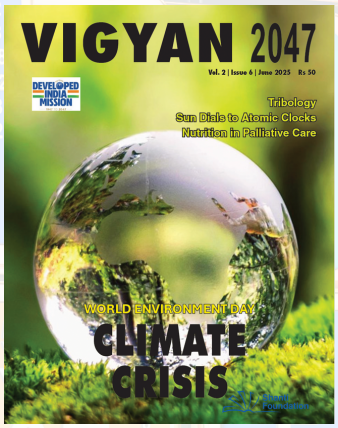
VIGYAN 2047
DEVELOPED INDIA MISSION
Tribology
Sun Dials to Atomic Clocks
Nutrition in Palliative Care
WORLD ENVIRONMENT DAY
CLIMATE
CRISIS


VIGYAN 2047
DEVELOPED INDIA MISSION
The Evolution of Tribology
Weaving Science Into Your Wardrobe
Hospice Project in Palliative Care
BIOTECHNOLOGY
A Window into Life's Toolkit
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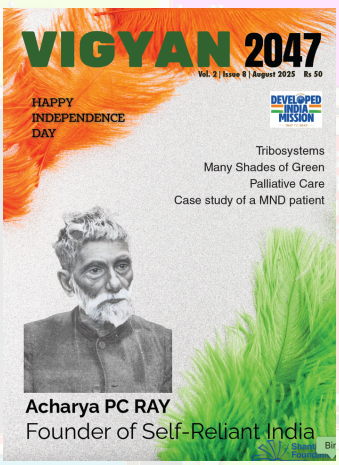
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HAPPY
INDEPENDENCE
DAY
Tribosystems
Many Shades of Green
Palliative Care
Case study of a MND patient
Acharya PC RAY
Founder of Self-Reliant India


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DEVELOPED INDIA MISSION
Quantum chemistry
Journey beyond borders
Tribology of prime movers
MND: When nerves fail
Per-Olov Löwdin
Father of Quantum Chemistry

New AI tools

Design tools
Autodraw · Flair AI · Booth AI · Stockimg AI · Clipdrop

Content Creation
Writesonic · Beautiful AI · Steve AI · Tome · Murf AI

Writing
Copy AI · Jasper AI · Quillbot · AISEO · Rytr

Coding
DeepCode · 10web · Akkio · Replit · Durable AI

Research
Consensus · Trinka · Paperpal · Writesonic · Scholarcy

Marketing
Simplified · Mutiny · ContentEdge · PepperType · Copy Smith

Copywriting
Adcreative · Bertha AI · Simplified · ArticleForge · Writesonic

Sales
Twain · Regie · Lavender · Warmer · Octane

Chatbots
YatterPlus · Quickchat · Typewise · Cohere · Kaizan

Twitter tools
TweetHunter · Tweetmonk · Postwise · Tribescaler · Tweetlify

Music
Jukedeck · Boomy · Amper · Brain FM · Melodrive

Vigyan 2047 (English)

Conceived as a forward-looking magazine, Vigyan 2047 was launched with the vision of connecting science with India's centenary of independence. It seeks to capture the aspirations of a nation preparing for its scientific future, while also learning from its past. As it now completes its first year of publication, we dedicate this anniversary issue to our authors, readers, and the entire community of supporters who believed in this mission.

Ariviyal Palagai (Tamil)

Recognizing the importance of sustaining existing efforts, we extended our support to ensure that Ariviyal Palagai–a Tamil science magazine–continued uninterrupted. Tamil, one of the world's oldest languages, deserves a vibrant platform for modern scientific ideas, and Ariviyal Palagai keeps that tradition alive. Kudos to Srikumarjee & his able team, duly guided by Dr TV Venkateswaran, science communicator par excellence.

The Road Filled with Challenges

Our journey was not smooth. Each step was marked by obstacles that tested our resilience:

Financial Sustainability: Science magazines are not commercial ventures; they survive on passion, not profit. Sustaining them requires balancing costs with innovative models of support.

Finding Authors: Writing science in regional languages is not easy. Translating complex terms, coining accurate equivalents, and preserving scientific rigour while remaining reader-friendly requires skill. Yet, we were fortunate to find authors who stood by us.

Digital Competition: In an age where information floods social media, a print or digital magazine must offer depth, credibility, and continuity–not just momentary distraction.

Institutional Recognition: Without formal identifiers such as ISSNs, publications remain vulnerable. Securing ISSN registrations for our magazines gave us the strength of legitimacy, visibility, and permanence.

Despite these hurdles, we persevered. Each issue we published was more than a magazine–it was a statement of commitment.

A Community Effort

We cannot speak of this journey without expressing our heartfelt gratitude.

To our authors, who braved the challenges of writing and translating, who took time out of their busy schedules to contribute knowledge and creativity.

To our readers, who not only embraced the magazines but also encouraged us with feedback, letters, and suggestions. Your enthusiasm is our fuel.

To our editors, reviewers, and designers, whose names may not appear in print but whose tireless work shines in every page.

To our institutions, partners, and friends, who extended both moral and logistical support.

The list of contributors grows with each passing month. It is not merely "our" journey anymore–it is a collective movement.

ISSN: A Seal of Strength

One of the proud milestones in this journey has been the ISSN registration for our magazines. For readers, this means recognition. For authors, it means credibility. For us, it means responsibility. With this step, our efforts are not only preserved but also indexed for the future.

Looking Forward: Expanding SCoPE

Our mission is not limited to a few magazines. We envision an ecosystem of science communication that thrives across multiple platforms:

Print: To retain the joy of reading, to reach classrooms, libraries, and homes.

Electronic Media: Leveraging radio and television to bring science stories to those without internet access.

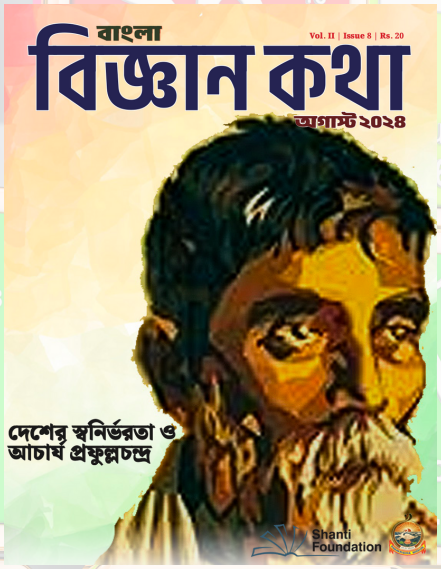
Digital & Social Media: Using the power of smartphones and platforms to engage young audiences, while ensuring content remains credible.

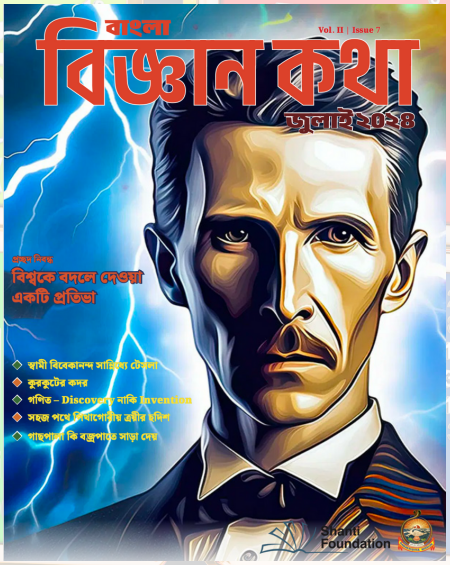
Workshops & Outreach:
Taking science communication to schools, universities, and communities through live engagement. We see a future where every Indian language has its own thriving science magazine, supported by networks of writers, editors, teachers, and students.

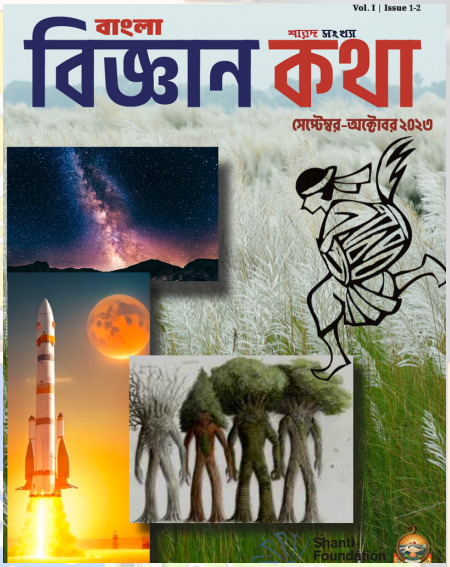
A Festival of Science and Society
As we bring out this anniversary issue of Vigyan 2047 and celebrate 24 issues of Bangla Bigyan Katha, the timing could not be more fitting. With Dussehra and Diwali around the corner, these magazines too are symbols of light–dispelling darkness with the flame of knowledge.
Our festivals remind us of the eternal victory of truth over falsehood, light over ignorance. Science too is part of that same tradition: it is our modern-day flame of wisdom.

A Call to Action
We have come far, but the journey ahead is even longer. To expand SCoPE, we invite:
Young writers to join us and experiment with writing science in their mother tongues.
Teachers and educators to use these magazines as teaching aids. Readers to continue supporting us by sharing feedback and spreading the word. Institutions and corporates to step forward and partner with us in this noble cause.

Conclusion
What began as a small response to the silence left behind by the closure of twenty science magazines has now become a vibrant movement. With Bangla Bigyan Katha, Vigyan 2047, and Ariviyal Palagai, we have only taken the first steps.
The journey is filled with challenges, but also with immense excitement. There is much more to learn, much more to share, and much more to build. With the blessings of our authors, the love of our readers, and the strength of our collective vision, we remain steadfast in our mission to bring science closer to society, in every Indian language possible.







Team SCoPE at Shanti Foundation Global: Gopal-Satish-Amitesh-Nakul

VIGYAN 2047 Volume 2 No. 10 October 2025 Pages 14–17

Tribology of Prime Mover: Electric Motors

Kamal Mukherjee

The word 'motor' refers to any power unit that generates motion, that is a 'prime mover', while while "electric motor" refers to a "prime mover using electricity." Thus, the electric motor is a unit used to convert electric power or electrical energy into mechanical energy. Fig.-1. This conversion is usually obtained through the generation of a magnetic field by means of a current flowing into one or more coils. The rotation is obtained by the attractive force between two magnetic fields.

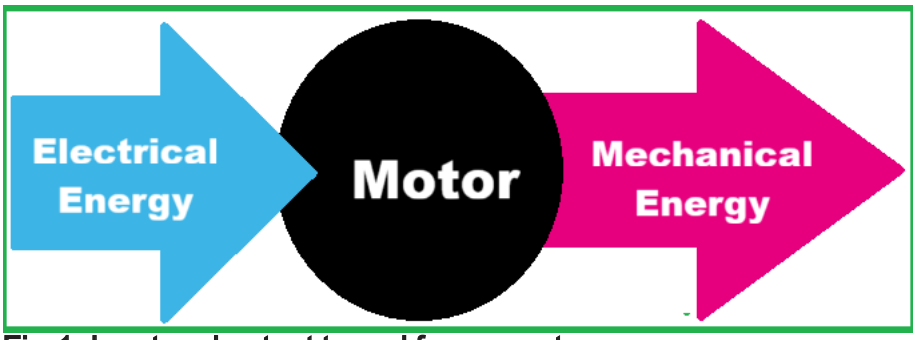


Fig-1: Input and output to and from a motor

The electric motors are very popularly used as a prime mover for driving the water pump in the house, operating the mixy in the kitchen, to run the blower to dry the hair, to dig a hole in dental teeth/ skull, to drive the electric locomotive, for driving the large stationary machines e.g. winches, hoists, power gen set, etc. But of late with the introduction of electric passenger vehicles, the electric motors have created full-fledged interest, R&D, funding, study etc. at a fast pace all over the world.

Electric Motors in an Automotive Application

The drawbacks of the internal combustion engine (ICE) are relatively low thermal & low mechanical efficiencies, fuel energy being dissipated as heat, the engine exhaust contributes to particulate, nitrous oxide and hydrocarbon emissions and to the greenhouse effect via carbon dioxide emissions and the maintenance of IC engines is far more due to comparatively large number of its parts. These drawbacks have enormous influences on national and international economies. The advantage of an electric motor compared to an IC engine is that there is no soot involved in the operation thus leading to improved environmental care.

If the energy content of fuel in a car is 100% for ICEV (internal combustion engine vehicles) then only 21.5% is used to drive a petrol car according to Holmberg et al (2019). Battery electric vehicles (BEV) differ from ICEV that the combustion engine is replaced by an electric motor & electricity storing,

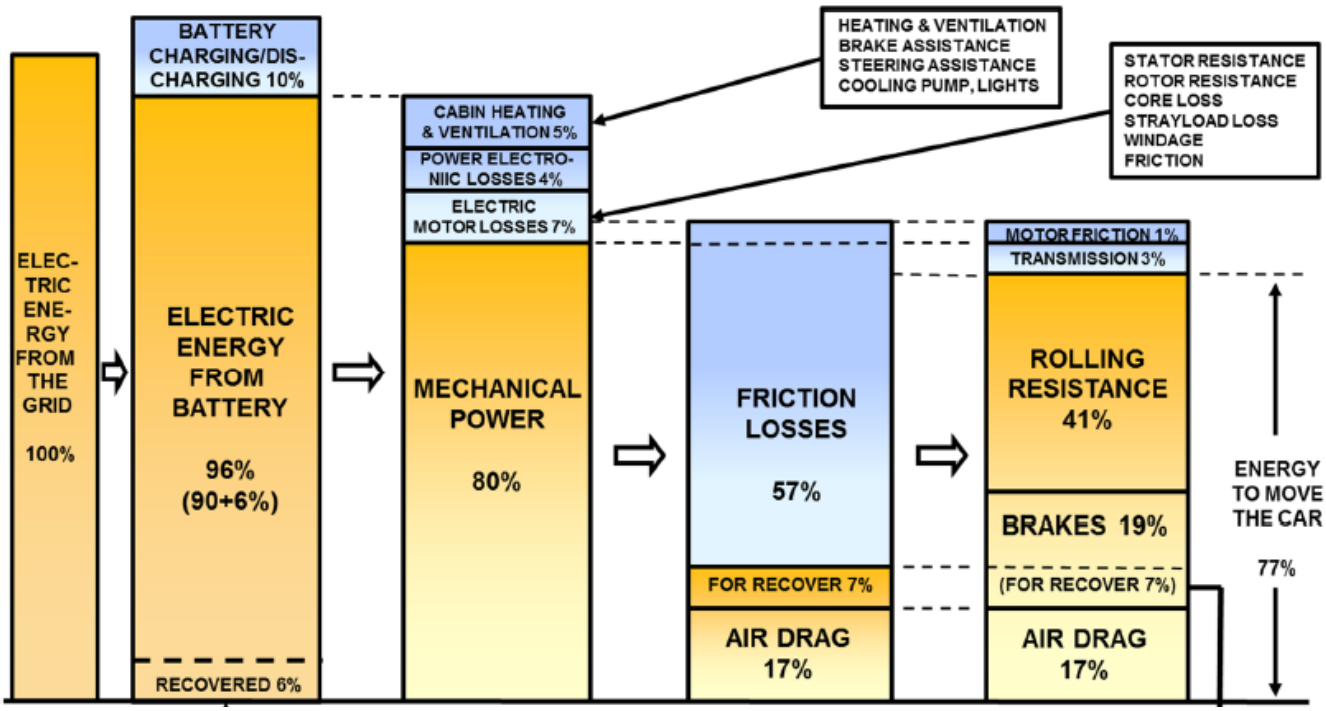


Fig-2:Distribution of energy in a typical battery driven passenger EV

charging, and control systems are added. With the same note if the total grid electric energy supplied by the battery is 100% in an EV (passenger vehicles powered by battery) then ~77% is used to drive it (Fig-2). That means the EVs are about 3.6 times more efficient than ICEVs on the basis of input energy. Moreover, the CO_2 emissions are 4.5 times higher for a combustion engine car compared to an electric car when the electricity comes from renewable energy sources.

The use of electric motors for power generation depends on the configuration in modern EVs. These include in-wheel motor (IWM) in multiple phase power systems and coreless machine (CM) in stator topology type. Similarly, in the rotor topology type synchronous brushed motor (SBM), reluctance motor (RM), synchronous permanent-magnet motor (SPM), induction motor (IM) and direct current motor (DCM) etc. The SPM provides the highest efficiency whereas DCM are the least efficient. SPM have become central to Electric Vehicle (EV) designs due to their high power-density and torque capabilities. SPMs employ an electrically excited stator and a rotor with embedded permanent magnets to create torque. PM brushless motors are the most used motors in the automotive industry.

New AC Drive Systems

AC drives offer many advantages over traditional DC drives. Unlike DC drives, they have no brushes or commutators that require maintenance and wear out. The Insulated Gate Bipolar Transistor (IGBT) inverter technology converts the alternator power first to DC and then to variable frequency AC as used in traction motor of railway, wheel motors of large capacity dump trucks in mining etc.

Electric Motors in an Industrial Application

Induction motor

The working of an electric motor is based on the fact that a current-carrying conductor produces a magnetic field around it. The magnetic field of the magnets interferes with that produced due to electric current flowing in the conductor. Since the loop has become a magnet, one side of it will be attracted to the north pole of the magnet and the other to the south pole. This causes the

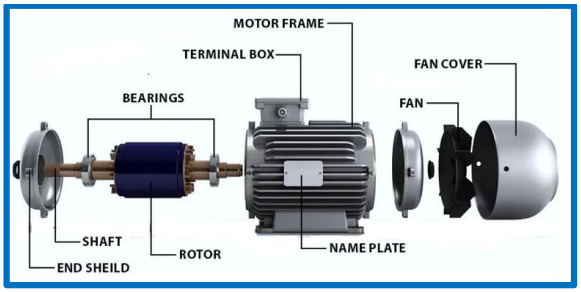


Fig-3: Schematic diagram of an AC motor

loop to rotate continuously. This is the principle of working of electric motor. Because an AC induction motor increases the flux enclosed by its stationary coils, it is a transformer with a rotating secondary (rotor). The rotor current's effect on the air gap flux causes torque. AC motors are roughly classified into commutator motors, synchronous motors, and induction motors. The rotor is housed inside the stator. The rotor is supported by the bearings at either both or one end and is covered by the side cover. A cooling fan is fitted to cool the insidious temperature as shown in Fig-3.

Servomotors

AC induction motors designed for servo operation are wound with two phases at right angles. For example, AC servomotors are used in applications requiring rapid and accurate response characteristics—so these induction motors have a small diameter for low inertia and fast starts, stops, and reversals. High resistance provides nearly linear speed-torque characteristics for accurate control. Wound-field DC motors (with copper segments in the rotor connected by magnetic-wire windings, and stator windings) are another option (Fig-4). More often, however, compact brush DC


Fig-4: A small Servo motor

motors are used as servomotors, because speed control is easy. The only variable is voltage applied to the rotating armature. Servo-built brushed DC motors also include more wire wound onto the laminations, to boost torque.

Role of Tribology for the Electrical Motors

Tribology is the multi-disciplinary subject that deals with wear and friction of the surfaces in motion. Electrical motors contain tribological components like sliding contacts (brushes), rolling contacts (ball/roller/bush bearings), damping rings, seals, washers etc. The advantage of these tribological components are they tend to fail before other components of the motor mainly because of friction and wear. So, it is the good indicator of the motor's health/performance. Thus, the tribo-diagnosis of the various tribo-components of motors determines the reliability, performance & life of the motor/generator. Some of the tribo-components are as follows:

Electrical Brushes

High-speed miniaturized motors rely on brushed and brushless technology. Typical DC motors with continuous running operation with less load and low starting current use precision metal brushes. For high torque applications, carbon brushes are preferred. Electric motor brushes are electrically conductive and work under wear conditions due to direct contact with the moving part (rotor) under the spring force in electric motors. These are used to transmit the electricity i.e. the polarity of the current flow under a constant spring pressure. It causes the faster wear of brushes so it is to be refilled frequently at a short time. This lead to improvise brushes with high conductivity. Thus, the brushes are now made with mechanical alloying (MA) by powder metallurgy. The parent materials as copper and silver are used for the electrical conductivity of the metal-matrix, graphite/graphene (C) are used as reinforcing materials, hexagonal boron nitride (hBN), molybdenum disulfide (MoS_2), and titanium diboride (TiB_2) are used to increase wear resistance and lubrication properties.

Bearings

Generally, three types of bearings are prevalent in a motor or generator. In small to medium application the ball bearings (balls have the 'point contact'—concentrated load capacity) and roller bearings (rollers have the 'line contact'-fairly more load capacity) are used. Whereas bush bearings (bush have the 'arc contact' for taking the high load capacity) are used in heavy duty applications.

Ball/Roller Bearings: The deep groove ball bearing with a focus on energy efficiency are being designed with ~30% reduction in friction losses in comparison to standard bearings. To further improve the bearing life, different advanced coating systems are used along with newly designed fluids & reducing the coefficient of friction. The coated roller bearings have resulted decrease of seven-folds in wear and improvement of ten-folds in bearing life in terms of fatigue. In coating development for reducing wear and friction, diamond-like carbon (DLC) and physical vapour deposition (PVD) coatings are quite prevalent besides some SiC ceramic matrix, etc.

A typical use in EV where the bearings wear often is the result of electric erosion and not a mechanical wear Fig.-5. The optical microscope images show the periodic wear patterns are formed by numerous microscale electrical pits.

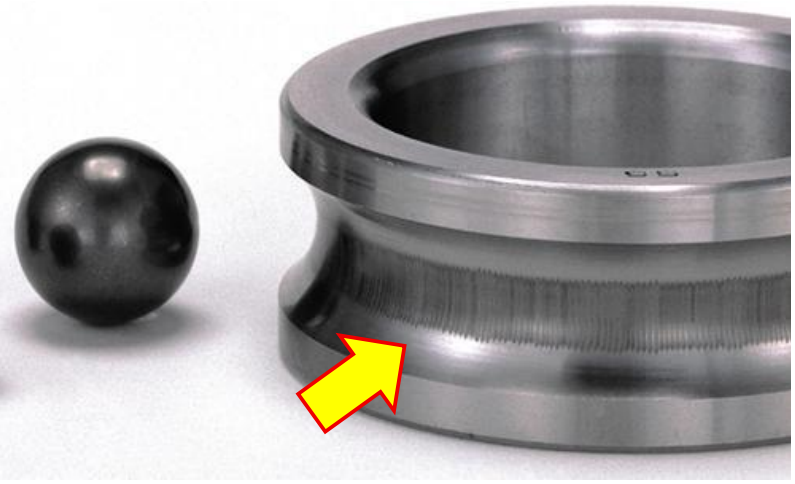


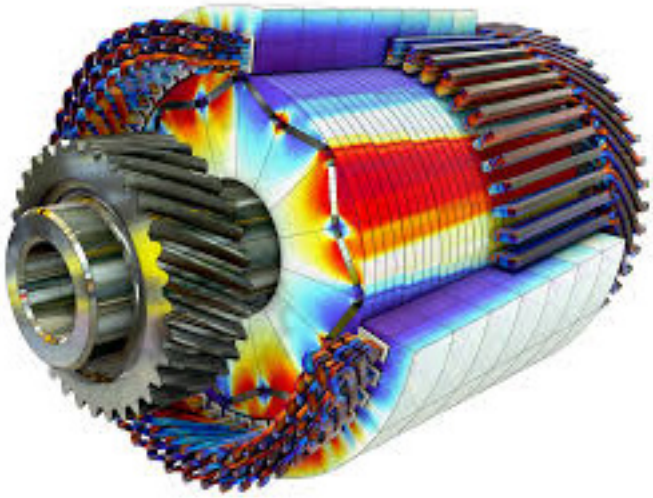
Fig.-5. Photograph of bearing inner race electrical wear

Bush Bearings: Less lubrication-based non-metallic bush bearings are the preferred choice for low speed, low load type and less service life applications. At higher speeds as well as at higher loads, the bush bearing encounters failures like wear, breakage, cold welding, etc. Sintered bush bearing is widely used option due to its low cost and suitability of wide working environment. For cost sensitive application with less service life expectancy, self-lubricated polymer-based bush bearing is the preferred option.

Lubrication

The challenges of EVs are distinct from those of electrical motors applied in traditional industrial operations. Electrically induced bearing damage (wear caused by electric discharge), and other factors are of greater concern in EVs. Electric motors are much quieter than those of ICE vehicles, drivers and passengers are more aware of any sounds and vibrations coming from the EV. Traditional Elastohydrodynamic lubrication (EHL) calculations and the electrical discharge model in bearings are completely separated phenomena. In real life the electrical discharge causes a temporary lubricant film failure, the result is brief metal-to-metal contacts that damage the bearing's raceways as well as negatively affecting the local material fatigue properties of the surface. ◆

***Kamal Mukherjee**, a prolific science writer and nutritionist, is an active member of the Tribological Society of India and has held executive leadership roles in major national organizations. He can be contacted at kamalcbm28@gmail.com.*



VIGYAN 2047 Volume 2 No. 10 October 2025 Pages 18–21

Stitches That Hold the World Together
The Science Behind Seams

Amit Vikram Singh

When you slip into your favorite shirt or zip up that weatherproof jacket before stepping outside, you probably don't think twice about the lines of thread running along the shoulders, sides, or sleeves. These subtle stitches, known as *seams,* are so ordinary and overlooked that we rarely pause to admire the critical role they play in our clothing. But behind each one lies a story of material science, physics, engineering precision, and human ingenuity.

Seams are not merely a functional necessity—they are the very backbone of our garments. They are responsible for holding fabric panels together, withstanding the movements and pressures of daily life, maintaining shape, and contributing to the overall aesthetic. In short, they are the silent architects of durability, comfort, and style.

At first glance, a seam might seem like a straightforward line of stitching. But there is a world of science that determines how that line behaves when tugged, stretched, compressed, or twisted. Whether you're running a marathon in breathable sportswear, working in a lab coat, or dancing in a silk gown, the performance of your clothes largely depends on the quality of the seams.

The strength of a seam starts with understanding the fabric it is joining. Fabrics can be woven or knitted, thick or thin, natural or synthetic, and each has its own behavior under stress. Woven fabrics like denim don't stretch easily and require strong, secure seams that resist breaking. Knitted fabrics like jersey, on the other hand, stretch with movement and need seams that can flex and rebound without damage. The thickness of a fabric affects how easily it can be penetrated by a needle, while its fiber composition influences everything from heat resistance to elasticity.

Once the fabric properties are understood, the next decision involves choosing the appropriate stitch type. Just like nuts and bolts in construction, stitch types determine how fabrics are bound together. The most common is the *lockstitch,* found in most everyday clothing, known for its tidy appearance and durability. However, it lacks stretch and may not be ideal for activewear. *Chainstitch* offers more flexibility, forming looped patterns that are great for garments requiring give. *Overlock* or *serger* stitches

are often used at fabric edges, helping prevent fraying while adding a clean, professional finish. Each type of stitch has its strengths and is chosen based on the needs of the garment.

Beyond the stitch type is the matter of how the fabric is joined—this brings us to seam types. There's the *plain seam,* a basic overlap found in most shirts and dresses. The *flat-felled seam,* famously used in denim jeans, is ultra-strong and lies flat to reduce bulk. *Bound seams* are common in unlined garments and use fabric strips to encase raw edges, offering a decorative and durable solution. *Lapped seams* are favored for heavy fabrics and waterproof garments, where layered construction adds strength and sometimes weather resistance. Each seam type is carefully selected based on the function of the garment and the fabric's characteristics.

One of the most overlooked aspects of seam quality is stitch density—how many stitches are made per inch. A higher density often improves seam strength, but too many stitches can actually damage delicate fabrics and cause puckering. Think of it like stapling a stack of paper: do it too often in the same area, and the paper weakens. A well-made garment finds the right balance, ensuring strength without compromising the fabric's integrity or the garment's flexibility.

Equally crucial is *thread tension.* If the tension is too tight, the seam may pucker or snap under pressure. Too loose, and it may unravel. The tension has to be just right—and that depends on the fabric type, the thread used, and even the sewing machine's settings. It's a subtle art that requires technical understanding and careful calibration.

Thread choice also makes a big difference. Cotton threads are soft and ideal for natural fabrics, but they lack the durability of polyester or nylon. For high-performance or outdoor clothing, stronger synthetic threads are used that resist water, abrasion, and UV light. In safety-critical garments like firefighter suits or military uniforms, threads made from advanced fibers like Kevlar or aramid are used, offering exceptional strength and heat resistance.

What's more, seam performance is not just about materials. It also depends heavily on the *conditions of sewing*—the needle size, the speed of stitching, the alignment of fabric layers, and, importantly, the skill of the operator. A master tailor or trained machine operator knows how to adapt to different materials, make micro-adjustments, and ensure consistent quality. Even with automated sewing machines in factories, human oversight is essential to spot irregularities and ensure every stitch is in place.

Seams at a Glance: The Science Holding Your Clothes Together

Factor	What It Means	Why It Matters
Fabric Type	Woven (non-stretch) vs. Knit (stretchable)	Determines the seam's need for strength or elasticity
Stitch Type	Lockstitch, Chainstitch, Overlock	Affects seam strength, flexibility, and appear-ance
Seam Type	Plain, Flat-Felled, Lapped, Bound	Each type suits different fabrics and purposes (e.g., jeans, dresses, hazmat suits)
Stitch Density (SPI)	Stitches Per Inch (SPI): more = stronger	Too few = weak seam; too many = puckering
Thread Type	Cotton, Polyester, Nylon, Kevlar	Impacts seam durability, elasticity, and resistance to elements
Thread Ten-sion	Balanced tension while sewing	Prevents seams from snapping or loosening
Sewing Skill & Tools	Needle size, machine settings, human precision	Directly impacts the quality, look, and longevity of the seam

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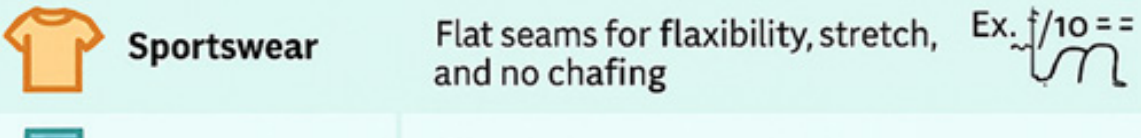
Seam Science in Everyday Life

Sportswear	Flat seams for flaxibility, stretch, and no chafing
Jeans	Strong flat-felled seams for durability
Hazmat Suits	Sealed/taped seams for chemical resistance
Designer Dresses	Hidden, smooth seams for aesthetic elegance



Seam Science =

Textile Enginering + Mechanical Precision

Human Comfort & Movement

The science of seams finds some of its most dramatic applications in technical clothing. In protective garments—like chemical suits, firefighting gear, or hazmat outfits—the seams must not only hold under stress but also seal out hazardous substances. Special seam constructions are used here, including taped seams, sealed seams, and multiple layers of stitching. These seams are rigorously tested under extreme conditions to ensure they meet safety standards.

Activewear presents a different challenge. Here, the focus is on stretch, breathability, and comfort. Seams must move with the body, resist sweat, and not chafe the skin. That's where *flatlock seams* come in—a type of seam that lies flat against the skin and prevents irritation, commonly found in yoga pants, compression gear, and running tops.

Even in everyday fashion, seam science is critical. A pair of formal trousers or a fitted dress must look sharp while remaining comfortable and durable. The seam should never draw unwanted attention—it should lie smooth and subtle, doing its job invisibly. But behind the scenes, those seams are calculated choices made by designers and sewing technicians who understand fabric behavior, garment movement, and customer comfort.

All this science, of course, remains mostly invisible to the consumer. When we try on clothes in a store or buy something online, we rarely inspect the seams—unless something goes wrong. A split seam, a puckered hem, or a popped stitch becomes a dealbreaker, suddenly making us aware of how much we depend on these little lines of thread.

Yet, the modern world of fashion would not exist without seam science. It allows us to create clothes that are lighter, stronger, and more functional than ever before. It enables the development of clothing that adapts to extreme environments—whether in space, underwater, or in chemical labs. It fuels innovation in wearable tech, where seams must now carry electrical conductors or sensors, opening a new frontier for smart clothing.

As we look to the future, this often-invisible discipline is evolving fast. Engineers and designers are experimenting with seamless bonding techniques, laser-cut joins, and ultrasonic welding that eliminate traditional stitching altogether. Threads infused with carbon, antibacterial agents, or moisture sensors are emerging. In this new frontier, the seam is no longer just about joining fabric—it's becoming a gateway to the next generation of intelligent, sustainable, and high-performance clothing.

In the end, the humble seam deserves our appreciation—not just as a line of stitching, but as a brilliant fusion of art and science. The next time you fasten a button or pull on a hoodie, take a moment to run your fingers along the seams. Behind that neat little line is a universe of design decisions, physics principles, and textile technologies, all working together to ensure your clothes fit, move, and last.

Because when it comes to making garments that perform as beautifully as they look, the science of seams is what truly holds it all together. ◆

Seam Science = A Blend of:

- ***Textile Engineering***
- ***Mechanical Precision***
- ***Garment Design***
- ***Human Comfort & Movement***

Seam Science in Everyday Life

Clothing Type	Seam Function
Sportswear	Flat seams for flexibility, stretch, and no chafing
Jeans	Strong flat-felled seams for durability
Hazmat Suits	Sealed/taped seams for chemical resistance
Designer Dresses	Hidden, smooth seams for aesthetic elegance
Smart Wearables	Seam-integrated sensors, conductive threads

Mr Amit Vikram Singh *is an international textile expert with decades of hands-on experience and an avid science-of-future ethusiast. He can be reached through amitvikram_16@rediffmail.com*

VIGYAN 2047 Volume 2 No. 10 October 2025 Pages 22–25

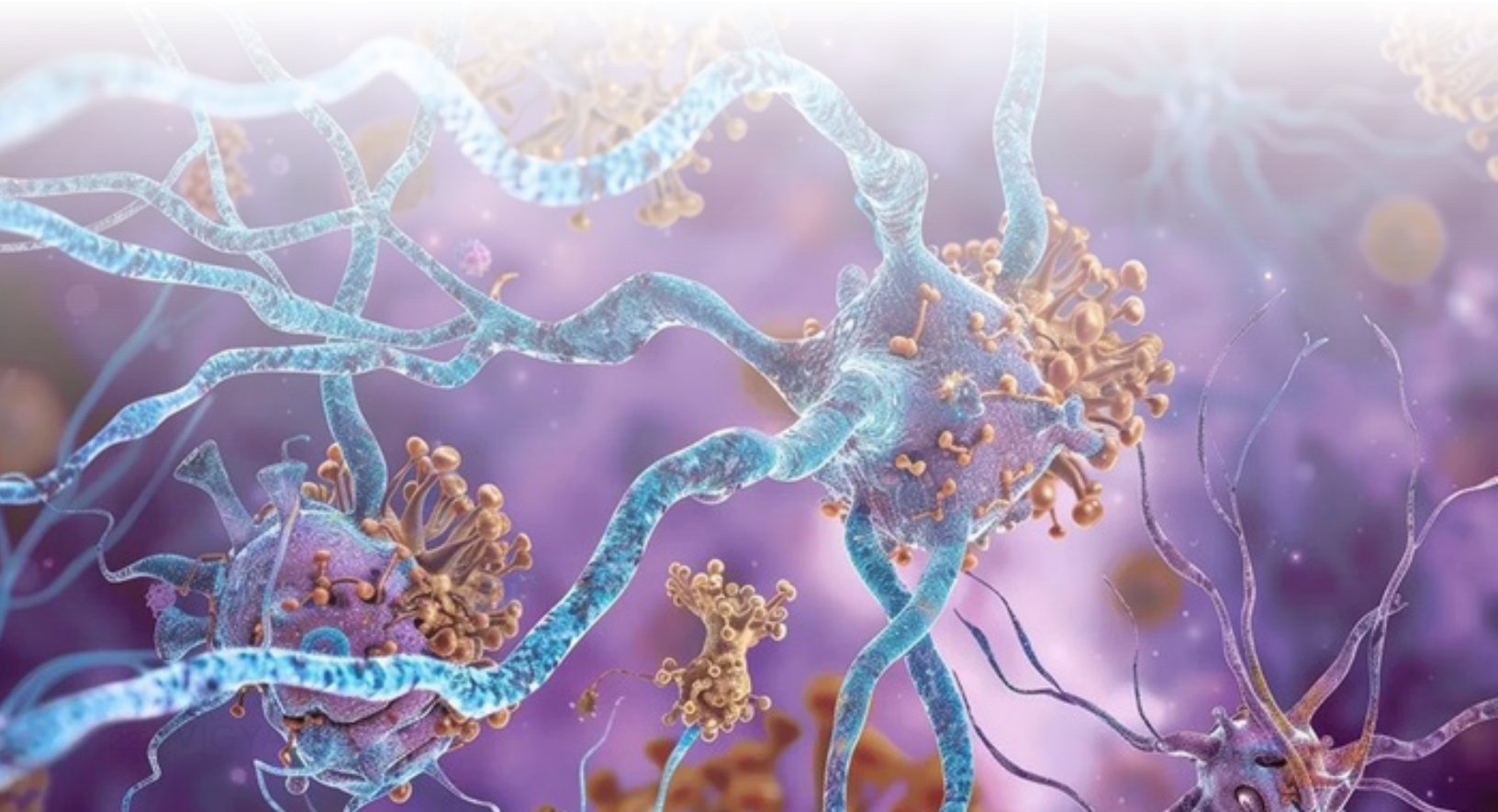
Bedbound to Footsteps

Long Road Through a Motor-Neuron Illness

A.K. Gupta

When 18-year-old Gulwez Khan first reached the OVIHAMS clinic in December 2019, he had been growing weaker for a year and a half. The weakness began in his legs and crept upward. His calves looked thinned; visible ripples—fasciculations—ran under the skin. After a fall on his back and a bout of fever with a urinary infection, he could no longer stand or walk without being carried. Sleep was light and easily broken by the slightest sound. Urine sometimes burned and turned muddy in colour. He had episodes of "night emission" that left him exhausted the next day, and he often dreamed vividly and sexually. Neck stiffness, cramps, tingling in the hands, and a general wash of fatigue completed the picture. An electromyography (EMG) study suggested a neurogenic disorder—signals from nerves to muscles weren't getting through properly. Lab tests showed very low vitamin D (15.5 ng/mL), a positive antinuclear antibody (ANA), normal muscle enzyme (CPK), borderline magnesium, and, on screening, HCV reactivity. B12 was high (likely from supplementation). In short: a frail teenager with a nerve-muscle problem, big sleep and urinary issues, and a family terrified by the pace of decline.

Gulwez and his family chose an integrative path anchored at OVIHAMS, with individualized homeopathic prescribing and steady lifestyle support. The aim was practical: preserve function, steady sleep and mood, and track any change—good or bad—so decisions could be data-led, not memory-led. Prescriptions were adjusted visit by visit as the symptom pattern shifted. Over the course of care, remedies used (in varying potencies and sequences) included Acidum phosphoricum, Staphysagria, Plumbum metallicum, Causticum, Lathyrus, Lachesis, Sepia, Zincum, Curare, Cocculus, China, Graphites, Sulphur, Thuja, Apis, Bryonia, Rhus tox, and a few others. None were "fixed"; the team



matched them to Gulwez's changing constellation of symptoms and emphasised physiotherapy, nutrition, hydration, sleep hygiene, and safety at home.

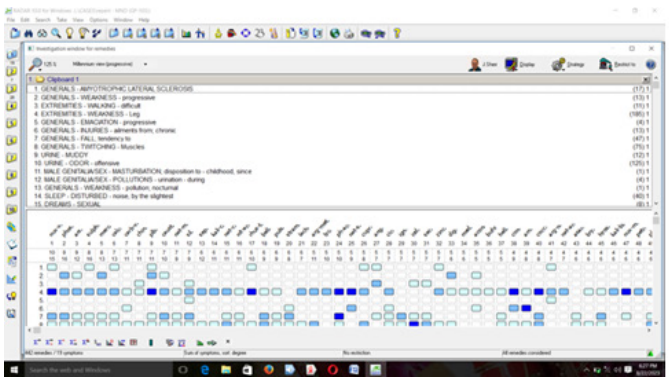
The first months were fragile but not fruitless. Sleep improved. He could close his eyes to settle headaches. The neck stayed stiff, and the fasciculations continued, yet the ANA later turned negative and vitamin D rose into the normal range. By April 2020 the "night falls" had eased a little, though vertigo appeared. In June, a small but meaningful milestone arrived: he could walk a few steps—just three to four at first—with support. Turning in bed remained hard. Nausea followed breakfast. His hands felt weak and tingly. In August the distance rose to 25–30 supported steps. He no longer needed a back brace to sit. Night emissions dropped to about once a week, though there were new annoyances: itching, dribbling semen with urination, and a stubborn morning nausea.

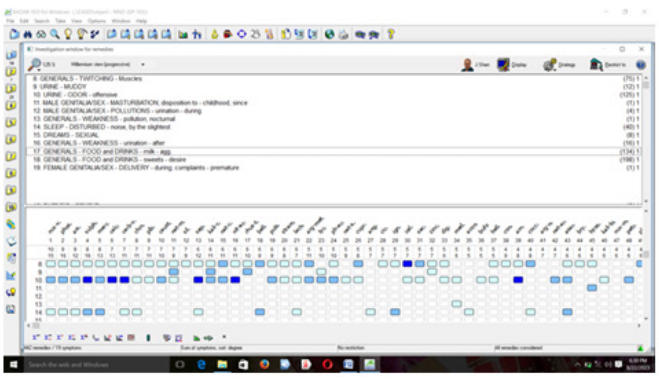
Through September and October 2020 the pattern stayed mixed. The legs cramped at night and trembled on standing; knee pain came with crackles; appetite dipped; breathlessness followed walks. Yet there were glimmers: on some days he walked 20–30 steps and the visible twitching softened from constant to "very slight" in the arms and legs. December brought back stiffness and bitter-tasting nausea. Early 2021 added pain in the palms but also a win—he could climb stairs with support. The old night-time pattern shifted: less emission during sleep, more dribbling with urination. Stiffness in the limbs loosened a little.

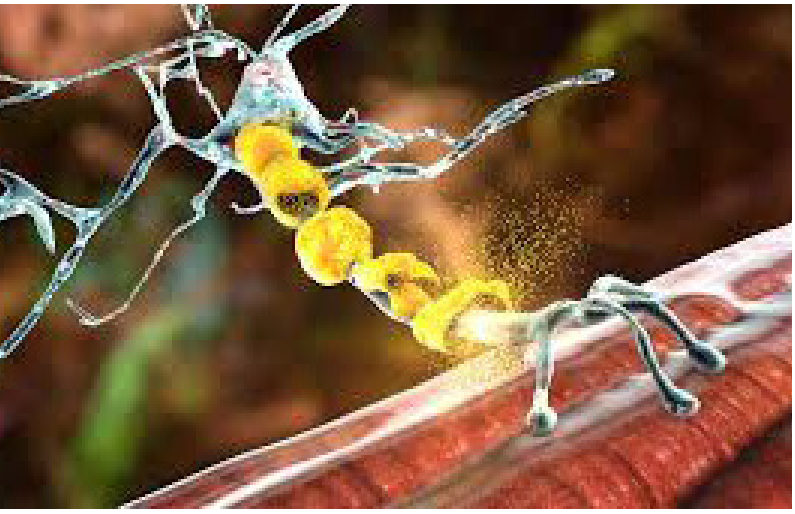
By March 2021 he could manage the stairs three to four times a day and walk roughly 500 metres on better days. Night emissions persisted

(five to six in a month), and each episode left him pale and weak. Urethral itching and knee pain followed those nights. Anxiety surged at times with palpitations, but sleep, thirst, and appetite were steadier than before. In June the improvements were visible to anyone who knew him: fasciculations milder, a full kilometre walked on good days, only to pay with back pain after long stints. There was also muscle thinning in the fingers, especially the left, and burning in the urethra after any seminal discharge.

By August 2021 his weight had stabilised (~72 kg). Weakness felt "much better," though he still had episodes of imbalance and numbness in the right leg after long sitting, and the familiar morning nausea with a bitter taste. He noticed that night emissions returned after heavy exertion. In late October the twitches spiked again, especially in the lower limbs; night falls briefly climbed to two or three times a day and sapped his legs. Constipation and gassy discomfort joined the list, but he was also steady enough to resume riding





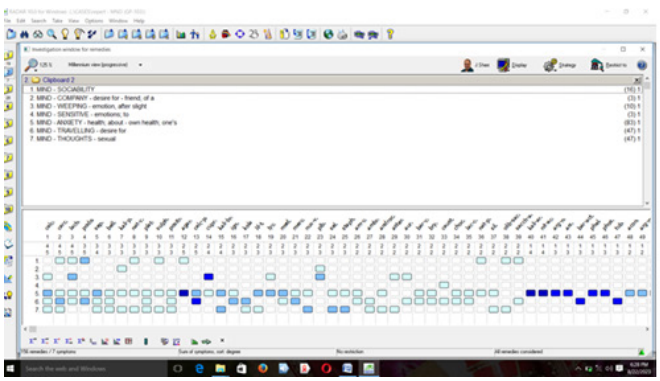


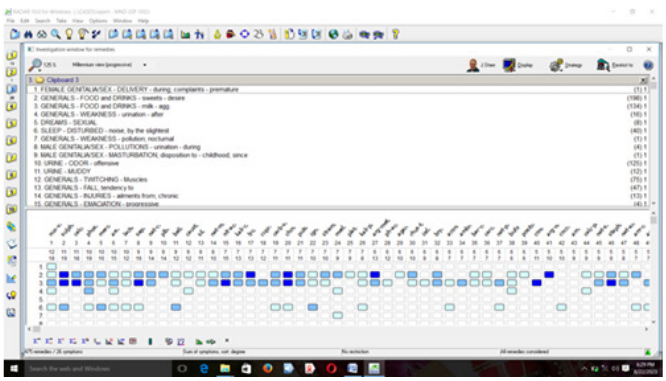
a motorbike. Lying down made fasciculations more noticeable. December 2021 brought another mixed entry: stronger overall, able to walk up to two kilometres on good days, yet with renewed leg pain after walks, sexual dreams with ejaculation, and weakness after emissions. His weight nudged up to 74 kg.

A dengue infection just before the new year knocked him back—platelets fell and fasciculations returned. He recovered gradually through early 2022: back pain eased, night emissions dwindled (none for ten days at one point), and he could walk 50–60 steps without support and balance himself better. Burning during urination hung on. A fall during sit-ups in May set progress back; darkness clouded his vision if he stood too quickly, and the morning nausea persisted. Through mid-to-late 2022, nights grew calmer, twitches in the thighs faded, sleep and appetite steadied, and bowel habits improved. By November, stiffness returned to the joints with crackles and leg pain on walking, but overall weakness was "much better," and night falls were down to once a week. In early 2023 sexual dreams briefly pushed emissions up again, and weakness followed those nights; there was offensive gas and morning nausea. By March 2023, the notes were short and quiet: no new complaints, fasciculations better, weakness better.

Two features of this journey stand out. First, OVIHAMS treated the process as a partnership: frequent reviews, careful documentation (including family videos), pre-defined things to track—distance walked, stairs climbed, sleep quality, frequency of emissions, intensity of twitching—and regular labs. It's a simple discipline that gives patients and families a sense of control and gives clinicians a basis for change. Second, the improvements that mattered to Gulwez and his family were the ones you can feel in daily life: going from being carried to walking short distances with support; then a few dozen steps; then a few hundred metres; then a kilometre; then, on good days, two. Sleep less fragile. Fewer exhausting nights. Less fear of falling. These are not abstract scores—they're a teenager's dignity returning piece by piece.

At the same time, honesty about evidence matters. For motor-neuron diseases as a group, high-quality clinical trials have not established that homeopathy changes the course of illness. Case stories like Gulwez's are not proofs; they are signals: places to look more carefully. There are several plausible contributors to his gains—natural variability and plateaus that can occur in some neurogenic syndromes; the steadying influence of physiotherapy, nutrition, and sleep routines; the power of expectation,





encouragement, and being heard; and, possibly, symptom-level effects of particular prescriptions on sleep, cramps, nausea, or urinary burning. Integrative care can improve the whole experience of illness even when we can't be sure which component moved which dial.

Turning observations into knowledge takes structure. One practical next step is a patient-friendly N-of-1 trial—planned blocks of "on-treatment" and "control/washout" over several months, with neurologist-blinded assessments where possible. Track a small set of meaningful measures every few weeks: an everyday function score such as ALSFRS-R; a 6-minute walk and Timed Up-and-Go; grip and quadriceps strength with a simple hand dynamometer; spirometry or SNIP for breathing; a short sleep/fatigue scale or wearable summary; and even surface-EMG counts of fasciculations. If outcomes reliably rise during treatment blocks and ease back off-treatment, that's stronger evidence than memory—still preliminary, but far more persuasive.

Families don't need a formal trial to borrow the mindset. Pick three goals that matter ("walk to the shop," "climb 10 stairs," "sleep through the night"), write them down weekly, and review them at each visit. Keep vitamin D replete and protein intake adequate; practise gentle chest expansion and physiotherapy; coordinate notes between homeopathic and allopathic teams to avoid conflicts and gaps; protect sleep with regular hours and a quiet, dark room; plan for setbacks after infections, heat, or overexertion; and seek mainstream medical review promptly for red flags like choking, rapid breathing decline, repeated chest infections, or severe weight loss. These basics help any care plan work better.

A humane bottom line ties the story together. Gulwez's journey reminds us that progress in chronic neurogenic illness is rarely linear and almost never attributable to a single lever. It shows a young person moving from bed to footsteps through a coalition of forces: family support, careful follow-up, lifestyle tuning, the psychology of hope, and homeopathy-centred treatment, alongside physiotherapy, nutrition, and rest. For those living it, the improvements are real and precious. The fairest way forward is to keep the person at the centre, measure what matters to them, integrate rather than isolate teams, be transparent about uncertainty, and protect safety with clear guardrails. Keep what seems to help, measure it honestly, drop what doesn't, and collaborate across systems so no one falls through the cracks.

To make journeys like this more common—and more accessible to families with limited means—Shanti Foundation, in partnership with OVIHAMS, is committed to public awareness and practical support for people with motor-neuron diseases. That means multilingual explainers on early signs and daily care, community talks in schools and neighbourhoods, caregiver training, and credible digital posts in local languages. It also means subsidised consultations, basic rehab kits (thera-bands, spirometers, ankle weights), assistive devices (sticks, walkers) and small home-safety grants, peer groups for morale and tips, brief counselling, and a modest assistance fund built with donors and CSR partners to tide families over flare-ups. OVIHAMS brings the clinical backbone; Shanti Foundation builds the bridge to the community. Together they help turn scattered steps into steadier paths—from bedbound to footsteps, one careful, measured gain at a time. ◆

Dr AK Gupta *is a profound homoeopathic practioner and founder director of AKGsOVIHAMS. He can be reached at drakgupta@ovihams.com*

BOOK REVIEW

Celestial Shadow Play – Solar & Lunar Eclipses by Dr TV Venkateswaran is a compact, engaging book that moves from myth to measurement with uncommon clarity. In fifteen short chapters, Dr Venkateswaran opens with Puranic accounts and sets them alongside the rational explanations of early Indian astronomers. He then lays out, in plain language, what solar and lunar eclipses are and why they occur, distinguishing total, annular, and partial phases while showing how timing and duration are determined through worked examples that combine geometry, orbital speed, and observer location.

The narrative continues through frequency and recurrence, with especially clear explanations of the Saros cycle, Saros series, and cycle numbering, and what these mean for real calendars and prediction. The author answers the two questions every newcomer asks—why eclipses don't happen every month and why visibility is restricted to particular regions—using orbit inclination, nodal alignment, and shadow geometry to make the answers stick. Historical interludes—most notably Aryabhata's reasoning for a spherical Earth—are used to bridge India's scientific heritage and modern astronomy. A dedicated chapter surveys ancient Indian computational methods for eclipse prediction, placing them in a global history of ideas. The book closes with the scientific value of eclipse observations and practical, safety-first viewing guidance.

The booklet's chief strengths are clarity and usefulness. Diagrams and step-by-step calculations make the geometry intuitive, and "what-if" thought experiments (e.g., changing Sun–Moon sizes or distances) invite readers to test their understanding. Historical vignettes about remarkable eclipse events add texture without romanticizing the past. Throughout, the author keeps a sharp line between tradition and evidence, presenting eclipses as natural "shadow play," not supernatural omens. Because the examples are classroom-ready and the mathematics is gently scaffolded, teachers can lift tables and figures straight to the board, and students can reproduce the calculations themselves.

This is an excellent fit for multiple audiences: students in Classes 8–12 (and non-science undergraduates) preparing for an eclipse or studying basic astronomy; teachers and outreach volunteers who need ready-to-use diagrams, worked timing/duration problems, and quick demonstrations; and general readers or parents seeking a reliable, concise guide to enjoy an eclipse safely. Compact yet authoritative, Celestial Shadow Play bridges India's astronomical heritage and modern science communication—exactly the sort of resource schools, community libraries, and science clubs can use to turn a rare sky event into a learning moment.

About the author: Dr TV Venkateswaran is a visiting professor at IISER Mohali and a former Senior Scientist at Vigyan Prasar (Government of India). His work spans the history of science in pre-modern India, pre-telescopic astronomy, and science–society–media studies. He has written 70+ popular-science books in Tamil and English, many translated into other Indian languages, and contributes regular columns on current science and technology.

Reviewed by: Dr CR Kumaran, Head & Assistant Professor, Department of Physics, Sri Kaliswari College, Sivakasi, Tamil Nadu

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Celestial Shadow Play – Solar & Lunar Eclipses
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Day-long Workshop on Familiarization with Quantum Science & Technology

FTK CIT Conference Hall, Jamia Millia Islamia, New Delhi

October 16th, 2025 Thursday

9.45 am onwards

KEYNOTE SPEAKER

Prof. John M. Dudley

Chair, International Day of Light 2025 Steering Committee

Professor at the University of Franche-Comté, France

Topics:

International Day of Light
International Year of Quantum Science & Technology
Quantum Computing & its Applications
Quantum Mechanics
Quantum Healthcare
Quantum Communication
and much more...

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Speakers:

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Prof Zahid H Khan | Dr Nakul Parashar | Dr Tabassum Jamal
Dr Saeed Uddin | Dr D Shailaja | Dr M Shoaib | Mr Venkatesh Sharma

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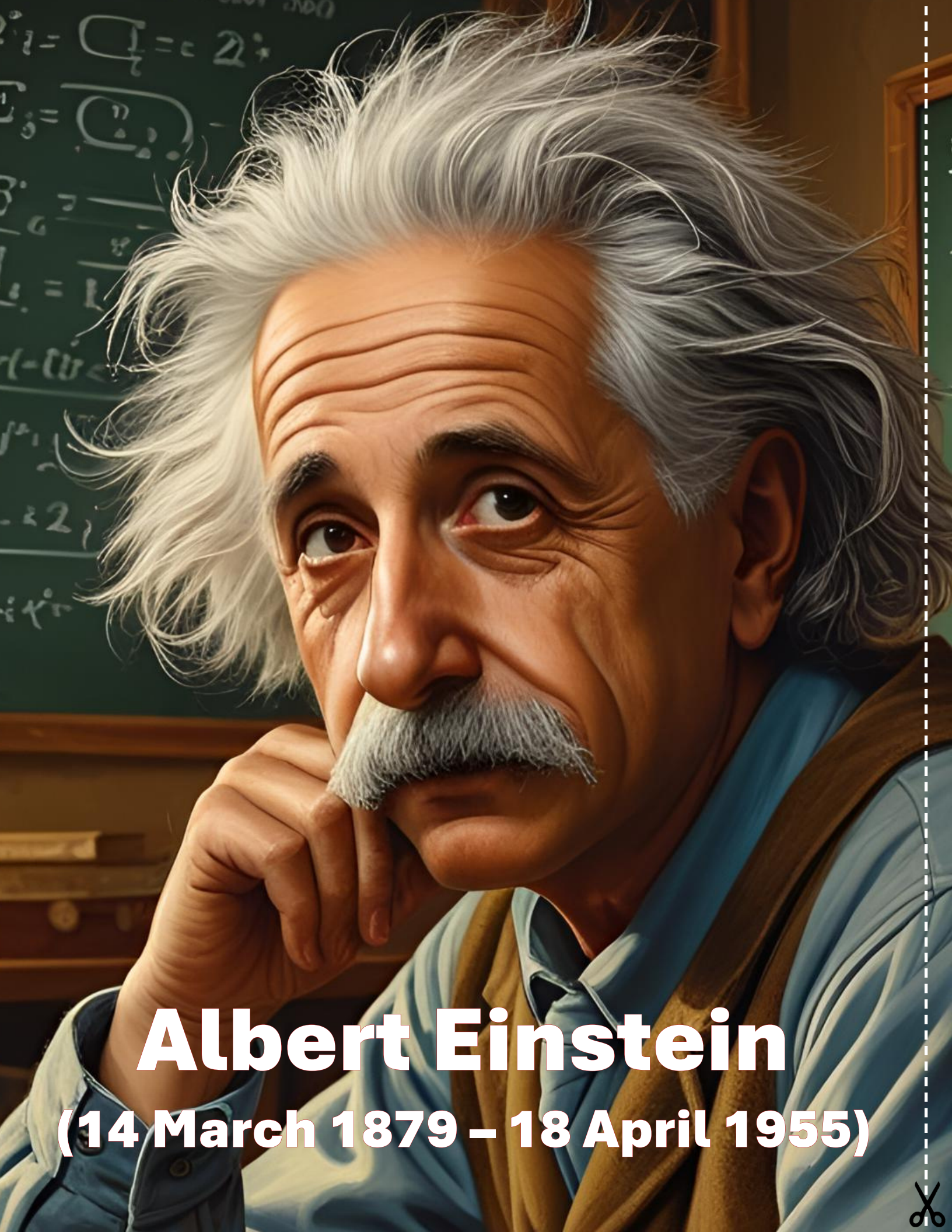

Albert Einstein
(14 March 1879 – 18 April 1955)

VIGYAN 2047 Volume 2 No. 10 October 2025 Pages 29–35

Are We Alone?[1]

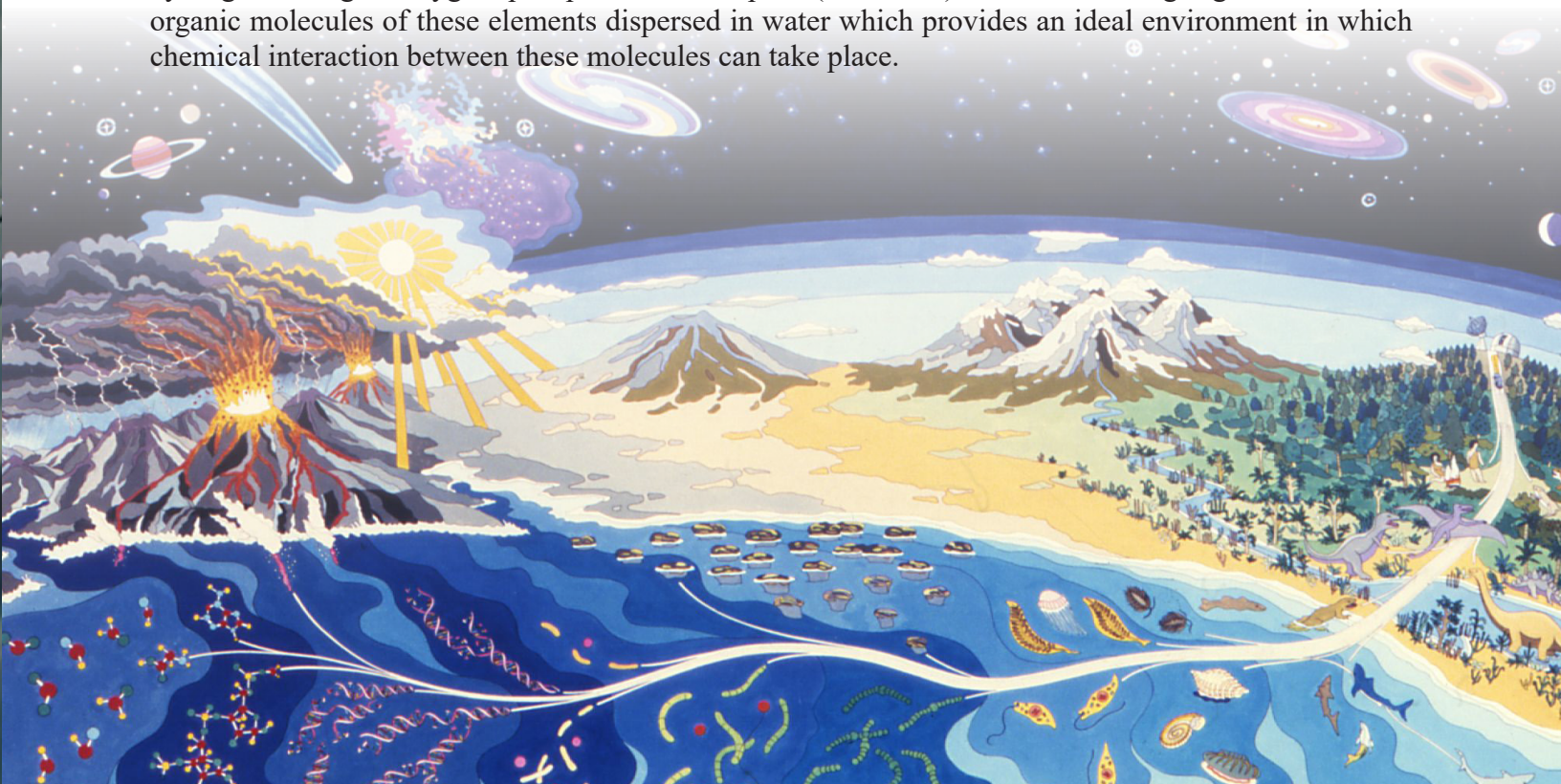
Govind Bhattacharjee

Are we alone in the Universe? Is there someone watching us from space? Is there life beyond Earth? To explore answers to these questions, we first need to understand three mysteries: what defines life, what the pre-requisites for life are and finally, how life has evolved and survived on Earth in the first place.

What really are the defining features of 'life'? Looking around, we can identify several characteristics of life—life grows, life replicates, life metabolises, life manipulates the environment for energy and sustenance, life displays a level of complexity that distinguishes it from non-life. Life has a sophisticated system for storing, processing and transmitting information to the next generation. Life adapts and evolves. But there is hardly any characteristic that is not shared by non-life. Crystals of salt grow on their own, computer programs can replicate and evolve, and computers possess highly sophisticated system of storage and sharing of information. Fire metabolises, releasing energy by burning. Weather exhibits incredibly complex behaviour. So none of these characteristics is unique to life.

Gerald Joyce, a NASA scientist, gave a simple definition of life as a self-sustaining chemical system capable of Darwinian evolution. But as Carol Cleland, a philosophy professor said, we are perhaps yet to develop a proper language of natural sciences to be able to define life, just like a proper definition of water needed our understanding of molecular chemistry. However, the 'most accepted working definition of life' is that living forms are those that use energy to build molecular structures and replicate themselves following a specific set of instructions embedded within themselves.

Scientists generally agree that for life to evolve and thrive anywhere, there are certain prerequisites, the most important of which is the presence of water. Further, there has to be a 'habitable zone' conducive to life, that is, a planet at an appropriate distance from the parent star on which water can exist in liquid state under ordinary temperatures and pressures.[2] There also has to be abundance of organic elements necessary for making the complex organic molecules required to capture and reflect the complexity of life. Ninety nine percent of all living materials on Earth are composed of only six elements—carbon, hydrogen, nitrogen, oxygen, phosphorus and sulphur (CHNOPS). All metabolizing organisms contain organic molecules of these elements dispersed in water which provides an ideal environment in which chemical interaction between these molecules can take place.



Water has some unique properties unlike any other liquid. Due to the strong chemical bond between hydrogen and oxygen, liquid water remains stable over a wide range of temperatures. Further, ice, being less dense, floats on water- it also means that oceans that harbour life freeze from the top when temperature drops and the top layer of white ice insulates the bottom layers of water protecting living forms below. Ammonia, in contrast, which remains a liquid from –78° to –33° Celsius, would solidify upwards from the ocean floor, freezing all living forms to death. Other liquids may not be as conducive to life as water.

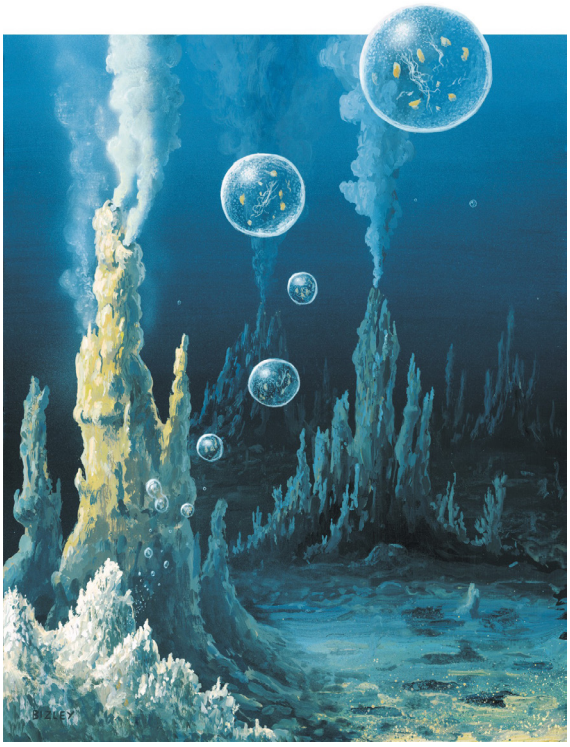
Apart from the presence of liquid water, other conditions necessary for life include a steady source of energy, like sunlight, for metabolism, which a star can supply. Such energy could also come from chemical reactions; that makes it possible, at least in theory, for life to evolve in sub-surface environments. A renewable supply of organic elements along with a stable interface between solids, liquids and gases as on land or ocean-surface are other prerequisites for life.

How did life evolve on earth? As J E Lovelock said in his book "*Gaia: A New Look at Life on Earth*"Z—Life was "an utterly improbable event with almost infinite opportunities of happening." Life on Earth evolved possibly as an accident, a random event that was the result of sundry combinations of chemicals taking place in the primeval oceans over billions of years of change and transformation that ultimately resulted in the formation of a molecule capable of replicating itself. From its cradle in the blue green waters of the primeval ocean where life probably evolved, it grew most luxuriantly through billions of years of trials and tribulations, taking myriad shapes and forms through endless chains of transformations.

The same process could also have happened in the interstellar clouds of gas and dust where the simple molecules and elements were present and chemical reactions among them could have been triggered by the energy of a nearby star. Indeed, ammonia and water vapour were discovered in interstellar space in 1968 through radio-astronomical observations in microwaves. In 1969, formaldehyde, another organic molecule, was discovered in the interstellar clouds of gas and dust. Obviously, if life processes could start on Earth out of chemical reactions after only 800 million years of its existence, the same processes would have a greater probability of occurring in the interstellar clouds, which are several billion years older. These processes could also have been triggered inside the nucleus of a comet, where heat provided by the decay of radioactive elements could have easily formed the 'warm little ponds' as on Earth.

On 28 September 1969, a large meteorite struck at a place called Murchinson in Australia. Among the debris were traces of five amino acids—glycine, alamine, glutamine, valine and proline, which were not of biogenic origin. In fact, they could be direct chemical precursors to organic evolution. Seeds of life could thus have been carried to Earth from the outer space, an extraterrestrial planet, by meteorites or other objects that bombarded the earth incessantly during its initial formative eons; they could also have come to earth through solar or stellar winds. But in whatever form the original living molecules existed in the beginning and wherever they came from, they were still far from becoming the kind of life we are familiar with. That would still take billion years of evolution. Consciousness and intelligence would still take many more million years to evolve.

By all accounts, life was an early feature of Earth - primitive life appeared almost as soon as the Earth's crust had solidified. The strip of land stretching from Greenland to Canada called the North Atlantic Craton has some of the most ancient rocks formed on this planet, dating back to nearly 3.8 billion years ago. Isua supracrustal belt is one such place in the interior of Greenland, where sedimentary rocks have been buried long and become metamorphosed. These rocks have been found to contain mineral graphite—a form of carbon which can come only from two sources: primordial inorganic carbon released during volcanic eruptions or organic carbon from buried remains of organic matter on the ocean floor. Carbon has two stable isotopes, with atomic weights 12 and 13 (C^{12} and C^{13}). Living organisms tend to contain a little more C^{12} than C^{13} in their tissues, as C^{12} is more reactive than C^{13}. The graphite in Isua was found to be richer in C^{12} by about 2 percent, indicating its organic origin from marine microbes which must have died and got buried in the sediments, subsequently becoming compressed and metamorphosed into graphite as old as these sediments. The origin of life thus dates almost back to the unremembered beginning of this planet, less than 800 million years since this rocky planet had come into existence.



The Sun was about a quarter less luminous then as its fusion reactions were far from consummate. It produced less energy and consequently the Earth also received less. But for the greenhouse gases carbon-di-oxide and methane which were abundant in the atmosphere of the nascent earth and partly neutralised the faint young Sun, the Earth would have been a frozen planet, with all its surface transformed into permafrost conditions unsuitable for evolution of life. Further, oceans that covered most of the Earth's surface, being dark, absorbed sunlight, while icecaps on mountains that reflected sunlight back into space were few. A temperature balance was thus maintained which was crucial to the evolution of life.

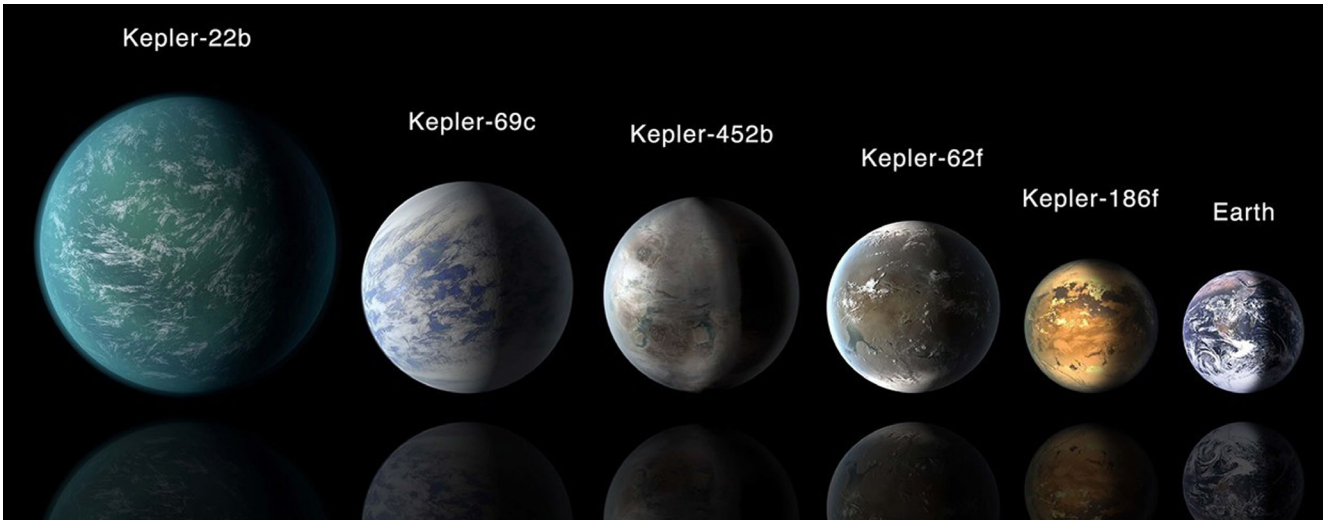
By 2.8 billion years ago, most of Earth's crust had already been formed and continents had started to emerge along with the development of large shelf areas around them. Weathering of these areas led to concentration of nutrients in the oceans, resulting in significant increases in the population of microscopic organisms. Till late in the Archean era, around 2.5 billion years ago, the atmosphere was primarily composed of methane, with less than one part per million of molecular oxygen. Oxygenation of its atmosphere—the so-called Great Oxidation Event—would occur in steps, first 2.4 billion years ago, taking the oxygen level to about 2 percent, then 750 million years ago, increasing the level of atmospheric oxygen to 3 percent, and finally about 580 million years ago, raising the oxygen content in the atmosphere to above 10 percent. This oxygenation was caused primarily by the evolution of photosynthetic oxygen-producing bacteria in the surface of oceans, an ancestor to the blue-green 'cyanobacteria' that today swarm in the lakes and oceans of Earth. The surge in oxygen would naturally lead to development of complex 'aerobic' or oxygen-breathing organisms.

Till then, life forms could only exist by breaking the complex substances and using the energy released. These complex substances, food for the primitive micro-organisms, were rebuilt from their simpler constituents by the action of ultraviolet light on oceans. But once oxygen was formed in the atmosphere, oxygen molecules split by sunlight into oxygen atoms combined with

other molecules of oxygen to yield ozone. The released ozone formed the ozone layer above the atmosphere, shielding the Earth from ultraviolet rays from the Sun. While the ozone layer protected life from the destructive ultraviolet rays which it still does, it also hastened the pace of evolution of life by cutting off ultraviolet light that was making food for the molecules of life. Replenishment of the chemical food supply thus no longer being possible, an acute competition now set off among the living molecules for food. As the primordial chemical soup was neared exhaustion in the oceans, organisms capable of synthesising their own food had to evolve, and the only energy available was that from sunlight. Organisms that could use this low-energy light to manufacture their own food had to learn to trap this energy. They were some mitochondria-like substances containing chlorophyll—the blue-green algae. These sea-dwelling microbes were probably the first cells, very simple 'prokaryotes', the ancestors to modern 'chloroplasts'—the sub-cellular bodies containing chlorophyll within plant cells where photosynthesis takes place.

As chloroplasts multiplied in the ancient seas, the blue green algae started using carbon dioxide in the atmosphere to produce molecular oxygen through the process of photosynthesis, gradually transforming the terrestrial atmosphere. Lime secreted by these algae would collect in the shallow oceans that received sunlight, forming the first life-created structures called stromatolites. Bubbles containing oxygen would form on these stromatolites by photosynthesis, then rise slowly to the surface of the sun-blanched oceans and detach themselves from water, freeing their oxygen into the atmosphere. Once the atmosphere was oxygenated and ozone layer was completely formed, it was safe for organisms to dwell on the surface of oceans and eventually to come to land from their watery abode, heralding the evolution of aerobic creatures. From now on, the evolution of life forms would proceed along two distinct directions—one developing into the oxygen-breathers and rapid-movers, evolved from the aerobic living forms, and the other evolving into the immobile plant kingdom, the breathers of carbon dioxide. These two forms would have a complementary and symbiotic relationship with each other. The change in environment brought about by the release of oxygen was thus the most significant event in the history of life. Gradually, from the simple prokaryotes, 'eukaryotes'—organisms with cell-nuclei would evolve. Subsequent advent of sexual reproduction would accelerate the pace of biological evolution manifold, making the process of evolution of life almost uncontrollable and leading to speciation, formation of new species, bringing myriads of forms and irrepressible diversity of life on Earth.

Fossil and other evidences establish that life had been remarkably resilient on Earth, holding onto the most extreme environments. In 2113, a microbe was retrieved from Lake Whillans, almost a kilometer underneath the Antarctic ice. Colony of microbes has thrived even in toxic environments of carbon monoxide and hydrogen sulphide 50 feet underground in a cave in Mexico. Superheated hydrothermal vents on ocean floors have been found to harbour a rich ecosystem of bacteria. Life, in fact, has been found to survive and proliferate in almost every extreme environment, in hot springs and frigid lakes deep below the Earth's surface, in



highly acidic, alkaline or radioactive sites—almost everywhere in every inconceivable environment. This only confirms that it can evolve and grow anywhere in the galaxies.

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Let us now look beyond our planet. There may be any number of Earth-like rocky planets within the habitable zone in other stellar systems within and outside our galaxy that may nurture life. Scientists have discovered nearly 3400 such planets, called 'exoplanets', beyond our Solar System, but so far, haven't had any evidence of extra-terrestrial. Exoplanets are detected indirectly from stellar properties like brightness, position etc. which are affected by the presence of planets—by tracking the motion of a star across the sky, by measuring Doppler shift of the stellar spectra or periodical decrease in starlight due to the movement of a planet across its face or by a technique called micro-lensing, using the bending of light beams by the star's gravity. They can also be detected by direct observations made by telescopes in space, like Hubble Space Telescope (2001), Spitzer Space Telescope (2003), Corot (2006) and Kepler Space Telescope (2009).[3]

Once an exoplanet is discovered, scientists look for bio-signatures of life in it. The planet's visible or infrared spectrum may reveal the presence of oxygen or methane, two gases produced by life through photosynthetic or other biological processes. They may look for the evidence liquid water which is essential for life. Ozone will provide another bio-signature as also compounds of organic sulphur or carbon-di-oxide. However, some of these gases and compounds may even be produced by abiotic processes; there also remains the possibility that even when no bio-signature is detected, some form of life can still be ebbing and flowing beneath the surface of the planets – in subsurface oceans of water or organic compounds like methane or ammonia.

Scientists have identified nine bodies inside the solar system where life might exist in subsurface oceans of water or other organic liquids like methane or ammonia: Mars, Ceres, the largest asteroid, Europa, Ganymede and Calisto - all moons of Jupiter, Enceladus and Titan, moons of Saturn, Triton, the largest moon of Neptune and Pluto. Mars once had free flowing water on its surface – some of it may still be flowing underground. Europa has a cracked surface covered with vast ice sheets covering oceans of liquid water underground—due to the internal heat generated by tidal forces of Jupiter's other moons; it may also have hydrothermal vents in its ocean floor like the Earth. Enceladus contain underground water and Titan has huge oceans and lakes of methane and ethane. Right now, Pluto is under close observation by the New Horizons spacecraft of NASA that has detected vast frozen, craterless, young plains in the northern icy mountainous region of Pluto, named "Tombaugh Region", after Clyde Tombaugh, who discovered

the planet in 1930. But so far there was nothing to suggest that life did or could exist on the planet.

It is understood that our best chances of detecting extra-terrestrial life would come from an alien civilization that is intelligent—at least as intelligent as us—and communicative too. In 1961, Frank Drake, a young radio astronomer, had formulated an equation that has since been known as the Drake Equation for estimating the number of alien civilizations that can be detected from the earth. The Drake equation runs like this:

$$\mathbf{N = R^* \cdot f_p \cdot n_e \cdot f_l \cdot f_i \cdot f_c \cdot L}$$

where

N = number of civilizations in the Milky Way Galaxy whose electromagnetic emissions are detectable;

R^* = rate of formation of stars suitable for the development of intelligent life;

f_p = fraction of those stars with planetary systems;

n_e = number of planets, per solar system, with an environment suitable for life;

f_l = fraction of suitable planets on which life actually appears;

f_i = fraction of life bearing planets on which intelligent life emerges;

f_c = fraction of civilizations that develop a technology that releases detectable signs of their existence into space; and finally

L = life time of such civilizations.

Except the rate of formation of stars suitable for life, all other factors still remain highly speculative. Even then, in 1961, Drake had estimated about 10000 such communicative civilizations in our galaxy. The Drake equation is a simple, fascinating equation that suggests that life being the end product of a natural, cosmic evolution, may not be unique and that we may not occupy any special position in this Universe in that sense, even though so far ours is the only kind of life known.

The Search for Extraterrestrial Intelligence (SETI) is the name for collective scientific investigations undertaken to search for intelligent extraterrestrial life. The search began in 1957 with the Lovell Radio Telescope mounted in Manchester, UK, to detect radio signals from intelligent civilizations. The SETI Institute was established in 1984 to "explore, understand and explain the origin, nature and prevalence of life in the universe" and which today comprises the largest distributed array of radio telescopes across the world. With increasingly high-powered of radio-telescopes now being deployed, searches have become much broader and deeper, but we have not yet succeeded in detecting any intelligent life elsewhere. And that is an enigma.

After all, our Earth is only a 4.6 billion years old planet orbiting a star that is too young in the Universe; there are stars in our galaxy itself that are

twice as old. If life was a random event, it must have arisen in the galaxy long before it did on Earth. By now, those civilizations would have mastered the technology of space travel or even time travel, and possibly even to travel at superluminal speeds. They should have colonized the galaxy by now. Such colonization would have been a necessity for their survival, because energy is the driver of all civilizations and they would have exhausted their planetary or even stellar supply of energy long back and thus would be forced to seek it elsewhere. Then why haven't we found any of them so far? Why haven't they discovered us? Why haven't they intercepted and responded to the several radio messages we have sent into space? This is the fundamental question Enrico Fermi asked in 1950, known as Fermi Paradox.

Maybe, we are truly alone in this vast Universe, making us a rarity and our Earth a 'Rare Earth' that shelters the only life in this Universe, in which case at least one factor in Drake's equation will have to be vanishingly small. Or maybe, they do not need to colonize the galaxy, having solved the energy problem by the use of advanced technology. But these answers look rather improbable, given that vastness of the universe and the deepness of time through which it has evolved. Another possibility is that they have already destroyed themselves through an Armageddon-type nuclear war; in fact, we in Earth had come very close to this in the last century.

There is of course another possibility - maybe they have indeed found us and are just watching us from space, refusing to communicate. A civilization that has the technological prowess to explore the galaxies must be a very mature civilization, and must have already conquered hunger, poverty, sickness, maybe even physical death. Conflicts and wars between their people must have been a thing of antiquity, as must have been hatred and jealousy, bigotry and social cleavage, while we are as yet far from conquering these evils. Our ways on this earth, where we constantly fight, bleed, kill and inflict unspeakable atrocities upon our fellow beings must seem extremely repulsive to an advanced, intelligent and sophisticated intergalactic civilization. We cannot blame them for hiding from us, rather we should be ashamed of ourselves. ◆

Notes:

[1]Published in January 2016 issue of Dream 2047, journal of Vigyan Prasar.

[2]This habitable zone called the circumstellar habitable zone (CHZ) is also known as Goldilocks zone, from the fairy tale of Goldilocks and the Three Bears, in which a little girl chooses one that is "just right" from various items, ignoring the ones too large or too small or too extreme.

[3]In January 2015, Kepler had discovered an earth-like exoplanet in our galaxy which has since been named as Kepler 452b, also known as 'Earth 2.0'. Three more Earth-like rocky exoplanets were discovered in July 2015 in the constellation Cassiopeia, only 21 light-years away from Earth.

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*Author **Dr Govind Bhattacharjee** a well known contributor in popular science, is a retired bureaucrat turned academician, currently a Professor of Practice at Arun Jaitley Institute of Financial Management. He can be reached at govind100@hotmail.com*

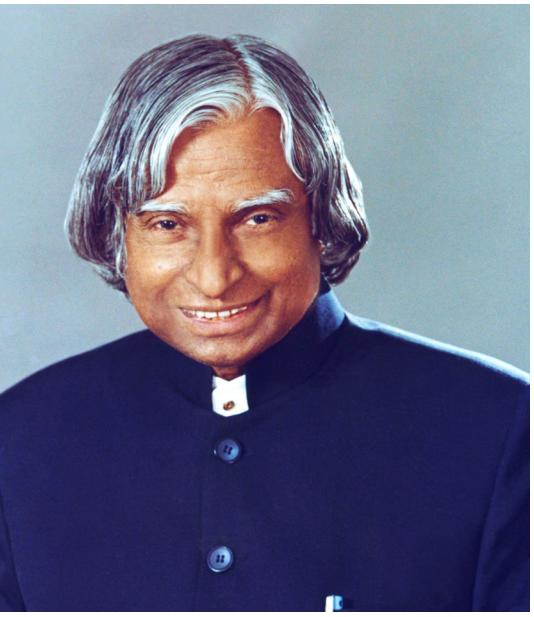
VIGYAN 2047 Volume 2 No. 10 October 2025 Pages 36–37

Celebrating the October Born Scientists

Bhupati Chakrabarti

These luminaries, born in the month of October, have each illuminated the path of human progress in their own right. Their discoveries have transcended the bounds of their respective fields, shaping the world as we know it. As we reflect on their lives and legacies, we are reminded of the boundless potential of the human spirit to inquire, innovate, and inspire. Through their work, these scientists have left an enduring legacy, a testament to the power of curiosity and the relentless pursuit of knowledge.

Meghnad Saha was born on 6 October 1893 and was a distinguished Indian astrophysicist and politician, best known for formulating the Saha ionisation equation, a foundational concept in astrophysics. This equation allows scientists to determine the temperature and ionisation states of elements in stars by analyzing their spectral lines, helping to link the spectral classification of stars with their physical properties. Saha's work on thermal ionisation revolutionized the study of stellar atmospheres and remains a key tool in modern astrophysics. He served as a professor at Allahabad University from 1923 to 1938, and later as Professor and Dean of the Faculty of Science at the University of Calcutta, a position he held until his death in 1956. He was elected a Fellow of the Royal Society in 1927 and served as President of the Indian Science Congress in 1934. In addition to his scientific achievements, Saha was deeply involved in nation-building, acting as the chief architect of river planning in India, including drafting the original plan for the Damodar Valley Project.



Dr. A.P.J. Abdul Kalam was born on 15 October 1931 and was a prominent Indian aerospace scientist, visionary educator, and the 11th President of India (2002–2007). Revered as the "Missile Man of India", he played a crucial role in advancing India's missile and space technology. After studying physics and aerospace engineering, Kalam began his career at the Defence Research and Development Organisation (DRDO) and later joined ISRO, where he served as the Project Director of India's first Satellite Launch Vehicle (SLV), which successfully deployed the Rohini satellite into orbit in 1980. In the 1980s, Kalam led the Integrated Guided Missile Development Programme (IGMDP), overseeing the creation of key missiles such as Agni and Prithvi. He was also a central figure in the Pokhran-II nuclear tests of 1998, which elevated India's strategic capabilities and brought Kalam national recognition. Outside defense, he co-developed the Kalam-Raju stent, a low-cost cardiac device, and the Kalam-Raju tablet for rural healthcare. Known for his simplicity and deep commitment to education, he inspired millions, especially youth, with his books, lectures, and vision for a developed India. Dr. Kalam's legacy lives on as a symbol of scientific excellence, integrity, and inspirational leadership in service of the nation.

Salimuzzaman Siddiqui was born on 19 October 1897 and was a Pakistani organic chemist specialising in natural products, and a professor of chemistry at the University of Karachi. Siddiqui studied philosophy at Aligarh Muslim University and later studied chemistry at Frankfurt University, where he received his PhD in 1927. On return to British India, he worked at the Tibbia College Delhi and the Indian Council for Scientific and Industrial Research. He later moved to Pakistan and worked in the Pakistan Council of Scientific and Industrial Research. He went on to establish the Pakistan National Science Council and was appointed its first chairman in 1961. In the same year he became a Fellow of the Royal Society. He later co-founded the Pakistan Academy of Sciences, and after retirement from the government, he founded the Hussain Ebrahim Jamal Research Institute of Chemistry. Siddiqui is credited with pioneering the isolation of unique chemical compounds from the Neem (*Azadirachta indica*), Rauvolfia, and various other flora. As the founder director of H.E.J. Research Institute of Chemistry, he revolutionised research of the pharmacology of various domestic plants found in South Asia to extract novel chemical substances of medicinal importance. During his career, Siddiqui published more than 300 research papers and obtained 40 patents mainly from the field of natural product chemistry. In addition to his scientific talents, Siddiqui was also an avid painter, poet, and a great connoisseur of Western music. His paintings were exhibited in the United States, Germany, India, and Pakistan.

Saleemul Huq was born on 2 October 1952 and was a renowned Bangladeshi-British climate scientist, internationally recognized for his groundbreaking work in climate change adaptation, particularly from the perspective of least developed countries (LDCs). He was the Director of the International Centre for Climate Change and Development (ICCCAD) in Bangladesh and a professor at Independent University, Bangladesh (IUB). Huq was selected as one of Nature's Top 10 scientists of 2022 for his influential role in global climate negotiations. He contributed significantly to the Intergovernmental Panel on Climate Change (IPCC), serving as a lead author and coordinating lead author in key chapters on adaptation and sustainable development across the Third, Fourth, and Fifth Assessment Reports. He was a key adviser to the LDC Group at the UNFCCC, engaging in every Conference of the Parties (COP) and shaping global discussions on adaptation, loss and damage, and climate finance. Huq also served as a Senior Adviser on Locally Led Adaptation at the Global Centre on Adaptation (GCA). Huq published reports and articles on climate change, particularly on adaptation to climate change. He was the lead author of the chapter on Adaptation and Sustainable Development in the third assessment report of the Intergovernmental Panel on Climate Change (IPCC). He was a Senior Fellow in the Climate Change Group at the International Institute for Environment and Development (IIED) and the director of the International Centre for Climate Change and Development. His contributions supported the UN Sustainable Development Goals, particularly Goal 13 (Climate Action) and Goal 17 (Partnerships). Through research, advocacy, and policy engagement, Huq became a leading voice for climate justice, leaving behind a lasting legacy of global impact.

Dr Bhupati Chakrabarti *is a retired faculty from the Department of Physics, City College, Kolkata and was the General Secretary of IAPT from 2013 to 2018. He can be reached through chakrabhu@gmail.com*

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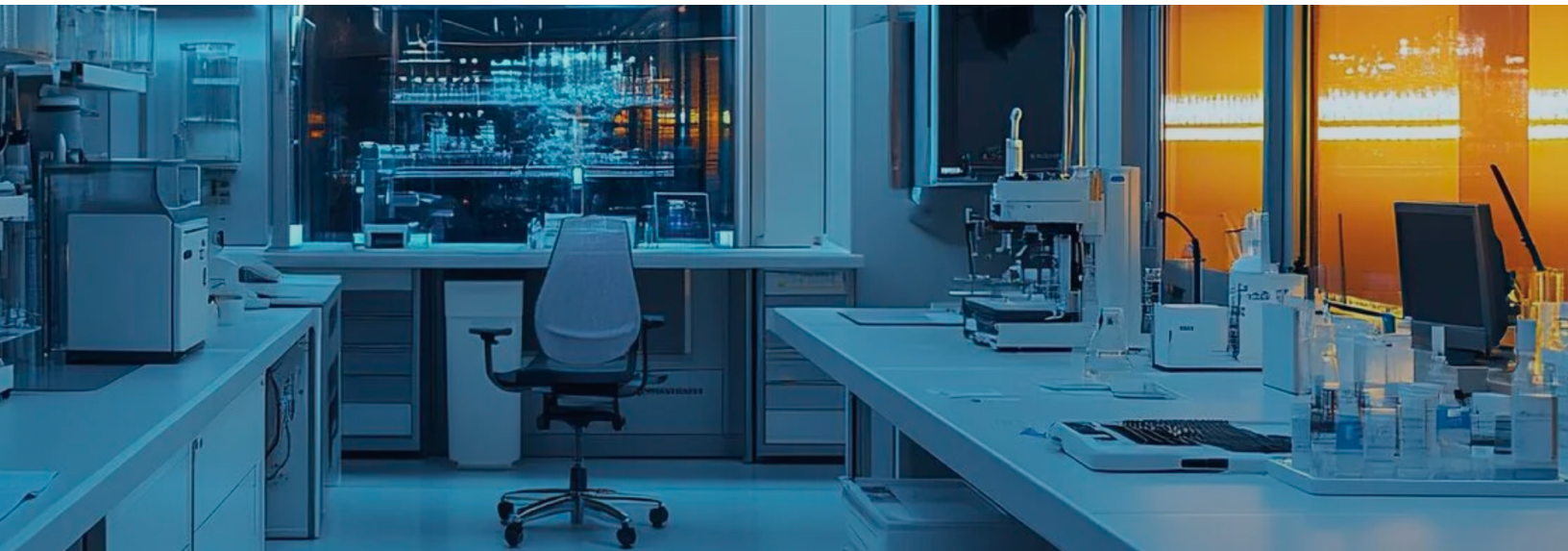
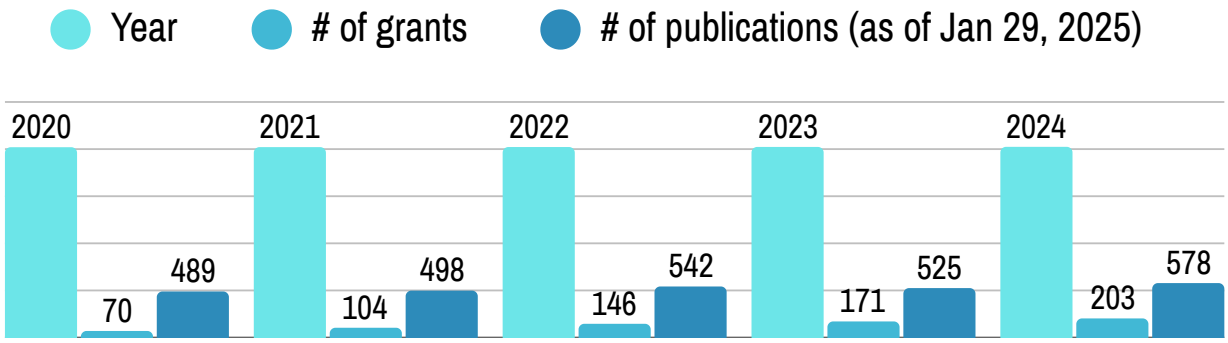
NU is dedicated to excellence in research, striving to make a meaningful impact on the socio-economic development of Kazakhstan and the region. Its research spans both fundamental and applied fields, with a strong focus on STEM disciplines, life sciences, social sciences, and education — aligning with the country's key development priorities.

NU continues to strengthen its research capabilities to tackle global challenges through collaboration with government, industry, research institutions, and other key stakeholders.

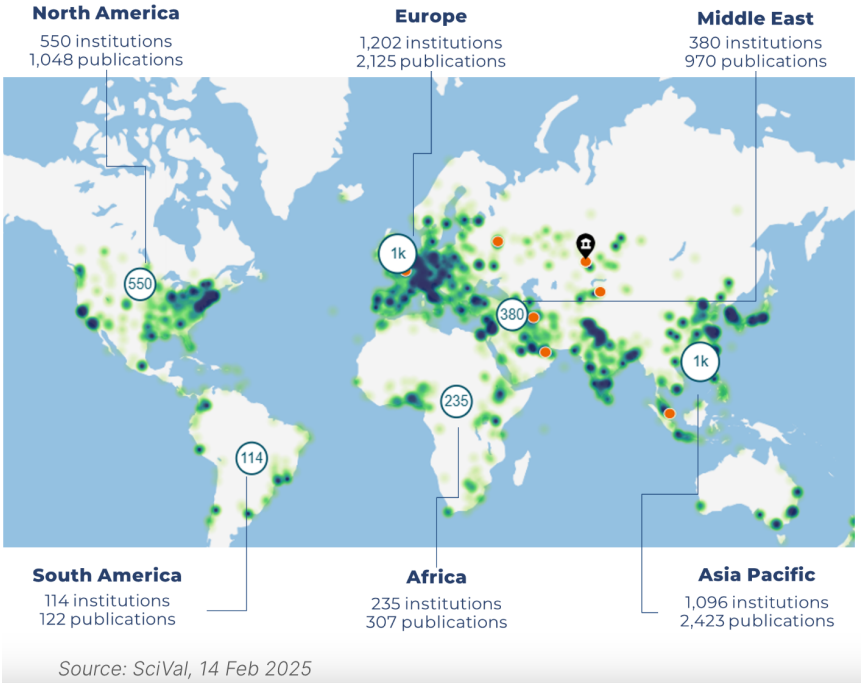


Interdisciplinary research at Nazarbayev University

NU measures the success of interdisciplinary research through a combination of collaborative grants, which assess funding secured for cross-disciplinary projects and the outcomes of these projects. It includes numbers of funded projects (grants) and numbers of publications, as well as the degree of collaboration across different disciplines involved. Annually, we announce `The Collaborative Research Program (CRP)`, which is a major research funding instrument of Nazarbayev University (NU) designed to advance its research excellence, share expertise, and contribute to the development of the Global Knowledge Economy and the well-being of global citizens. The CRP specifically supports strategic interdisciplinary research collaborations of high intellectual merit required to holistically solve complex problems that deliver evidenced innovation and socioeconomic improvement of the region. NU researchers are actively conducting research within grant and program-targeted funding sponsored by the Ministry of Science and Higher Education and other external funds, based on an interdisciplinary approach. The primary research outputs include publications in high-ranked journals. Publication authorship reflects interdisciplinarity appropriate to call requirements within cross-functional teams. The following table presents a summary of interdisciplinary research achievements at the university, tracking the number of grants awarded and publications produced over the past several years. It highlights the annual progression of research activity, showing trends in funding and scholarly output from 2020 to 2024. The data reflects the university's ongoing commitment to fostering cross-disciplinary collaboration, with a focus on increasing both grant funding and academic contributions.



NU faculty members successfully build international research partners and cross-institutional research networks supporting interdisciplinary projects. Purpose designed interdisciplinary collaboration is a key success strategy that brings diverse perspectives together to share partner resources necessary to solve complex global issues. Interdisciplinary collaboration with top universities expands NU's professional networks, fosters global partnerships, and grows our international research footprint.



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